

THE ADVANTAGES OF THE SYSTEM OF RICE INTENSIFICATION (SRI) IN ENVIRONMENTAL PROTECTION AND CLIMATE CHANGE MITIGATION IN RICE PRODUCTION – A REVIEW

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ARTICLE INFO		ABSTRACT
Received:	14/4/2021	Because of the large area under wet cultivation, more water usage, and high use of chemical inputs conventional rice cultivation is one of the major sources of CH ₄ and N ₂ O causing environmental pollution and climate change. To solve this problem, System of Rice Intensification (SRI) has been researched and applied in about 15 million smallholder farmers in more than 60 countries. Results of almost all researchers show that applying the SRI helped to save energy and water from fertilizer production. Besides, it also protected the environment by saving fertilizer residue discharged into the environment. The SRI's sparse transplant principle also helped to ventilate, limit pests and diseases, and increase biodiversity and natural enemies in rice fields. Besides, the GHG emission reduction (CH ₄ , CO ₂ , N ₂ O) based on SRI's farming principles is alternate wetting and drying, converting the fields from anaerobic to aerobic and using compost fertilizer (straw). The entire above helps decline of CH ₄ , N ₂ O, CO ₂ in fields applying the SRI. Furthermore, the yield of SRI is higher and the input lower than those of conventional cultivation. In this article, we synthesize SRI research results in Vietnam and around the world to provide evidence proving that the SRI has contributed to environmental protection and climate change mitigation.
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HỆ THỐNG CANH TÁC LÚA CẢI TIẾN (SRI) TRONG BẢO VỆ MÔI TRƯỜNG VÀ GIẢM THIỂU BIẾN ĐỔI KHÍ HẬU - BÀI TỔNG QUAN

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THÔNG TIN BÀI BÁO		TÓM TẮT
Ngày nhận bài:	14/4/2021	Do diện tích canh tác ướt lớn, sử dụng nhiều nước hơn và sử dụng nhiều hóa chất đầu vào, canh tác lúa thông thường (CRC) là một trong những nguồn chính của CH ₄ và N ₂ O gây ô nhiễm môi trường và biến đổi khí hậu. Để giải quyết vấn đề này, hệ thống thâm canh lúa (SRI) đã được nghiên cứu và áp dụng ở khoảng 15 triệu nông hộ sản xuất nhỏ tại hơn 60 quốc gia. Kết quả của hầu hết các nhà nghiên cứu cho thấy áp dụng SRI sẽ giúp giảm thiểu chất thải rắn, tiết kiệm năng lượng và nước từ sản xuất phân bón. Bên cạnh đó, nó còn bảo vệ môi trường bằng cách giảm dư lượng phân bón thải ra môi trường. Nguyên lý cấy thưa của SRI còn giúp thông thoáng, hạn chế sâu bệnh, tăng đa dạng sinh học và thiên địch trên ruộng lúa. Bên cạnh đó, kỹ thuật tưới của SRI là nước – cạn xen kẽ đã làm môi trường ruộng lúa từ yếm khí sang hiếu khí và sử dụng phân ủ đã làm giảm phát thải CH ₄ , CO ₂ , N ₂ O. Hơn nữa, áp dụng SRI cho năng suất của lúa cao hơn canh tác truyền thống, trong khi đầu vào thấp hơn. Trong bài viết này, chúng tôi tổng hợp các kết quả nghiên cứu SRI ở Việt Nam và trên thế giới nhằm cung cấp bằng chứng chứng minh SRI đã góp phần bảo vệ môi trường và giảm thiểu biến đổi khí hậu.
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1. Introduction

Rice is the most important agricultural staple for more than half of the world's population. According to FAO in 2019 [1], the rice cultivated area and rice production worldwide is 162,055,938 ha and production of 755,473,800 tones, respectively. In which, the production shares of paddy by Asia accounts for up to 92.6%. However, farmers are slowly losing motivation to produce rice due to high production costs and disproportionate income.

In Madagascar in 1980, Father Henri de Laulanié introduced the System of Rice Intensification (SRI) [2]. The SRI has been developed in over 60 countries with 15 million smallholder farmers in the world [3]. By 2015, Vietnam had 35 provinces applying SRI with the total applied area of 436,377 ha, and the participation of 1,910,255 farmers [2]. The SRI has helped improve income [4], [5], ensure food security while minimizing negative impacts on the environment and enhancing farmers' resilience to climate change and ensure environmental sustainability. The SRI is a rice farming method that brings high economic benefits to farmers through input reduction because it saves 70-80% of seed and 60% of water [2]. The SRI is also based on the ecological principle of equal harmony between people and natures. Moreover, SRI contributes to reducing greenhouse gases (CH_4 , N_2O , CO_2) [6]. The objectives of the study are to give an overview of SRI studies in Vietnam and around the world, and to provide evidence to prove that SRI can contribute to environmental protection and mitigation of climate change.

