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Research Article

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Enhancing Agricultural Resilience: A Review of the System of Crop Intensification

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Abstract

Modern agricultural technology predominantly related to the green revolution has made farmers access enough machinery and bought inputs to foster ever big areas by counting on improved varieties, more capital investment, and agrochemicals. All these production strategies have been linked to increased financial and ecological costs for agriculturalists and the environment. Farmers, despite a high use of inputs, are not in a position to achieve optimum crop yields. It is important to make the best use of agricultural inputs, in conjunction with better management practices, if we are to achieve sustainable intensification. Therefore, something called system of crop intensification (SCI) has appeared which aims at improving the land's efficiency, labor, water, seed etc. The system of crop intensive practices allows crops to grow and expand, which improves production in a sustainable and environmentally friendly manner. system of rice intensification (SRI) became the basis of SCI as the ideas and practices of SRI improved the production of irrigated rice and it is now being adopted in various crops such as finger millet, wheat, maize, and pulses. SCI approaches are especially important for resource restricted, nutritionally susceptible populations since SCI, like SRI, requires few bought inputs. This article describes the principles and practices of the SCI together with examples of successful experimentation as well as adoption done in different crops around the world.

Keywords

Sustainability, Resilience, Hidden hunger, System of crop intensification

Introduction

High input-based agriculture provides short term profits, but it is detrimental to soil health, ecological balance, and the sustainability of agriculture in the long run. Therefore, it is necessary to strengthen and maintain soil health systematically. Productivity and resilience of land resources need to be increased. One of the practices aimed at increasing agricultural productivity, sustainability, food security and resilience to climatic change by adapting how we manage our crops, soil, traditional water sources and nutrients is cropping intensification [1]. The principles of the SCI can be applied to a variety of crops such as rice, wheat, beans, sugarcane, and mustard. In order to improve production in a sustainable and environmentally friendly way, the system of intensive crop management allows crops to grow and expand. Given that the SCI, such as SRI, requires very small amounts of inputs to be bought off farm, this approach is particularly important for resource limited population with low nutritional status. However, as detailed in this paper, it is conceivable to measure up these processes for viable production with adequate mechanization. In both large and small farms, it is possible to encourage the establishment of larger, more efficient root systems and to increase and maintain more valuable soil life, which can mitigate the effects of drought, storm damage, extreme temperatures, pests, and diseases. SCI is an agricultural production approach that aims to maximize and optimize the profits received by better utilizing available resources such as soil, seeds, water, nutrients, sun energy as well as air. It is a constant need to analyze farming alternatives in setting, captivating into justification of all aspects, exchanges of time plus space; so, as the field activities can be carried out in a judicious manner, with land area utilized adequately by crops rather than simply a solitary crop. It is also critical to include environmental services [2]. Therefore, conventional farming practices need to be overhauled by adopting SCI to be more cost-effective and sustainable.

One of the most important modern agricultural progresses, which spread to farmers' fields, is a rice intensification system that was set up in Madagascar in the 1980. SRI is a promising rural innovation that has emerged from the traditional research system. In order to increase the productivity of available land, labor, water and energy as well as improving food security in vulnerable farmer communities, it changes traditional paddy growing practices with more effective management of plants, water, soil and nutrients. A set of principles is included in the strategic roadmap which includes using young seeds, one seedling hill^{-1}, square plantings, mechanical weed control, and intermittent wet and dried organic matter addition.

The adoption of these concepts has been claimed to boost rice yield by 50% to 100% [3]. SRI practices have recently been extrapolated to other crops such as wheat, Teff grass, maize, sorghum, finger millet, soybean, black gram, kidney bean, lentil, mustard, sugarcane, tomato, brinjal, chili, potato, carrot, and onion under the name SCI. SCI practices, like SRI, have been shown to enhance crop output levels by more than twofold [4]. As for SCI, like SRI, counts on purchased supplies negligibly; it is especially useful for resource-limited and nutritionally challenged households. This piece brings along a whole lot of experiences in acclimatizing and bringing the ideas and approaches of SRI to use for sustainable development of diverse crops (Figure 1).

The necessity for sustainable strengthening

The requirement for long-term agricultural intensification although different organizations use different terminologies, there is widespread arrangement that farming zones all over the world must follow customized plans for feasible escalation if worldwide food security demands be fulfilled during the era [5, 6]. It is these ideas which share a common denominator of being different from the type of growth that has taken place in agriculture over the past 50 years. Farmers are now able to benefit from enough land, machinery and purchased inputs that will enable the cultivation of increasingly large areas; an increase in their output by using better crop varieties with more water, increased capital investment, fossil fuel energy, as well as agrochemicals. Modern agricultural technologies, particularly those connected to the green revolution, have made this possible. More recent, more extensive production strategies, which were categorized by both fewer inputs and less results have been improved by using more inputs to produce more output. However, it has also been connected to higher costs for farmers and ecosystems in terms of the economy and the environment [7].

