The U.S. Government's Global Hunger & Food Security Initiative

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

Briefing Paper #1: Sustainable Intensification Principles and Concepts

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

What is Sustainable Intensification?

Sustainable intensification (SI) is defined as an agricultural process or system where valued food, fiber or other productivity is maintained or increased while enhancing positive sustainability outcomes, protecting and improving valued assets including social, environmental, human and economic.

When successful, the sustainable agroecosystems have a positive impact on natural, social and human capital, while unsustainable forms of agricultural intensification continue to deplete renewable capital assets.

The idea that the goals of enhanced sustainability and intensified production are not mutually incompatible started to gain traction at the end of the 1990s, in parallel with increasing emphasis on external inputs rather than systems management as a source of productivity growth. Intensification had previously been synonymous with types of agriculture that resulted in environmental harm. The combination of the two terms was an attempt to indicate that desirable outcomes, such as more food and better ecosystem services, might actually reinforce each other. Both could be achieved by making better use of land, water, biodiversity, knowledge, social organization, and new technologies. SI is now central to both the UN's Sustainable Development Goals and wider efforts to improve global food and nutritional security.

SI is best considered as an umbrella term that covers and contains a wide range of different agricultural practices and technologies that can be applied by farmers in different ways to suit their specific agroecological, economic, social and cultural circumstances, as well as differing farming systems.

Over the past four decades, a wide range of different terms for more sustainable forms of agriculture have come into widespread use. Examples include agroecology, regenerative agriculture, alternative agriculture, evergreen agriculture, agroecological intensification, save and grow agriculture, and sustainable intensification. Some of these draw on earlier traditions and principles in permaculture, natural farming, and forms of organic agriculture, and most incorporate various mixes of scientifically established basic resource management and production principles.

Sustainable systems increase productivity and the natural resource base simultaneously and are often diversified and multi-purpose. They create new flows of ecosystem services that benefit farmers and the planet.

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There are some 5 billion hectares of farmland worldwide. A recent study (2018) showed that SI was being practiced by 30% of the world's farmers (163 million) on 9% of the world farmed area (450 million hectares). This represents encouraging progress, and yet also indicates how much more needs to be done.

SI is Multipurpose

Agriculture is unique as an economic sector as it directly affects many of the very natural and social assets on which it relies for success. These influences can be both good and bad.

Industrialized and high-input agricultural systems rely for their productivity on simplifying agroecosystems, bringing in external inputs to augment or substitute for natural ecosystem functions, and externalizing some costs and impacts. Pests tend to be dealt with by the application of synthetic and fossil-fuel derived compounds, wastes flow out of farms to water supplies, and nutrients leach to the soil and groundwater. As a result, there has been widespread and increasing costs caused by agriculture to natural ecosystems and human health. In this sense, industrial agriculture has not been sustainable.

Outside the OECD area, many current agricultural development approaches are leading to extensive resource degradation. especially in parts of Asia, Africa and Latin America. Consequently, there is often extensive soil degradation, severe aquifer depletion and widespread biodiversity loss resulting from the emphasis on external inputs to drive intensification for food security. Nevertheless, there are substantial areas of smallholder SI across low- and middle-income countries.

A major theme of SI is thus to create agricultural systems that are multipurpose for intensification and sustainability, have positive side-effects, and do not shift negative effects in ways that impose costs on other systems or people.

In 2023, the UN FAO published a new analysis of the hidden costs of agri-food systems in 154 countries: this covered local environmental impacts, greenhouse gas and nitrogen emissions, blue water removals, the social costs of undernourishment, and health costs from non-communicable diseases (including obesity). Some impacts could not be monetized: those associated with child stunting, pesticide exposure, land degradation, antimicrobial resistance and illness from unsafe food.

The external costs amounted to US$13 trillion in 2020 (range of $11-15 trillion), some 10% of world GDP, and equivalent to US$35 billion per day. The FAO data show that negative externalities exceed the value of the food created in several countries. Worldwide, every $1 of agri-food value created produces $0.31 of costs; but in the USA, $1 of value creates $1.33 in costs, and in the UK, $1 creates $2 of costs. In the USA, the agricultural and food sector is worth $1.2 trillion per year, yet it shifts $1.6 trillion of costs to others.

Multipurpose SI systems aim to create wider economic benefits by cutting out the negative externalities.

One key challenge for the future is to find new methods and tools for monitoring and evaluation to measure the outcomes of novel impact pathways.

The Idea of Redesign

The concept of sustainability is best thought of as open, emphasizing values, outcomes and impacts, rather than means, applying to any size of enterprise and farm, and not predetermining technologies, production type, or particular design components. In short, SI varies from place to place, and over time.

Key principles of effective SI redesign include a systems or multi-disciplinary approach embracing environmental, economic and social aspects, combined with a participatory action development approach to match SI opportunities with the realities for farm systems and household priorities. Generally there are many opportunities for improved integration of resources, crops, trees and animals that can boost system productivity. Clearly, the redesign of sustainable intensification will be very different in rainfed compared to irrigated farming systems, or humid crop-led farming systems compared to pastoral farming systems, or in remote farming systems compared with systems with excellent services. The two variables of agroecological potential and degree of access to services differentiate farming systems in a useful way for the redesign for SI.

Central to the concept of all types of sustainable intensification is an acceptance that there will be no perfect end point. No system is expected to succeed forever, and no package of practices is expected to fit the differing ecological and social dynamics at every location. There will be new pests, new weather patterns, surprising market shifts, changes in policy. Successful and sustainable agricultural systems need to have the capacity for continuous innovation.

The concept of Redesign is also central to sustainable intensification. Redesign harnesses the agroecological processes of predation, parasitism, allelopathy, herbivory, nitrogen fixation, pollination, and trophic dependencies to develop system components that deliver beneficial services for the production of crops and livestock. A prime aim is to influence the impacts of agroecosystem management on externalities (reduce negative and increase positive), whilst increasing productivity for farmers. Redesign aims to make transformative changes across whole landscapes and countries.

Redesign is best considered a continuing process requiring social and institutional innovation. It is dependent on representation, engagements and participation of all stakeholders and using feedback between outcomes and activities to direct, redirect and fine-tune SI trajectories. There is a need to create and make productive use of human capital in the form of knowledge and capacity to adapt and innovate and develop forms of social capital to promote common landscape-scale change, such as for positive biodiversity, water quantity and quality, pest management, and soil health outcomes.

SIIL Highlights – *This is a short synopsis of highlights from the SIIL. All key accomplishments of the SIIL will be available in the 10-year report, including the final decade indicator numbers.*

The SIIL has funded and supported researchers who have produced over 1,000 publications. presentations, dissertations and other documents over the past decade (2014-2024) on Sustainable Intensification concepts, methods and outcomes.