2. Materials and methods

Research approach: because this is overview research, we did not use the primary data collection method, but only the secondary data collection method. The materials were collected from various sources such as the published scientific journals, research reports; internet (Research Gate, Science Direct, SRI Journal Articles, Rice Sciences, SRI-RICE, databases such as Literature Analysis and Retrieval System Online); and unpublished such as master and doctoral theses.

Data collection: The priorities for selecting documents are: Synthesize literature review of SRI in the world, particularly in textbooks, magazines or reviews and summaries; next are the sources of information coming from relevant journal articles. Priority is given to studies with the most current publication date and backward over time. In addition, access by reference source at the end of the articles to survey broader studies; the next is to read books related to the SRI in the library or eBooks; Find the articles, interviews of the scientific seminar on SRI.

Data processing methods: Use statistical parameters such as to synthesize the number of documents found related to rice cultivation, SRI helping environmental protection and mitigation climate change, then use the comparison method, make statistical tables and charts.

3. Finding and discussion

Conventional rice cultivation (CRC) is a farming practice characterized by continuous flooding, and high grain rates, while SRI is low seed rates and in the alternative wet and dry (AWD) condition. Planting with high density of 15 x 10 cm is in CRC, while that of SRI is of 25 x 25 cm. SRI transplanting is 8 to 15 days early or 2 to 3 leaves, but that with CRC is 21 to 35 days late. The SRI use more organic fertilizers, while CRC uses inorganic fertilizers. In weed control, CRC uses herbicides, while grass is treated by farmers by raking and hand weeding in SRI (Table 1).

Table 1. The practices of CRC and SRI of rice cultivation

Practices	CRC	SRI
Seed selection and preparation	Seeds are not selected or treated	Seeds are soaked for 24 hours prior to seeding to eliminate non-viable seeds
Nursery management	Flooded nurseries, densely seeded	Non-flooded nurseries, often raised beds, non-densely seeded

Practices	CRC	SRI
Uprooting and transplanting	21 – 35 days seedling, sometimes up to 60 days	Early transplanting of 8 – 15 day of seedling or 2-leaf seedling
Spacing	15-20 x 10 cm	25-30 x 20-25 cm
No. of seedlings/hill	3 - 7	1
No. of seedling/m ²	130 - 400	16 - 33
Water conditions	Continuous flooding of fields during crop cycle	Alternate wetting and drying (AWD), keeping soil moist
Use of fertilizers	Chemical fertilizers	Organic fertilizers, complemented if needed with chemical fertilizer
Use of herbicides	Yes	No

3.1. Economic benefit

The input savings from applying SRI to rice cultivation are based on its farming principles. The amount of seeds in the SRI was reduced by up to 92% [7] and the seed cost declines by 90% [4] compared to CRC. In CRC, the field is constantly flooded, which requires a tremendous amount of water for each crop. However, with SRI, the amount of water is done according to alternate wetting and drying (AWD). Therefore, saving water for irrigation (energy costs for pumping water) can help farmers get benefit from this. The amount of water used in irrigation in rice fields by the SRI method has decreased from 25 - 65% [2], [8] - [14]. Besides, SRI decreases transplanting work by 50%, reduces nitrogen fertilizers by 25 - 30% and reduces pesticides, rice yield increases by 13 - 29%. Therefore, SRI increases the efficiency of land use, labour, investment, and people's income [4], [15]. This is in line with Johannes Dill and et al. [5] who proved the use of fewer seeds (70% - 90% lower costs), fertilizers (35% - 40% lower costs), and almost no pesticides (80% - 90% lower costs).