There are other types of intensification available than that, which is primarily dependent on enhanced utilization of external resources. Agroecology as a whole could be used to investigate additional intensification alternatives. This seeks to utilize as much of the natural resources as possible, comprising of the classes and hereditary varieties found in environment. Specifically, when land and aquatic resources become not so much in comparison to the human populace which relies on them, resource deficiency keeps a higher emphasis on betterment of the administration of all available environmental resources. In recent years, a phenomenon known as crop intensification (SCI) has evolved in many African and Asian nations, increasing the productivity of the land, seed, water, labor, and capital means that farmers engage in growing a diverse range of crops [8, 9]. As mentioned below, prominent organizations for example the Ethiopia's government Agricultural Transformation Agency [10] and the World Bank [11] are taking notice of this emergence. The experience of farmers and others with the rice intensification system has contributed to the ideas and practices that have made SCI possible [4, 12] (Table 1). The ideas related to the SCI and SRI are shared with other agroecological innovation areas, e.g. agricultural forestry, conservation agriculture, integrated pest control or integrated management of range and animals based upon proven agronomic theory and practice. The common features involved in SCI crop management, extrapolated by farmers and others from their SRI experience, can be summarized as follows (Figure 2):

Table 1: Principles and practices of SCI.

Principles	Practices
To increase the production, use of renewable resources and on farm resources is emphasized	Principles of conservation tillage and crop rotation should be used to achieve sustainable intensification
Increasing resource use efficiency along with optimization of external input application to lower the negative impact of food production on environment and narrow the yield gap	Addition of leguminous crop for biological nitrogen fixation and cover crops in rotation
Use of improved crop varieties and livestock breeds	Integrated pest management
Food waste should be lowered with increasing productivity	Sustainability of soil and water conservation, soil health management
-	Protection of plant genetic resources and improved varieties
-	Insufficient irrigation, additional irrigation, water management, fertigation

Source: [14].

- Early and careful establishment of healthy plants with special attention paid to safeguarding and nurturing their potential for core system expansion along with the benefits that go along with it.
- Significantly lowering crop density, transferring, or sowing seeds with more space between each plant.
- Water use in a way that benefits plant roots and soil bacterial growth.
- To support more root growth and to benefit the soil biota, it is essential that soils are enriched with organically material and maintained well.

Several other crops, including finger millet, mustard, and teff, have been found to benefit from careful transplantation of immature rice seedlings, an important technique used in the SRI methodology, but not in all crops. In combination with other methods, it may be possible to apply seeding directly. SCI is a component that can reduce the number of workers required. Or it's even more successful with some crops, such as wheat. Crop establishment is a critical component of agro-ecological management, whether for SRI or SCI. These four concepts can significantly increase the production and profit from 'intensively' managed crops (Table 2). As shown in India and Ethiopia, improved production processes brought together and raised under the banner of SCI are being scaled up significantly:

- Under one of its programs in Bihar state, the World Bank has proven significant production and profitability benefits for food-dependent households. According to the research, 348,759 farmers were adopting SCI methods on over 50,000 acres as of June 2012. Their yield improvements were summarized as 86% for rice, 72% for wheat, 56% for pulses, 50% for oilseeds, and 20% for vegetables. Rise in profitability for these various crops were calculated to be 250, 86, 67, 93, and 47% respectively [11] (Table 3).
- In order to increase tef production, which represents the country's major source of grain, the system of tef intensification is being proposed and tested in two different iterations. Ethiopia's 160,000 farmers took part in on-farm trials with the less labor-intensive, direct-seeded version of tef production and saw an average yield increase of 70% [10]. Thus, new opportunities for increasing agricultural production are emerging that can directly reduce food dependency for several billion people while also being environmentally friendly. Therefore, the fact that SCI productivity gains are being achieved in areas with the highest levels of food insecurity such as Ethiopia, Bihar state in India, the hills of Nepal, and the Timbuktu region in Mali makes the yield improvements all the more significant for improving people's lives and livelihoods.

Table 2: SCI experimentation, crop, and country.