The SIIL has trained several thousand scientists to PhD, Masters, and Bachelor degree levels, together with delivery of short-term training programs for a further 10,000 people, thus creating domestic capacity in partner countries for continuing innovation in SI.

The SIIL has collaborated with 120 national and international entities to help spread understanding of SI concepts, methods and approaches.

The SIIL has been building SI methods for climate-smart agriculture using nature-based solutions (NBS) in all fourteen partner countries.

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

SIIL Briefing Paper #2: Sustainable Intensification and Impacts on Productivity

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

Five Renewable Assets

The sustainable intensification of agriculture aims to produce sufficient agricultural produce for all the global population using practices that enhance natural resources, recover the climate and boost smallholder livelihoods. Through knowledge of SI, farmers, policy makers and business leaders can also understand both the options to transform industrialized food systems and set out the multiple paths towards sustainable ways of living that are good for people and nature.

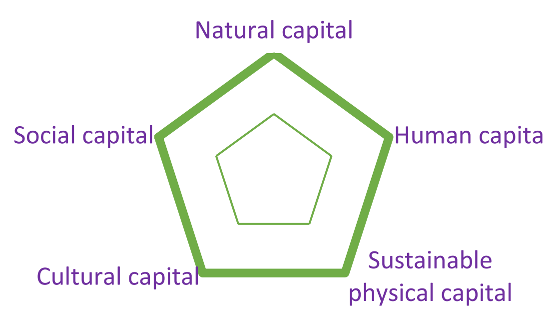
Sustainable intensification results in what has been called regenerative good growth: increased productivity that does not impose environmental and social costs locally or globally. Good agricultural growth centers on the recognition, protection and enhancement of five renewable assets (Figure 1). These assets represent various types of capital (as described in the Sustainable Livelihoods approach). When SI uses these assets, it also grows them. Finance is not included as a renewable capital in this model, as it is better conceived of as a service derived from configurations of these assets, just as are food, flood protection and trust.

Figure 1. Five renewable capital assets for good growth.

The five assets are defined in these ways:

i. Natural capital: the stocks of natural resources in whole ecosystems (clean air and water, flood control, tree and soil carbon, biodiversity) and the associated climate which provide beneficial services that sustain all economies and societies making human life possible;

ii. Social capital: the trust, reciprocity and relationships that increase togetherness, kindness, the connectedness and collective action between and within communities that reduce the cost of transactions, and the social institutions that emerge to hold people together;



iii. Human capital: the capability of individuals, expressed in knowledge, skills, health and nutrition, the value of which grows across healthy and long life-courses and is enlarged for individuals when citizens and organizations collaborate and share knowledge;

iv. Cultural capital: the place-based assets created by people that comprise customs and rituals, arts and language, stories and laws, science and technology and all forms of spiritual tradition;

v. Sustainable physical capital: the human-made assets and infrastructure valuable to agriculture, comprising machines, buildings, housing, factories, utilities, energy generation, transport, and communication systems, and that when these are sustainable, they create positive externalities when in operation.

SI Increases Productivity

There is a common and outdated misperception that paying attention to the environment (natural capital) results in inevitable trade-offs: you can have the environment, but productivity will have to fall. This is now known to be untrue.

Productivity can be measured in many ways: increased food and fiber output per hectare or per year; reduced costs or inputs or labor; total production per farm; internal flows of livestock feed. Provided there is appropriate deployment of the five capital assets and farm households have appropriate incentives to adopt appropriate SI technologies and practices, agricultural productivity and farmer income increases.

For agricultural systems, there is evidence of increased system outputs and reduced input needs, through increases in crop productivity, such as by farmer field schools on all crops, and in grazing and pasture productivity; increases in tree and agroforestry cover on farms; reductions in the use of pesticides in integrated pest management; and adoption of organic and zero-budget systems.

Regenerative agricultural economies are those with circular flows of energy, information, resources, nutrients and money, which thus minimize the use of non-renewable resources and eliminate negative externalities. At entry level, Circular economies (CEs) set out to reduce, reuse, recycle and recover. When more developed as innovative and diverse, they produce system shifts. CEs are being promoted by a number of national governments and multilateral agencies to help in the transition to more sustainable and net zero economies.

It is in lower- and middle-income countries that some of the most significant progress towards sustainable intensification has been made in the past two decades. The largest study was of 286 projects in 57 countries. In all, some 12.6 million farmers on 37 Mha were engaged in redesign transitions involving sustainable intensification. For the 360 reliable yield comparisons from 198 of the projects, the mean relative yield increase was 79% across the wide variety of systems and crop types. Some 25% of projects reported relative yields of more than 2.0 (i.e. 100% increase), and the geometric mean showed a 64% increase in yield for eight different crop groups.

A further study of twenty countries in Africa where sustainable intensification had been developed found that crop yields, as an indicator of system productivity, rose on average by a factor of 2.13 (i.e. slightly more than doubled). The SI methods comprised crop improvements, agroforestry and soil conservation, conservation agriculture, integrated pest management, horticultural intensification, livestock and fodder crops integration, aquaculture, and novel policies and partnerships. These projects had recorded benefits for 10.4 million farmers and their families on 12.8 Mha. The timescale for these improvements varied from three to ten years.

A further meta-study in Asia and Africa identified 85 IPM projects with combined changes to crop productivity and pesticide use for rice, maize, wheat, sorghum/millet, vegetables, potato/sweet potato, soybean/bean and cotton/tea. The time elapsed from project start to measurement of reported impact varied between one to five years. The mean yield change across crops was an increase of 41%, combined with a decline in pesticide use to 30.7% of the original use (down by 69.3%). A total of 35 of 115 (30%) crop combinations resulted in a transition to zero pesticide use.

SIIL Highlights – *This is a short synopsis of highlights from the SIIL. More key accomplishments of the SIIL as a result of Sustainable Intensification and impacts on productivity will be available in the 10-year report.*

Bangladesh:

In the polders, the introduction of rice-fish culture in flooded paddy fields has raised total system productivity, with the fish providing a new protein source.

During FY 2023, six service providers (husband-wife) harvested rice produced sustainably from 41 hectares of land and earned an increased income from US$169 to US$882. This has resulted in a greater increase in interest for others in the community.

Burkina Faso:

Trials of dual-purpose cowpea and sorghum varieties have shown increases in grain yields and fodder/green manure biomass, thus benefitting farm families and increasing soil organic matter and carbon.

Cambodia:

Seed broadcasters were developed by the Appropriate Scale Mechanization Consortium (ASMC) for use on 800 hectares of farmland, increasing productivity, lower costs, and improving the local economy.

The Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CESAIN) has successful partnerships built around Agricultural Technology Parks and farmer-to-farmer programs that have drawn in new funding sources to support agricultural research and extension institutions in Cambodia that are benefiting smallholder farmers.