Table 2. Rice yields applied SRC and SRI (ton/ha)

Country/region	CRC	SRI	Time	Author/ Reported
Madagascar: TefySaina	2.0	8.0	1994-1999	Norman Uphoff
Philippin: Mindanao	2.0	4.9	1999	Celso Limas
China: Sichuans	-	29.0	2004	CAU
Heilongjiong	-	12.5	2005	Jin Xueyong
Guiyang, Guizhou	-	12.9	“	Zhou Weijia
Sichuan Agri.Univer	-	11.8	“	Ma Jun
Wen Zhon, Zhejiang	-	10.1 – 10.4	“	Wu Cun Zan
Tian Tai, Zhejiang	-	11.5 – 12.0	“	Zhu Defeng
Meishan, Sichuan	-	13.2	“	Liu Zhibin
Leshan, Sichuan	-	12.1	“	Tang Yonglu
Jianyang, Sichuan	-	7 - 6	“	Xu Xiuli
Hunan	-	13.5	“	Yuan Longping
Taoyun, Yunnan	-	18.0	“	Zhu Defeng
Yunnan	-	20.4	“	Liu Zhibin
Indonesia	-	7.8	2002	Nippon Koei
Indonesia: Sukamandi	4.1 - 5.4	6.3 – 6.8	2003	Sunendar
	5.9 - 6.9	9.5	2006	Kartaatmadja
Cambodia: Kandal	2.0	5,0	1999	Koma Saing Yang
Takeo	3.6	5.8	2000	

Country/region	CRC	SRI	Time	Author/ Reported
Cambodia		4.1	2004	GTZ
Thailand: Chiangmai	4.8	5.4 - 8.3	2000	Phrek Gypmantasiri
Myanmar: Myitkyina	4.0	5.8	2001	Humayun Kabir
Sri Lanka: Bopitiya	3.7	15.8	2000	H.M. Premaratna
Mallawalana	3.7	10.5 - 15.7	2001	H.M. Premaratna
Namal Oya	3.7	8.5	2001	H.M. Premaratna
Bangladesh	-	2.4	2002-04	IRRI-BD/BRAC
India: Tamil Nadu	-	2.8	2004	TNAU
Andhra Pradesh	-	3.8	2003- 04	ANGRAU
West Bengal	-	3.2	2004	IWMI—India
Nepal	-	8.2	2006	DADO
Vietnam: Dong Tru	4.1	4.9 – 5.0	2005	Norman Uphoff
Thai Nguyen	6.6 - 6.8	7.0 – 7.9	2004	Hoang Van Phu
Thai Nguyen	6.1	7.1 – 7.5	2005	Hoang Van Phu
Bac Giang	6.6 – 6.9	7.4 – 8.5	2005	Hoang Van Phu
Thai Nguyen	5.32	12.4	2011	Hoang Van Phu

(Source: [4])

The results of an experiment in four Lower Mekong Basin countries (Cambodia, Laos, Thailand and Vietnam) showed that SRI practices helped increase rice yield by 52%, farmers' net economic return per hectare by 70% [16]. The total input costs for SRI farmers were between 18% and 27% lower than those of CRC farmers while increasing profits by an average of 155% [5]. According to Thakur in 2015, the SRI practices provided new possibilities for food security and poverty reduction [17]. This is similar to the results of studies of several authors [2], [5], [10], [18] - [21] (Table 2).

3.2. SRI in relation to environmental protection and climate change mitigation

3.2.1. Reducing environmental pollution

According to FAO and the International Rice Board (IRC), the efficiency of using nitrogen fertilizer is only about 35- 40% [22], which means that only about 35-40% of fertilizer is used by crop, the rest 60-65% is lost. With phosphorus and potassium, fertilizer efficiency rates are 40- 45%, so 55- 60% of the residue will go into the soil and groundwater causing environmental pollution. Besides, according to the fertilizer industry report in 2019 of FPTTS group, Vietnam consumed 11 million tons of fertilizer per year [23]. The average need for a hectare of rice requires 430 kg of fertilizer, with an area of 7.5 million hectares of rice in Vietnam, it is necessary to use up to 3,225,000 tons [24]. But only about 35-60 % of the fertilizer is absorbed by the rice plants, the residue of fertilizer release into the soil and groundwater would be 1,290,000 tons, accounting for more than one-third of the total amount of fertilizer used. Besides, to produce 1 ton of P_2O_5 , 6 tons of solid waste will be discharged into the environment, consuming 15 tons of water and losing 1 GJ of energy [25]. If a large amount of unnecessary fertilizer is reduced, this will both help save costs for the people and protect the environment. In addition, an evaluation in China has concluded methane (CH_4) emission could be reduced from organic fertilization of rice field [14].

The statistical studies and reports in Table 3 show that after applying the SRI method, the amount of chemical fertilizers has decreased from 25- 86%. The data proves that the benefits of using the SRI without chemical fertilizer are very beneficial in protecting the environment.