Crop	Country
Finger millet (*Elusine coracana*)	India (Karnataka, Jharkhand, Uttarakhand), Ethiopia (Tigray), Nepal, Malawi
Wheat (*Triticum aestivum* L.)	India (Bihar), Nepal, Afghanistan, Mali, Pakistan (Punjab), Ethiopia (Tigray, Oromia), USA (Maine), Netherlands
Maize (*Zea mays* L.)	India (Uttarakhand, Assam)
Pulses: cowpea/black-eyed pea (*Vigna unguiculata*); chickpea/garbanzo beans (*Cicer arietinum*); mung bean/green gram (*Vigna radiata*); lentil/black gram (*Vigna mungo*); pigeon pea/red gram (*Cajanus cajan*); common/haricot/kidney bean (*Phaseolus vulgaris*), soybean (*Glycine max*), groundnut/peanut (*Arachis hypogea*)	India (Karnataka, Tamil Nadu, Bihar, Uttarakhand), Ethiopia

Source: [14].

Table 3: Effect of SCI on different crop yield.

Crop	Country	Conventional yield (t/ha)	SCI yield (t/ha)
Finger millet	India (Karnataka)	1.25 - 2.5 (3.75 max)	4.5 - 5.0 (6.25 max)
	Ethiopia (Tigray)	1.3	4.0 - 5.0
	India (Uttarakhand)	1.5 - 1.8	2.4
	India (Odisha)	1.0 - 1.1	2.1 - 2.25
Wheat	India (Bihar)	2.0 - 2.25	3.87 - 4.6
	Nepal (Khailali and Dadeldhura)	3.4	6.5
	Afghanistan	3.0	4.2
	Mali (Timbuktu)	1.0 - 2.0	3.0 - 5.0
	India (IARI research)	5.42 (SRP)	7.44
Maize India	(Himachal Pradesh)	2.8	3.5
	India (Assam)	3.75 - 4.0	6.0 - 7.5
Pulses	India (HP/UKD/MP)	-	46% average increase across seven pulses
	India (Bihar)	-	56% increase across different pulses

Source: [14].

With the growing population and demand for agricultural land, soil and water losses have emerged as a major issue worldwide, especially in developing countries. Results from a study have proved that applying organic mulch had various positive effects on soil and water conservation. Soil loss and water runoff rates a greatly reduced with the increased rates of mulching [15]. To achieve the goal of zero-hunger and poverty alleviation, the population is dependent on agriculture to fulfil their demands. Furthermore, all agricultural plans depend on increasing the usage of chemicals to attain additional production which will eventually pose higher pressure on financial investments and on the environment as well. Hence optimizing the use of chemical fertilizers along with the organic sources in a balanced manner proves to be a better alternative. As reported by various researchers, using chemical and organic sources together is quite promising to achieve enhanced production and greater stability [16].

Case Studies

Finger millet (status in India and Nepal)

A study revealed that around 40 years back millet growers in Haveri district situated at northern Karnataka state of India created a farming practice known as guli ragi ('hole imbedded millet'). Which was established by replacing conventionally disseminated seeds by young enough seedlings of about 20 - 25 days old transplanted into 45 cm x 45 cm square holes @ two seedlings in each hole. It was suggested including a handful of manure or compost to improve soil fertility in guli ragi cultivation. An ox drawn weeding device that works like a stirrup hoe, loosening up, elevating, and airing the surface soil while cutting over the roots of weeds was employed by farmers [17, 18]. Even though guli ragi needs additional work from growers, their efforts are amply rewarded. Another study includes an elderly woman farmer, Mama Yehanesu, who tried experimenting with finger millet in the year 2003. While drifting from the usual practice of broadcasting the seeds, she preferred transplanted 30-day seedlings at 25 - 30 cm spacing and received a yield of around 1.8 tons that season. Also, with this method an additional application of compost gained a whooping yield of 7.6 t/ha. Neighboring growers who witnessed this outcome began utilizing transplanting approaches to produce finger millet and later began receiving normal yields of 4 - 5 tons/ha [9]. In the woreda (district), over 90% of farmers are currently utilizing crop intensification approaches for finger millet, tef along with other field crops, finding SCI spacing with supplementary concepts to be valuable.

A study done by NGO PRADAN with the farmers for the application of SCI approaches to be followed in finger millet in the state of Jharkhand in 2006. The adoption of SRI practices to this rainfed crop produced results parallel to those reported with irrigated rice. Earlier researchers from Andhra Pradesh's state agricultural university worked to check whether root growth is affected by transplanting finger millet seedlings at a very early age and found out that root growth is indeed affected by transplanting seedlings at 10,15 and 21 days. The results were inferred to be similar to that of rice grown under SCI practices.