The successful development of Wild Food Gardens and nurseries at schools, engaging students to develop responsibility toward nature and healthy foods; leading to the incorporation of green labs into the curriculum are a few of the key accomplishments of the S-3 project of SIIL.

Ethiopia:

The research team found that multiple maize crops cultivated after irrigated and fertilized vegetables or fodder increased maize yield substantially as compared to baseline conditions due soil fertility improvement from residual nutrients from dry season cropping.

Senegal and Niger:

The Institut Sénégalais de Recherches Agricoles (ISRA) and Centre d'Etude pour l'Amélioration de l'Adaptation à la Sécheresse (CERAAS) have developed dual-purpose millet varieties for dryland systems where both grain and fodder yields are higher. This has improved the livelihoods of 3,000 crop and livestock producers, with notable nutritional benefits for women and children.

Tanzania:

The research team evaluated bidirectional learning and extension approaches to promote SI technologies among researchers, extension, agro-dealers, NGOs, and farmers and analyzed household surveys.

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Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

SIIL Briefing Paper #3: Sustainable Intensification and Natural Capital

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

Net Positive and Nature Positive

In the past 50 years, 17% of global land and 10% of marine area has come under legal protection, and a total of 195 countries plus the EU have signed the Convention on Biological Diversity. Nonetheless, Nature and biodiversity worldwide are under threat, and therefore ecosystem function and the provision of services. Rates of extinction are 100 to 1000 times higher than the pre-industrial background. Between 1970-2018, according to the WWF, the relative abundance of monitored wildlife populations around the world showed an average 69% decline. Globally, 40% of all land area has become degraded, with 24 Gt of fertile soils lost each year, with particularly adverse impacts on smallholder farmers and the poorest communities.

Agricultural systems can impact on nature and biodiversity in good and bad ways. The multi-purpose and multi-functional approach that Sustainable intensification takes to food and fibre production can help to bend the curve of biodiversity decline (Figure 1). Sustainable practices and approaches are variously termed Nature-Based Solutions (NBS), Negative Emissions Technologies (NETs), and Nature Positive Production (NPP) as they are focussed on improving the health of natural assets such as soil, water, and biodiversity.

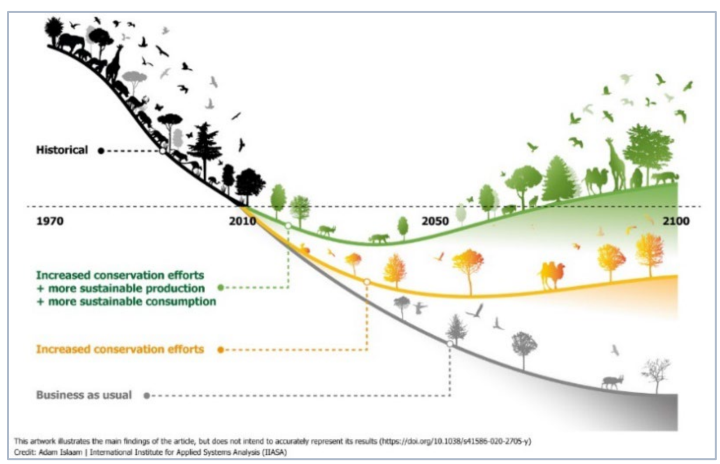

Figure 1. Bending the curve of biodiversity decline

This shows declines 1970-2020 (black) and three potential scenarios to 2100: grey is business as usual; orange is increased conservation efforts; green is increased conservation together with more sustainable production and consumption. Source: WWF (2022) and Adam Islaam (IIASA)

Similar ideas are being deployed in both nature conservation and business. *Nature-Positive* is key concept and currency, suggesting an optimistic, intuitive and clear summary of what governments, businesses and civil society need to do to grow natural capital. Similarly, the term *Net Positive* has been applied to small and large businesses, which will grow and prosper over the long haul by “serving the world, and by giving more than they take” (Polman and Winston, 2021). Nature-positive means that positive outcomes for nature are firmly and equitably included amongst the multiple objectives of agriculture production systems.

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Businesses will not thrive by failing societies, and profits will come not from creating the world's problems, but rather from solving them. Others have called for regenerative businesses to focus on active co-creation, and to think of growth as human-growth, thus going beyond the existing destructive paradigm.

How SI Helps

SI preserves and improves natural capital and key ecosystem services. It increases productivity and reduces the use of harmful or potentially harmful compounds and releases. SI can impact ecosystem services in many ways:

- Increase in irrigation water availability and efficiency of use;
- Improve forest productivity of wood, forage and secondary products;
- Increase carbon sequestration in soils by conservation agriculture;
- Reduce surface water flows, flooding and soil erosion.

Carbon Removals and Sequestration

Agriculture and food systems cause 25% of greenhouse gas emissions. A major priority for sustainable intensification is thus to support the transition to net zero or net positive agricultural systems by which agriculture, in the broad sense of annual crops, perennials and livestock remove more carbon from the atmosphere than it emits.

The central understanding from developments in SI is this: modern, industrialised agricultural systems have depleted, eroded and lost substantial soil and vegetative carbon. In order to turn agriculture and land use systems into carbon sinks again, the SI of agriculture will have to be deployed and adopted widely on hundreds of millions of hectares.

These have been many soil-based blunders of industrialised agriculture: ploughing destroys soil microbes (bacteria and fungi) and releases bound carbon, large machinery damages soil structure and increases soil erosion, pesticide compounds are widely toxic to microbes and beneficial insects, and parasitic-control compounds and antibiotics routinely fed to livestock kill microbes and beneficial insects, such as dung beetles. As a result of these methods, agricultural soils have lost 25-75% of their carbon stocks compared with natural or undisturbed neighbouring soils.

These are the three components of SI systems that seek to increase carbon sequestration through redesign:

a. Ploughing is replaced by no-tillage practices;

b. Monocultures of crops is replaced by diversified crop rotations and patterns;

c. Organic matter is deliberately added to soil in the form of plants (such as cover crops, green manures, legumes, agroforestry and residues) and additives (such as biochar, fermented mixtures, compost).

Carbon removal and sequestration in soils and in above-ground biomass has the potential to make a substantial contribution to the race to net zero. Cuts in fossil fuel emissions remain the priority, and holding global temperature increases to less than +2^{o}C cannot be achieved without dramatic cuts to emissions. Carbon capture will play an important role in both helping make the transition to net zero and creating sustainable and resilient agricultural systems for the future. Soils create new sinks of carbon capital.

Another key SI practice that absorbs atmospheric carbon is agroforestry which sequesters carbon and boosts system productivity, especially when combined with cropping and livestock in synergistic farm designs. Agroforestry is one type of farming system that demonstrates the importance of the key farm diversification principle of SI that often increases both productivity and resilience while enhancing the natural resource base.