Table 3. *The amount of chemical fertilizer was applied (kg/ha/crop)*

Country/region	CRC	SRI	% Reduction	Source
Sri Lanka	150	21	86	[26]
Cambodia	116	67	58	[27]
Cambodia	150	75	50	[28]
Eastern Indonesia	250	125	50	[29]
Bamako, Mali	280	140	50	[30]
Timbuktu, Mali	198	148	25	[31]
Vietnam	700	506	28	[32]

3.2.2. Biodiversity conservation

The SRI's strategy for weed control is cono-weeding by hand with simple mechanism. Maintaining aerobic soil conditions also supports larger populations of beneficial soil biota [29] and enhances the numbers and diversity of the soil biota (mostly aerobic) [33]. Given the much low plant density in the SRI method, less humidity builds up within the plant canopy as air can circulate more easily among the plants. This provides pest and diseases with a less favorable environment compared to densely planted and continually-flooded conventional rice paddies [34], [35] (Table 4).

Table 4. *The incidence of sheath blight after SRI application in Vietnam*

Province	Year	% reduction of sheath blight	Source
Thai Nguyen	2004	3	[8]
	2006	19 - 52	[5]
	2011	2	[36]
Bac Kan	2010	10 - 13	[19]

Furthermore, insect diversity studies were conducted in paddy plots planted organically under SRI in Lubok, Melaka, China and another study in Binh Dinh, Vietnam [15]. The result indicated that SRI has ensured a good balance between the populations of pests, beneficial insects (predators and parasitoids) as well as other insect community during the various phases of paddy development without any loss in yield. These show that SRI is an effective way to conserve, use and enhance biodiversity crucial to sustainable food security [37].

3.3 SRI in relation to climate change mitigation

Rice paddies are considered one of the most important sources of CH₄ and N₂O emissions. Methane released from agricultural activities largely comes from inundated rice fields and ruminant animals, which together produce almost half of human-induced methane [38]. Currently, it is estimated that emission from rice fields is 53% of Vietnam's total emissions in the agricultural sector. Therefore, adoption of SRI in Vietnam can contribute a lot to the reduction of GHG emissions [39].

CO₂ is a primary concern when referring to GHG emission. However, CH₄ takes 23-25 times more and N₂O takes 310 times more a contribution to the global warming of the atmosphere than CO₂ [38]. Rice fields are presently one of the agricultural sector's main producers of CH₄ given that methanogen bacteria thrive in flooded soil conditions [2]. This is similar to the results of Nguyen et al [40] and Africare, Oxfam America [38]. The report of Dung and Phu show that converting paddy soils from anaerobic to aerobic status substantially reduced methane emissions [2], which is also the same opinion as Rajkishore [40] and Primitiva Andrea and Mboyerwa [41]. The research in the Nepal Terai, measuring CH₄ and N₂O emissions in rice fields of SRI found that CH₄ was reduced fourfold in SRI fields, whereas N₂O was reduced fivefold [43]. In addition, Alfred Gathorne-Hard et al. [20] found SRI management reduced GHG emissions by over 25% on a per-hectare basis.

Table 5. *The greenhouse gas emissions after the SRI application*

Source	Country	Relative reduction of GHG / GWP emission (%)				
		CH ₄	N ₂ O	CO ₂	GHG*	GWP**
[41]	China	30	-	-	-	-
[42]	Japan	25 - 35	-	-	-	-
[3]	Vietnam	21 - 24	15- 22	22 - 27	-	-
[17]		-	-	13 - 16	-	-
[44]	Northern Vietnam	14 - 67	-	-	22 - 72	20 - 66
[6]	Denmark	75- 90	-	-	85 - 87	-
[45]	Indo-Gangetic	61- 64	-	-	-	-
[45]	Indo-Plains	-	-	-	27 -30	-
[46]	India	40	-	-	-	-
[47]		-	-	-	40	-
[1]		-	-	-	67 - 71	-

Note: (-) No figures available; *GHG is Total GHG emission, ** GWP: Global warming potential

Table 5 show that applying the SRI, helps to reduce GHG emissions, of which the most significant gas reduction is CH₄ gas up to 90% in Denmark. The same thing also demonstrated in the study of Quynh et al. [15] and Rajkishore et al. [1]. The outcome was applying SRI can decrease CH₄ emissions 47-69%, decline amount of CO₂ equivalent per kilogram of paddy 46-65% [48]. The above studies were tested on many rice types and regions with different weather patterns but have been shown to be positive with GHG emissions reduction.

3.3.1. Reducing GHG emissions from burning rice straw

In several countries, rice straw is no longer used strictly after crop harvest in agricultural cultivation. The farmers often burn straw directly in the field instead of using it as animal feed, compost or serving people's daily lives (fuels). Open-burning of straw residues also contributes to global warming through emissions of greenhouse gases (GHGs) such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) [49], [30].