The application of principles of SRI to finger millet commenced in 2007 in in the Himalayan foothills (Uttarakhand), with the collaboration of the NGO People's Science Institute (PSI) with five farmers who focused on transplanting seedlings just 15 - 20 days old at 20 cm x 20 cm spacing which eventually led to an increase in their yield by 33% on comparing to the identical variety grown using their standard procedures (Figure 1).

The results of controlled studies that examined SCI have been released by the scientists from the Institute of Agriculture and Animal Science in Rampur. In SCI approaches, an estimate of about output, 82% greater than direct sowing and 25% greater than transplanting with grownup seedlings were observed [19] (Figure 2).

Status of wheat in India and Nepal

As revealed by the studies on system of wheat intensification (SWI), it can be deducted that the wheat intensification system, which works on the principles of SRI for rice production, was settled mostly in India, while SWI has begun with farmer participation in Nepal, Pakistan, Afghanistan, Ethio-

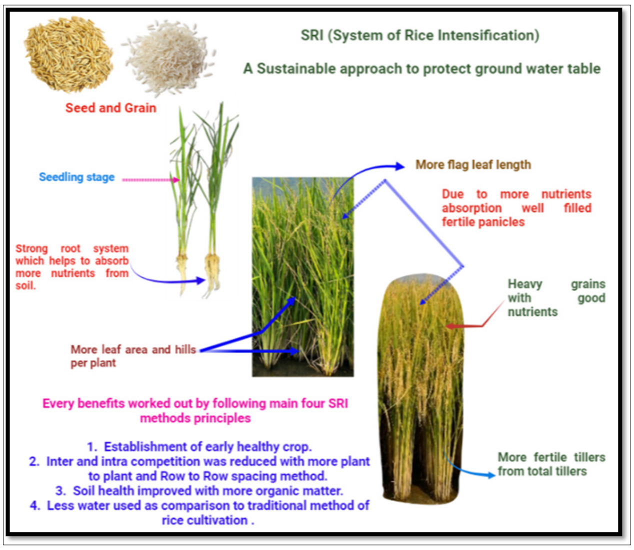

Figure 1: System of rice intensification.

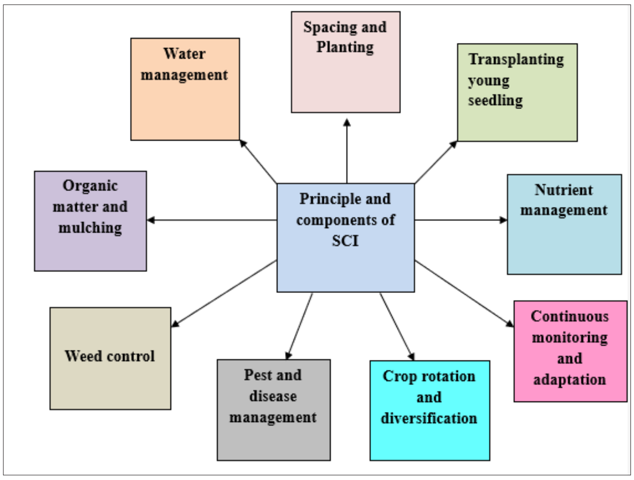

Figure 2: Principles and components of SCI.

pia, and Mali. Yields differ significantly amongst and inside countries due to variances in growth circumstances (pedology and climate) and seasonal distinctions.

PSI-NGO in Dehradun undertook the first trials with modified SRI methods for wheat in 2006. As a result, PSI expanded SWI use to agriculturalists in Madhya Pradesh. SWI yields averaged 3.0 t/ha among new adopters. According to the data collected by PSI, farmers from 2016 have shown greater interest in SCI approaches as compared to the year of 2013. Another example include an NGO based in Bihar, which started taking initiative and worked with 415 farmers for on farm trials in Gaya and Nalanda in the year 2008 - 09 rabi season with funding received from the Bihar Rural Livelihood Promotion Society (Jeevika). Results recorded farmer's initial average yields using SWI technologies were 3.6 tons/ha. The next year, with the help of Jeevika and World Bank-supported programmed, the number of SWI farmers climbed to 25,235, and then to 48,521 in 2010 - 11, with average SWI yields of 4 tons/ha. Farmers' costs per hectare increased as the result of SWI practices, but their costs per kilogram of grain produced decreased by 28% as a result of the higher yield. Farmers who worked with non-governmental organizations rather than government workers saw further production gains. According to the Jeevika program, average SWI yield gains in 2012 were 72%, with households' net income/ha from wheat output increasing by 86% under SWI [11], an estimated 500,000 farmers in Bihar were employing SWI methods on around 300,000 hectares, with yields of 4 - 5 tons/ha representing a 60 - 80% increase on average. In 2008 - 09, Madhya Pradesh's rural livelihood mission began offering SWI to farmers in tribal areas, beginning in the Shahdol district. Farmer's traditional farming practices, which necessitated more seeds, inputs, and water resulted in an average yield of 3 t/ha. Following that, New Delhi has promoted SWI in the states of Chhattisgarh, Gujarat, Jharkhand, Maharashtra, Odisha, and West Bengal, in addition to Bihar and Madhya Pradesh, through the various state rural livelihood projects.