SI succeeds when farmers have adequate incentives and enabling institutions to adopt and adapt SI practices that improve the natural resource base and increase system productivity and resilience. The crucial incentive for smallholders is quick returns from the adoption of the SI practices, viz, increased livelihoods and resilience including food, income and other capitals.

A variety of international organisations and alliances, including UN FAO, the CGIAR, and the Global EverGreening Alliance, put the worldwide potential land capture at 10 Gt C per year, using a range of agricultural, forestry and pasture regeneration and restoration approaches.

SIIL Highlights – ***This is a short synopsis of highlights from the SIIL. More key accomplishments of the SIIL pertaining to natural capital will be available in the 10-year report.***

Cambodia:

Successfully hosted many trainings of students and teachers in small-scale SI for ecologically sensitive gardens for vegetables, such as cover crops, combined with training in rootstock and grafting techniques for tomato and eggplant. The team has seen a large interest within the villages for adoption to this technology to increase productivity and combat climate changes.

Students through the S3-Cambodia project propagate native trees, shrubs, vines, and other plants in a plant nursery and bring the cuttings to Indigenous communities who live in the forest to combat the vast deforestation.

Ethiopia:

The research done in Ethiopia was successful in the development of maize multiple cropping systems with tomato and onion, increasing income for farmers from the same area of land, and reducing the use of pesticides on tef that had been polluting drinking water wells.

Haiti:

Producers from the Haiti Agricultural Partnership: Center of Excellence on Mitigation, Adaption, and Resilience to Climate-Change in Haiti (CEMARCH) work to plant newly developed varieties of avocado trees that are better suited for the changing environment.

Beekeeping production workshops, seminars, and research have been led through CEMARCH to teach the local population the environmental and financial benefits of this agriculture venture.

Senegal:

The Sustainable Intensification in Dual-Purpose Pearl Millet-Leguminous Crops-Livestock Systems to Improve Food and Nutritional Security and Natural Resources Management for Rural Smallholder Farmers in Senegal project has worked with leguminous crop to improve food and nutritional security and natural resources management for rural smallholder farmers in the region.

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

SIIL Briefing Paper #4: Sustainable Intensification and Social Capital

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

What is Social Capital?

Social capital is the term used to describe the importance of social bonds, trust and reciprocity, and collective action through agreed norms and standards (including rules and regulations!).

It is the structure of relations between and among actors, especially farm-households, that encourages sustainable productive activities. It also comprises durable networks of relationships of mutual acquaintance and recognition, with membership of groups providing the backing of collectively-owned capital for mutual benefit, for example, irrigation water users groups, grazing groups, farmer marketing or input acquisition groups, community forest users groups, farmer innovation platforms, and many more.

The idea of social capital emphasises the importance of building relations of trust, reciprocity and exchange, agreeing common rules and sanctions, and developing connectedness through groups.

These aspects of social infrastructure function as resources for individuals to realise personal and community interests. As social capital lowers the costs of working together, it tends to facilitate cooperation. Individuals have the confidence and the means to invest in collective activities, knowing that others will do so too. In the context of SI, many forms of social capital enable and facilitate the adoption and local improvement of SI practices, especially in the case of sustainable natural resource management. But social capital also confers many advantages to communities when reducing crop-livestock tensions and negotiating with input suppliers or purchasers of grain, livestock or timber products. In this sense, social capital can be the buffer and local power which enables farmers to retain a larger share (cf. traders) of the benefits from the adoption of SI. In relation to science and technologies, farmer innovation platforms create situations where a community of farmers can co-adapt and co-create SI practices along with researchers, extension agents and value chain operators.

They are also less likely to engage in unfettered private actions that result in resource degradation, though this is no guarantee that tragedies of the commons will not occur. Social capital can also have a downside, with exclusion and elite capture resulting in non-democratic outcomes for some. It may also be deployed deliberately to oppose the existing structures of states and international institutions.

Working Together for SI

For as long as people and cultures have managed natural resources, collective action has produced systems of efficient and effective offtake as well as offering potential for sustaining natural capital and valued flows of ecosystem services. But the political economy of the latter part of the 20th and early 21st centuries prioritised individual action over the collective, and many rural institutions were harmed or destroyed. Since then, a wide range of new social movements, networks and federations have emerged to support transitions toward sustainability and equity.

Concerns over the cost of ignoring local institutions and group approaches began to emerge in the 1980s, with project evaluations showing that the creation of farmer and rural institutions led both to sustained performance after project completion and to fairer use of natural resources. New forms of participatory methods and systems of collective learning and action were field-tested, putting farmer knowledge and their capacity to experiment at the centre of practices for improvement.

By the mid-1990s, the linear diffusion and technology transfer models were increasingly seen as ineffective: non-adopters had been termed laggards, extension staff had become poorly motivated, and research systems had been prevented from becoming learning systems.

Since then, a wide range of new forms of social organisation have been intentionally formed to support transformations in agricultural landscapes. These have sought to build political strength for land rights, to protect against resource extraction, to increase market strength and power (such as through cooperatives), to link farmers and consumers through food chains, and to re-establish forms of co-management for natural resources. All these structures are forms of social capital.

Types of Groups for Social Capital

Many forms of social capital have emerged in support of transitions towards greater SI of agriculture. These include transnational farmer movements, national land rights and anti-land grab movements, national rural unions, and agroecology and social movements. At the same time, organisation around food has advanced in the form of food sovereignty and justice movements, and alternative food networks and movements, particularly from urban food production landscapes and many involving consumers as well as growers/farmers.

A further form of social capital occurs within defined geographic territories and has a significant impact on the development and spread of sustainable intensification. Intentionally formed groups within communities provide the context for innovation, negotiation and experimentation, bringing together individuals with different skills and knowledges.

There have been many adaptations in terminology for these systems of co-learning: farmer field school, learning lab, science and technology backyard platform, science field shop, innovation platform, farmer-led council, agroecosystem network, farmer cluster network, joint liability group, landcare group.

What is common to these social innovations has been an understanding that individual farmers, scientists, advisors and extensionists all undertake a transformative journey. Their worldviews change, resulting in the formation of broader epistemic communities of common interest. For sustainable outcomes, cognitive social capital in the form of beliefs and worldviews also changes.

A recent study of 122 initiatives in 55 countries found that the number of rural social groups had grown from 0.5 million (at 2000) to 8.54 million (by 2020). The area of land transformed by the 170-255 million group members was 300 Mha. Most of this was in poorer countries.

Over the past two decades a variety of novel social infrastructure has created platforms for collective transitions toward greater sustainability of agriculture and land management amongst rural communities across the world (Table 1). These have increased greater flows of knowledge and technologies and built trust amongst individuals and agencies.