Table 6. *The percentage of rice straw is burned annually in the field*

Year	Country/ region	Rice straw was burned (%)	Source
2006	Philippines	95	[50]
2000	India	62	[51]
2013	Egypt	53	[52]
2006	Thailand	48	[50]
2018	China	26	[51]

Table 6 indicated that straw burning is still very large. In Eastern China, straw burning emissions could contribute up to 56% of total emissions in the summer (CO, SO₂ and NO_x) [55]. According to Jian Wu et al. [54], the average emission of CH₄ is 32% of the total emissions of outdoor straw burning. Besides that, Ryan R. Romasanta and et al. [49] pointed out straw burning accounted for 39% of the annual GWP over the entire cropping cycle in Laguna (Philippines). In Vietnam, the proportion of straw burned in the field accounts for 51% and 78.5% for spring and summer crops respectively. The largest CO₂ emissions were 738.8 thousand tons/year (89.6%); followed by CO emissions of 58.4 thousand tons/year (7.1%) [54]. Therefore, the principle of SRI is to use organic fertilizers. There have been many studies using post-harvest straw to compost fertilizer for the next

rice crop [31], [55], [56]. This helps to reduce huge amounts of GHG emission, which are released directly into the environment without any treatment.

3.3.2. Save energy

According to Ramana Rao et al. [57], the energy input and output in a rice production cycle of CRC and SRI was illustrated in table 7.

Table 7. The energy input and output of the main elements in rice production (energy equivalent: MJ/ha)

Items	CRC	SRI	Difference
A. Inputs: Human labour (h)	872.2	1,058.4	186.2
Diesel fuel (L)	7,883.4	6,306.7	1,576.6
Machinery (h)	2,508.0	2,006.4	501.6
Water for irrigation (m ³)	17,340.0	12,750.0	4950
Electricity (kWh)	36,505.8	26,842.5	9,663.3
Seeds (kg)	432.0	90.0	342.0
Total energy input (MJ)	95,116.6	78,678.3	16,438.3
B. Outputs: Grain (kg)	49,290.0	63,585.0	58,656.0
Straw (kg)	57,600.0	52,300.0	5,300.0
Total energy output (MJ)	106,898.0	115,885.0	8,987.0

Note: (h): Hour; (m³): cubic meter; (L): litre; (kWh): Kilowatt-hour. Source: [57]

The first is human labor which is calculated per hour, using the SRI will cost 1,058 h/ha while CRC is only 872 h/ha. This is explained by the fact that with SRI people will weed regularly by themselves because of their labor instead of spraying pesticides like CRC. However, the difference here is not large, farmers only spend 186 hours (about 7-8 days), thus, using SRI can reduce the use of pesticides, which will adversely affect the environment.

Reported by Valsecchi et al. [58], CO₂ emissions per litre of diesel burned is 2.67kg. Thence, with 1,577 liters of diesel oil saved about 4,210.590 kg of CO₂ emissions reduced to the atmosphere in each crop season. Therefore, SRI also has the potential to reduce the amount of electrical energy used in agriculture. As mentioned, the number of seeds used in SRI was 342 kg/ha less than CRC, which is about 80% of the seeds in each rice crop being reduced [57]. Research by Truong et al. [32] show that the energy input in CRC was 7,415 MJ/ha higher than SRI, equivalent to about 20%. However, it did not help the CRC have a higher output than that of SRI. SRI had output of 22,122 MJ/ha which was 21,849 MJ/ha higher than CRC.

4. Conclusion

The cultivation principles of SRI are different from CRC. Many authors believe that applying the SRI will decrease input (seed, fertilizer, water). The SRI uses mainly organic fertilizer, greatly limit the amount of chemicals. Almost all experiments and studies indicated that fertilizer in a rice crop of the SRI method decline by 25 - 80%. In the biodiversity conservation aspect, the AWD irrigation method, the transition from anaerobic to the aerobic environment and low planting density make it difficult for pests to reproduce while minimizing the use of pesticides, create a natural enemy environment, contribute to preserving biodiversity. The SRI makes reduction of GHG emission when the rice cultivation converting anaerobic to aerobic. The GHG emission might be growing less from the burning of rice straw, which can be solved by using rice straw to compost. Finally, in energy saving, the total energy input of the SRI is 12 - 20% lower than the CRC, while the output is 8 - 10% higher. In conclusion, SRI can help farmers save input costs while ensuring output. At the same time, it has made a contribution to environmental protection and climate change mitigation based on its farming principles.

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