According to trials, the SWI method increased wheat production by 91 percent and 100 percent respectively. Only one or two germinated seeds were dabbed on each hillside, spaced 20 cm apart, as a substitute for broadcasting and line sowing of SWI seed in Nepal. Studies carried out in 2014 at the Dailekh Agricultural Research Station revealed that SWI techniques led to better plant constructions with a considerably higher root length, larger leaf area, increased weight of grain and more filled grains per spike as compared to wheat grown by line feeding or broadcasting. This has been attributed to the plant's deeper, more uniformly distributed root systems [20].

SWI on station trials

SWI was tested at the Indian Agricultural Research Institute (IARI) in New Delhi for 2 rabi seasons, 2011 - 12 and 2012 - 13 [21], Direct-seeded SWI performed the finest of the treatments examined across all parameters. (Researchers discovered in their 1st season of testing that transplanting in wheat under SWI was not as effective as direct sowing, as Malian agriculturalist trials also revealed). During the first season, when weather conditions were somewhat average, the direct-seeded SWI plots yielded 30% more than the SRP (standard recommended practices) plots. Soil testing was done in the experimental plots for each growing season and revealed that the status of N, P, and K in SRP plots were normally reduced, despite the fact that they had been well-supplied with fertilizer during the trials. There is a need for more systematic evaluations including controls and replications ought to be taken up for SWI and other versions of SCI.

Status of maize and pulses in India

Maize being the third most key cereal crop in the world after rice and wheat is unfortunately less explored in terms of SCI in order to increase the cultivation of maize than that of wheat and rice.

A case study showed that PSI situated at Dehradun has collaborated with smallholders in Himachal Pradesh, Uttarakhand, and Madhya Pradesh states to boost maize output using modifications of SCI practice. Trials were set up to test the impact of varying spacings between hills. The yields of 6 tons per hectare were achieved in the SCI forms used by farmers. Given that, millions of families in dozens of countries rely on this crop for nourishment and, in some cases, profits, hence, further editions and evaluations of SCI methods to progress maize production, particularly to help climate-stressed households and food insecure community should be a priority for SCI development. Maize yield increases have not been as histrionic as in certain other crops under SCI supervision. However, making SCI improvements with maize may have a higher overall influence on people's well-being than any other crop.

Pulses productivity has been considered by promoting the improved seeds that are properly selected and enhancing the early growth of plants in order to stimulate the root growth. Other efforts such as decreasing the spacings i.e., increasing plant density with enhanced organic matter.

In India, PSI initiated work using SCI ideas to boost pulse output in Uttarakhand state in 2007. PSI discovered that SCI yield upsurges about 45% across 7 types of pulses, with substantially lesser seed requirements and, probably more importantly, with less loss from either water scarcity or water excess. Due to a lack of resources and institutional backing for elevation of SCI for pulse crops in India, the spread has been primarily resourceful, often quick locally but gradual overall. Demonstrating the benefits of SCI practices with pulses has typically begun with a farmer or NGO project. According to the Bihar state poverty-reduction initiative, SCI methods increased pulse yields by 56% on average for 41,645 resource-limited households on 15,590 acres in 2012. Though, the use of crop intensification ideas and procedures for enhancing pulse cultivation is not as progressive as SRI for rice or SWI for wheat, these technologies are expanding regardless of whether they are labelled as 'SCI'.

Conclusion

As per this review SCI is an evolving phenomenon which is still in progress. Most of the data presented in this review is collected from reports of on farm trials and works done by NGO's that have been published in journals available online as SCI has been exploited very less through systematic research except for SRI. This information has been compiled in order to convey these opportunities to the notice of a larger addressees concerned with enhancing agricultural production, food security, as well as one that wishes to save environmental resources and assist farmers in dealing with growing climate stresses today and in the future. Because such crop management practices modifications cause no harm, their investigation, demonstration, and reworking represent an opportunity for both farmers and the agencies and professionals who work with them to increase farmers' yields and incomes in environmentally friendly ways.

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Conflict of Interest

None.

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