Layers of social capital are also important in ensuring local priorities reach upwards to influence policy and practice. In Andhra Pradesh, the 830,000 women's self-help groups (SHGs) are organised into village level federations (of 15-30 SHGs) each, and these into distinct federations of 40-60 village organisations. In Japan, 1000 teikei purchasing groups are linked to organic and natural farming and have organised into federations, with some leaders elected as members of parliament. In Australia, the Landcare movement communicates farmers needs and opportunities to State and national leaders. In Brazil, farmers clubs coordinated effectively with input providers, agricultural extension and ultimately agricultural researchers in the development of no-till agriculture, just as APRESID did in Argentina.

The overwhelming evidence from the field and reported in the published literature is that collective management of resources can lead to redesign and also result in net increases in system productivity. There have been few counterfactual examples.

Table 1. Eight categories of social capital for sustainable agriculture and land management

Category	Social capital types
1. Integrated pest management	Farmer field school (FFS), push-pull systems of IPM, IPM clubs and FFS alumni groups
2. Forest management	Joint forest management (JFM), community-based forestry (CBF), participatory forest management (PFM), agroforestry
3. Land management	Watershed and catchment management, conservation agriculture (CA), integrated biodiversity, farmer clusters
4. Water management	Participatory irrigation management (PIM), water user groups (WUGs), farmer water schools, farmer-led watersheds
5. Pasture and range management	Management intensive rotational grazing groups, veterinary groups, dairy groups, agro-pastoralist field schools
6. Supporting services	Microfinance groups, multifunctional farmer and non-farmer groups, farmer business schools
7. Innovation platforms	Research platforms, co-production groups, science and technology backyard platforms, field science labs, agricultural technology parks
8. Intensive integrated crop-livestock-fish systems	Community supported agriculture groups, biogas-pig-vegetable groups, aquaculture

SIIL Highlights – *This is a short synopsis of highlights from the SIIL. More key accomplishments of the SIIL pertaining to social capital will be available in the 10-year report.*

Bangladesh:

A major achievement from the SIIL Polder project in Bangladesh is the implementation of Cluster-Based Farmer Field Schools at four learning hubs throughout the cropping years. This is an approach that brings together two different models of water management groups and farmer field schools. In the polders, water management organizations have been established, resulting in greater trust, sharing, and fair use of water.

Senegal, Burkina Faso, Ghana and Mali:

Five Agricultural Technology Parks have been developed by iREACH (Innovation Research, Extension and Advisory Consortium Hubs) as co-production platforms in villages. These ensure farmer engagement with SI thought testing and evaluation of 25 technologies and innovations.

Cambodia:

The Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CESAIN) and the S-3 project has worked to build collaborative networks of local and regional partners to ensure adoption and adaptation of SI innovations, and to attract new sources of external funding.

Agricultural cooperatives were developed and strengthened for sustainable intensification of agriculture as part of the Scaling Suitable Sustainable Technologies (S-3) programme. In addition, the programme engaged with policymakers to influence the integration of sustainable intensification practices into agricultural policies and strategies, particularly in schools.

Haiti:

Local collective capacity is being built through the Haiti Agricultural University Partnership: Center of Excellence on Mitigation, Adaptation, and Resilience to Climate-Change in Haiti (CEMARCH) to create farm system resilience to climate change, the training of farmers in SI methods, and the award of 104 scholarships for degree level training.

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

SIIL Briefing Paper #5:

Designing SI-Based Transformations by Increasing Human and Social Capital

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

Platforms for Co-Production

Across all agroecosystems, there is considerable evidence of improvements across, landscapes and farm household economies as a result of increases in knowledge and human capital. This human capital can often reduce the need for formerly costly purchased inputs, as human inputs to design and redesign systems of production increase the efficiency that SI enables.

SI can result in the following changes to individuals, groups and communities:

- Changes in the worldviews of farmers, and of scientists and extensionists working with farmers in novel innovation platforms;
- Positive role of women leaders in group effectiveness and conflict resolution over common resources;
- Emergence of new leaders of groups, especially by women, and changes in the relationships between women and men;
- Increases in the savings and repayment rates of members of microfinance groups this really relates to financial and social capital;
- improved awareness of system scale interdependencies and impacts of externalities;
- enhanced personal confidence and empowerment, and increased capacity for forward planning and risk management.

Farmer Field Schools

One of the finest innovations in public engagement for SI has come from the remarkable social innovation of farmer field schools. These were launched at the end of the 1980s using adult education and agroecological methods.

Research had shown that in irrigated rice systems the more pesticide used, the greater the pest damage: insecticides were killing beneficial insects and arthropods, which had been exerting pest control for free. It was also known that most farmers would not know this: detailed entomological knowledge is rarely a feature of local knowledge systems. They asked: could rice farming be amended to reduce insecticide use, could the beneficial insects do enough, and could a system of learning be created to allow farmers to demonstrate to themselves that they would not lose their crops?

The first farmer field schools were established in south-east Asia, and over a 30-year period have spread to 90 countries and nearly 20 million farmers. More than one million farmer field schools have been run, notably at scale in Bangladesh, Burkina Faso, China, India, Indonesia, Kenya, Philippines, Sri Lanka and Vietnam.

Farmer-field schools are called "schools without walls," and groups of about 25 farmers meet weekly during the entire crop season to engage in experiential learning. The aim is to develop human capital in the form of field observation, analytical skills, and understanding of agroecological principles. Farmer cooperation also increases, and over the years, these schools have evolved to include other crops, livestock, agroforestry and fisheries.

Public Engagement and Participation to Increase Human and Social Capital

Public Engagement can lead to the formation of human and social capital and the development of regenerative cultures, where natural, social and human assets are built. Christian Wahl observes that, "A regenerative future requires the capacity to listen and learn from diverse perspectives."

This is what Patricia Wilson of the University of Texas calls ensemble awareness: the quality of presence and relational awareness. Transformative outcomes are sought in both outer and inner journeys. Deploying public engagement means changes in both attitudes and mind. It implies generative patterns of practice, where creativity leads to new ways of seeing the world and acting in it.

The story is reframed through public engagement and ownership, and people are able to say, "We did it ourselves."

When little effort is made to build local interests and capacity, then people have no stake in maintaining structures or practices once the flow of incentives stop or policies change. If people do not cross a cognitive frontier, then there is unlikely to be sustained change that might be counted as improvement.

Public engagement is a multi-dimensional concept that can incorporate communication, co-creation, dialogue and the creation of social capital. Its deployment and methods and approaches have differed widely, representing variations in values and principles.

The first typology to express these variations was created as a *ladder of participation*. Since then, a number of spectrums, ladders and typologies have been developed and refined. All show a spectrum from passive (people are told what has been decided) to consultative modes (people are asked set questions), to co-created (people work together in joint analysis), to transformative (where the worldviews and behaviors of all actors change), and finally to self-mobilizing and connected (citizens take action independently of external institutions). A recent typology of public engagement is depicted in Table 1.

Table 1. Typology of Public Engagement for Sustainable Intensification

Types of Public Engagement	Characteristics of Each Type of Public Engagement
Passive-Informative	Public engagement is unidirectional, with information being pushed outwards. Information belongs only to professionals and experts, and thus external systems are unlikely to change. This type can be positive where the information is useful and interesting, but it can also be manipulative.
Consultative	Public engagement centres on asking questions to gather information about the world. Organisations and professionals are in listening mode, and professionals are under little obligation to take on board people's views. This PE may include bought forms of participation (for food, income or other material incentives).

Co-Created	Organisations and professionals work together with people in co-created platforms for joint analysis, development of action plans and formation or strengthening of local groups. Learning methods are used to seek multiple perspectives. This increases knowledge, data and perspectives. Sometimes this public knowledge can feel like a threat to the status of professionals and experts.
Transformative	Public engagement changes worldviews and values, causing permanent shifts in choices and behaviours of individuals and groups. Organisations and professionals change, and social capital founded on trust, reciprocity and institutions is built.

Guidelines for Public Engagement to Aid SI Transformations

To many organisations, PE looks too hard to do. It means giving up some power and much certainty. If public engagement is to involve people, then their perspectives, ideas and views matter. They will change processes and priorities by being able to express wishes and wisdom, and thus help create new knowledges. Public engagement brings a positive premium. It changes minds, institutions and environments. It can lead to changes that people in their systems recognise as improvements.

Here are five simple guidelines for transformative platforms to create SI:

1. *Choose* methods and approaches carefully using the typology, and ask: what can be done to escalate engagement and hear more voices?
2. *Think* about how public engagement can transform existing systems, structures and institutions towards greater sustainability and equality; the process will change the people involved, so tell them in advance what could now be achieved.
3. *Be flexible* and open to changing research and education systems, and modes of institutional working: if you involve people, they will bring new ideas.
4. *Ensure* the principles of co-production are part of all technology and method development. Power structures may constrain, but they may also change with increasing clarity and breadth of voices working together.
5. *Tell stories* about impact and outcomes, and ask: what was surprising, and how did the world and its institutions change?

SIIL Highlights – *This is a short synopsis of highlights from the SIIL. More key accomplishments of the SIIL pertaining to human capital will be available in the 10-year report.*

Bangladesh:

The low-lying polders suffer high tides, flood, inundation and high salinity. The SIIL Polder project used Cluster-Based Farmer-Field Schools and 40 Learning Hubs to train 5,000 farmers in SI methods. Rice yields rose by 2-3 fold to 3 tonnes per hectare per year, and female farmer incomes increased five-fold. Some 7,000 farmers have benefitted from the transformations brought about by SI. The use of adaptive research and trials to fit rice-reaper technologies and operating skills for farm women has proven successful, enabling them to take charge of the rice harvest and ensure a better work-life balance.

The SIIL Polder Project has published annual magazines titled, 'Polder Tidings' that share recent successes in fieldwork and research, highlights student and professional leaders in the community, and shares upcoming initiatives in the polders.

Burkina Faso:

Farmer and artisanal skills and capacities have been built to increase innovation rates and local adaptation of mechanised seed planters and fodder choppers, both of which reduce labour requirements and stress at critical times of the year.

Cambodia:

The Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN) works to improve food and nutritional security in Cambodia by supporting agricultural research, education, and innovation.

The S-3 programme successfully developed extension materials and guides based on the research outputs to disseminate information to farmers, extension workers, schools, and local communities. They conducted training sessions and workshops for farmers, extension agents, and agricultural professionals to transfer knowledge and build capacity in implementing SI practices.

Guatemala:

The Feed the Future Guatemala Scaling Agriculture Technologies Coordination Activity was recently created to strengthen existing agricultural research, education, and outreach entities in Guatemala through investment in human and social capital.

Haiti:

CEMARCH is a partnership between six Haitian universities that seek to strengthen partner capacity, fosters agricultural education, training, research and extension, and links farmers with the private sector to address food and nutritional security.

The Digital Tools, Farming Systems and Geospatial Consortium:

The consortium has developed modelling tools and remote sensing products, established a Youth Assembly for Plant Science in Cambodia, has trained students on coding and GIS use, prepared virtual training methods, and worked with farmer cooperatives and local institutions.

The Appropriate Scale Mechanisation Consortium:

The consortium has developed no-till planters to aid the uptake of conservation agriculture, together with tractors, hand-tools, rollers and crimpers, seed broadcasters, water lifters and solar drip-irrigation.

Additionally, the consortium has created Innovation Hubs in West Africa for maize and livestock systems leading to technological development and scaling, capacity building, and the training of 1,400 farmers.

West Africa:

A farmer-centred integrated approach with a focus on women and youth has helped spread knowledge and understanding on a thousand farmers for a suite of mechanical technologies: rippers, planters, forage clippers, weeders and silage making. Agricultural Technology Parks (ATPs) are developed within many of SIIL focus countries (Cambodia, Senegal, Haiti, e.g.) to facilitate an effective flow of information, technologies, and innovations.

iREACH/Feed the Future Activity Tracker: An initiative which first launched in West Africa, works to aid in the coordination, alignment, and integration of research, extension, and advisory activities within the Feed the Future Innovation Lab community and USAID Missions in relevant focus countries.

SI Toolkit App: The app is an interactive version of the Sustainable Intensification Assessment Framework which is meant to be used as a resource to help adapt your research to provide the best outcomes for farming families and communities.

Feed the Future Innovation Lab for Collaborative Research on Sustainable Intensification (SIIL)

SIIL Briefing Paper #6: Twelve Effective Approaches for Successful SI

Jules Pretty, P.V Vara Prasad, B. Jan Middendorf, John Dixon, Cornelia Butler Flora and Peter Thorne

1. Farmer Field Schools for Integrated Pest Management

Farmer-field schools (FFS) ("schools without walls") centre on groups of up to 25 farmers meeting weekly during the entire crop season to engage in experiential learning. The aim is to use co-learning so that farmers' innovative capacity is improved.

FFS are both an extension method and increase knowledge of agroecology, problem-solving skills, group building and political strength. Over the years, FFS have evolved to include crops, livestock, agroforestry and fisheries. Many analyses have shown how FFS increase farm productivity, reduce pesticide use, and improve ecological literacy.

Integrated Pest Management (IPM) is the integrated use of a range of pest (insect, weed or disease) control strategies in a way that reduces pest populations to non-economically important levels, minimizes risks to human and animal health, and can be sustainable and non-polluting. Inevitably, sound application of IPM is a more complex and knowledge-intensive process than relying on spraying of pesticides: it requires a high level of human capital in the form of field observation, analytical and ecosystem literacy skills and understanding of agroecological principles; it also benefits from cooperation between farmers.

2. Conservation and No-Till Agriculture

The central principle of Conservation Agriculture, and its variation Conservation Agriculture-based Sustainable Intensification, is improved soil health. A variety of measures to mitigate soil erosion, improve water-holding capacity and increase soil organic matter are deployed to improve soil health and boost crop yields.

Three key features are reduced soil disturbance through reduced or zero tillage, mulching and green manures, and maintenance of year-round soil cover and crop rotations, seeking to maintain an optimum environment in the root zone in terms of water availability, soil structure and biotic activity.

Optimal CA uses all three features, though many farmers only practice one or two. Currently, CA systems are practiced across a range of agroecological conditions, soil types and farm sizes. CA practices have been spreading by some 6 Mha annually to a total of more than 200 Mha worldwide.

3. Participatory Water and Irrigation Management

Participatory irrigation management and the establishment of water user associations began in the 1980s, with many building upon existing legacy systems, such as the subak groups in Bali that have been effective for 5000 years or the *qanat* systems of Iran. In the past 20 years, 220,000 water users' associations, participatory irrigation groups, water user groups and farmer managed irrigation systems have been established.

Without regulation or collective control, water tends to be overused by those who have access to it first, resulting in shortages for tail-enders, conflicts over water allocation, and waterlogging, drainage and salinity problems. The same challenge exists for the many watersheds crossing national boundaries (e.g. the Mekong). Where social capital is well-developed, then groups with locally developed rules and sanctions are able to make more of existing resources than individuals working alone or in competition.

Where effective groups operate, there has emerged good evidence of increases in rice yields, higher farmer contributions to design and maintenance of systems, changes in the efficiency and equity of water use, decreased breakdown of systems and fewer complaints to government departments. In China, a quarter of all villages have Water User Associations, and these have reduced maintenance expenditure whilst improving the timeliness of water delivery and fee collection. Farm incomes have improved whilst water use has fallen.

4. Innovation Parks and Platforms

The best applications of SI occur when they are co-produced between farmers/local people and external experts. In working in the same physical space, we may call these platforms for co-production. In some countries these co-production spaces are termed agricultural technology parks (ATPs) and learning hubs.

Innovation platforms in West Africa have resulted in increased yields and income for both maize and cassava systems; and in Bangladesh platforms have led to adoption of direct seeded rice and early maturing varieties that have changed patterns of both wet and dry season farming, increasing incomes and cutting labour costs.

Science and Technology Backyard Platforms (STB) were established in China to increase the sharing of knowledge and skills between scientists and farmers. STBs bring agricultural scientists to live in villages, who then use field demonstrations, farming schools, and yield contests to engage farmers in locally developed innovations. Success centres on in-person communication, socio-cultural bonding, and the trust developed amongst the partners.

In Cuba, the Campesino-a-Campesino movement has developed an approach to agroecological integration that is redesigning systems through peer-to-peer exchanges, teaching and cooperatives. There are 100,000 peasant farmer members of Campesino-a-Campesino in Cuba.

5. Natural Farming

Natural farming was developed as a concept in Japan by Masanobu Fukuoka (The One Straw Revolution). It has come to be developed and spread in several Indian states, beginning as Zero Budget Natural Farming (ZBNF) in Andhra Pradesh.

The phrase Zero Budget refers to the aim of achieving dramatic cuts in production costs by ending dependence on external synthetic inputs and agricultural credit. It is not meant to signify 'zero costs.' Instead, it is meant to signify that the need for external financing is zero, and that any costs incurred can be offset by a diversified source of income.

Community-Managed Natural Farming is supported in Andhra Pradesh by state research and extension institutions, together with many civil society grassroots initiatives, and is now being practised by 630,000 farmers. The state aim is to support the transition to NF by all six million farmers by 2030. On-farm crop diversity and per hectare productivity has increased, and costs to farmers have fallen in all three agroecological zones: the intensive rice systems of the coast, the rainfed drylands, and the upland forests. Farm family health has improved through the reduction in use of pesticides.

Key to the scaling of NF in Andhra Pradesh has been the work done from the early 2000s to build a dense, multi-layered community-based extension ecosystem. This ecosystem is organised across 3 scales: a zone (80 households); a Gram Panchayat (roughly a village-level administration) and finally, a cluster of five Gram Panchayats. Peer to peer learning is key: Community resource persons (CRPs) are farmers who have been designated as community-level extension agents. Farmer field schools are held weekly, facilitated by trained conveners, and include male and female farmers engaged in NF best practice. Farmers transitioning to NF are thus embedded within a supportive network of peers, practitioners and formally trained agronomists.

6. Integrating Legumes with Cereals

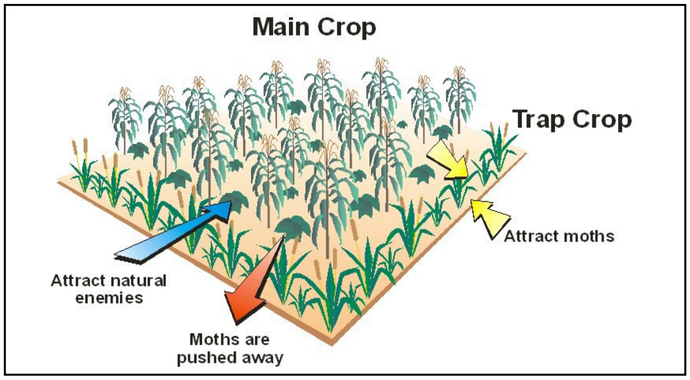
In many forested regions, Indigenous people have farmed with slash and burn methods. Fields are cleared in the forest, cropped for a couple of years, and then fallowed as families move on to new sites.

There have been several approaches to developing intensive settled agricultural systems that are more productive. The velvetbean (*Mucuna pruriens*) was introduced to maize systems in Honduras, Guatemala and Togo, substantially increasing maize yields. Mucuna is grown as a soil improver. It can fix 150 kg of nitrogen per hectare and produce 50-100 tonnes of biomass annually. This plant material falls on the soil as a green manure, suppressing weeds and helping to build the soil. Build the health of the soil, and farmers no longer need to burn trees to create new fields.

Such improvements to soil health change the way farmers think. They see the benefit of staying in the same place, and of investing in the same fields for themselves and their children. At the Usumacinta River border of Guatemala with Mexico, the Cooperativa La Felicidad (Happiness Cooperative), where 250 farmers grow *mucuna* in maize, and have begun a journey across a cognitive frontier towards settled and sustainable agriculture. Mucuna is called the bean manure (*frijol abono*): farmers say the bean manure destroys the weeds, and all the crops flourish more.

7. Push-Pull Diverse Cropping with Legumes

One example of how ecosystem services can be used in sustainable intensification comes from Kenya, Uganda and Tanzania from a system now adopted by 250,000 small farmers. Researchers found that maize mixed with grasses around the field edge with legumes intercropped pushed away the corn stalkborer and pulled it into the resinous grasses that were toxic to stalkborer eggs and larvae. The mix of plants emitted semiochemical hormones that pulled in parasitic wasps and predators, and then also suppressed weeds within the fields.



The modern simplified system of monocropped maize had required costly pesticides and fertilizers to do this work and was now replaced by this diverse one called *vutu sukumu* (push-pull) that needed no external and costly inputs. Yields for farmers have increased. Positive externalities arise from nitrogen fixation by *Desmodium* and elimination of pesticides, in the provision of high-quality fodder, enabling farmers to diversify into dairy and poultry production, in turn increasing the availability of animal manure for crops and soils.

8. Integrated and Intensive Crop and Biodiversity Redesign

In both industrialised and developing countries, a growing number of crop systems have been redesigned using agroecological principles. Redesign and deployment of multiple interventions has seen increased rotational diversity, use of wildflowers for pollinators and other beneficial insects, conservation headlands and trap crops, composted animal manures, and grain legumes, often with large reductions in input use without yield compromise.

In many countries, fish, crab, turtle and duck have been reintroduced into rice systems, reducing pest and weed incidence, often eliminating the need for pesticides, and thus producing increased system productivity through new animal protein. Both the Systems of Rice and

Crop Intensification (SRI and SCI) emerged from complete redesign of paddy rice cultivation: reduced planting density, improvement of soil with organic matter, reduced use of water, and very early transplantation of young plants have led to considerable yield increases with reduced requirements for water and other external inputs.

Since inception, SRI principles have been adapted from rice to wheat, sugarcane, tef, finger millet and pulses, all again emphasizing changes in resource use and application combined with crop planting design. The governments of Cambodia, China, India, Indonesia and Vietnam have endorsed SRI/SCI methods in their national food security programmes, with one million Vietnamese rice farmers now using SRI.

9. Agroforestry on Farms

Agroforestry has long been used in traditional agricultural systems, particularly in the tropics. Two types of deliberate redesign have been deployed with trees and shrubs: i) their introduction into cropped systems, and ii) new forms of collective management of woodland and forest within agricultural landscapes.

Legume tree-based farming systems offer a route to increased availability of nitrogen while reducing or avoiding synthetic fertilizers, leading to the use of the term *fertilizer tree*. Shrubs (e.g. *Gliricidia, Sesbania*) are introduced into crop rotations, increasing fuelwood production and nitrogen fixation, but still increasing net cereal yield over a five-year rotation. System sustainability, productivity and resilience can be improved even further by combinations of agroforestry with conservation agriculture, sometimes known as conservation agriculture with trees.

In other systems, perennial trees (e.g. *Faidherbia*) are introduced into dryland and silvo-pastoral systems, with trees leafing when crops are not growing, resulting in re-greening of some 5Mha in Niger, Burkina Faso and Mali, with the outcome of amended local climate, increased wood and tree fodder availability, and better water harvesting.

10. New Crop Varieties with Good Crop Management

Varietal improvements, particularly focussed on increased yield and pest resistance, in combination with improved crop management, have long been at the forefront of agricultural intensification. Yield improvements in key agricultural staples - wheat (208%), paddy rice (109%), maize (157%), potato (78%) and cassava (36%) between 1960 and 2000 were key to reducing malnutrition in the developing world by increasing output and reducing food prices.

To develop varieties that are adapted to SI systems, plant breeders need access to the widest possible sources of desirable traits, which are found in cereal accessions held in germplasm collections, in wild relatives, and in landraces in farmers' fields. Among traits identified are more rapid establishment and faster root growth, cultivars suited to zero-tillage, genotypes with higher water-use efficiency, and dual-purpose dryland cereals with high grain and fodder yields.

Varietal improvements will also need to focus on improved nutritional content, better resource use efficiency and the reduction of greenhouse emissions. There is also scope for increasing the share of perennials in the global crop mix: beneficial traits may include the ability to be grown on resource-poor and marginal lands and the ability to sustain more production per unit of land than most annual crops. Breeding plants with deeper and bushy root systems may also offer improved soil structure, water and carbon sequestration, nutrient retention and higher yields.

The best varietal improvements will build in responsiveness to good crop and farm management, to exploit G x M interactions. Some varietal plasticity is required to match different types of crop management which, ideally, should be attuned to the combination of crop rotations, livestock and agroforestry on the farm system.

11. Patch Intensification and Small-Scale Gardening

The intensive use of patches (small areas of land) can be effective and highly productive for farm families, particularly for cultivation of vegetables or rearing fish, poultry or small livestock. These may be located in gardens, at field boundaries, in urban or rural landscapes, and managed individually or collectively.

Examples include allotments, community gardens or farms, vertical and urban farms, and community supported agriculture, and aquaculture ponds and tanks. Raised beds for vegetables in East Africa have been beneficial for large numbers of women, homestead garden production has spread in Bangladesh, and in China full redesign has been exemplified by integrated vegetable and fruit, pig and poultry farms with biogas digesters. Farm plots are very small (0.14 ha), and yet farmers are able to recycle wastes, produce methane for cooking, and reduce burning of wood and crop residues, with implementation by 50 million households.

12. Pasture Redesign

Pasture redesign has arisen from the adoption of Management Intensive Rotation Grazing (MIRG), and the deployment of agropastoral field schools.

In Brazil, redesigned *Brachiaria* forages in maize-rice and millet-sorghum systems have through increased net productivity led to large increases in all-year forage, which is used both for livestock and as a green manure.

MIRGs are an example of pasture redesign, using short duration grazing episodes on small paddocks or temporarily fenced areas, with longer rest periods that allow grassland plants to regrow before grazing returns. These systems replace external inputs including feed with knowledge and high levels of active management to maintain grassland productivity. Well-managed grazing systems have been associated with greater temporal and spatial diversity of plant species, increased carbon sequestration, reduced soil erosion, improved wildlife habitat and decreased input use. As many have replaced zero-grazed confined livestock systems, the animals themselves have to be bred for different characteristics: large mouth, shorter legs, stronger feet and hooves, larger rumen.

SIIL Highlights – *This is a short synopsis of keys to success from the SIIL. All key accomplishments of the SIIL will be available in the 10-year report.*

Keys to success: co-production successes arising from clear goals, shared vision and understanding of vision, sustained long-term funding, clear metrics of success, regular knowledge exchange and reflections, good relationship with donors, and presence of an advisory committee for oversight.

Six key lessons learned from the overall SIIL portfolio:

i. interventions should always be site and culture-specific;

ii. local people will absorb information when they are ready;

iii. each person has unique roles to play;

iv. institutions are made of people;

v. good intentions yield good results at the right time;

vi. when you try to solve a problem, look first at the relationships of people involved.