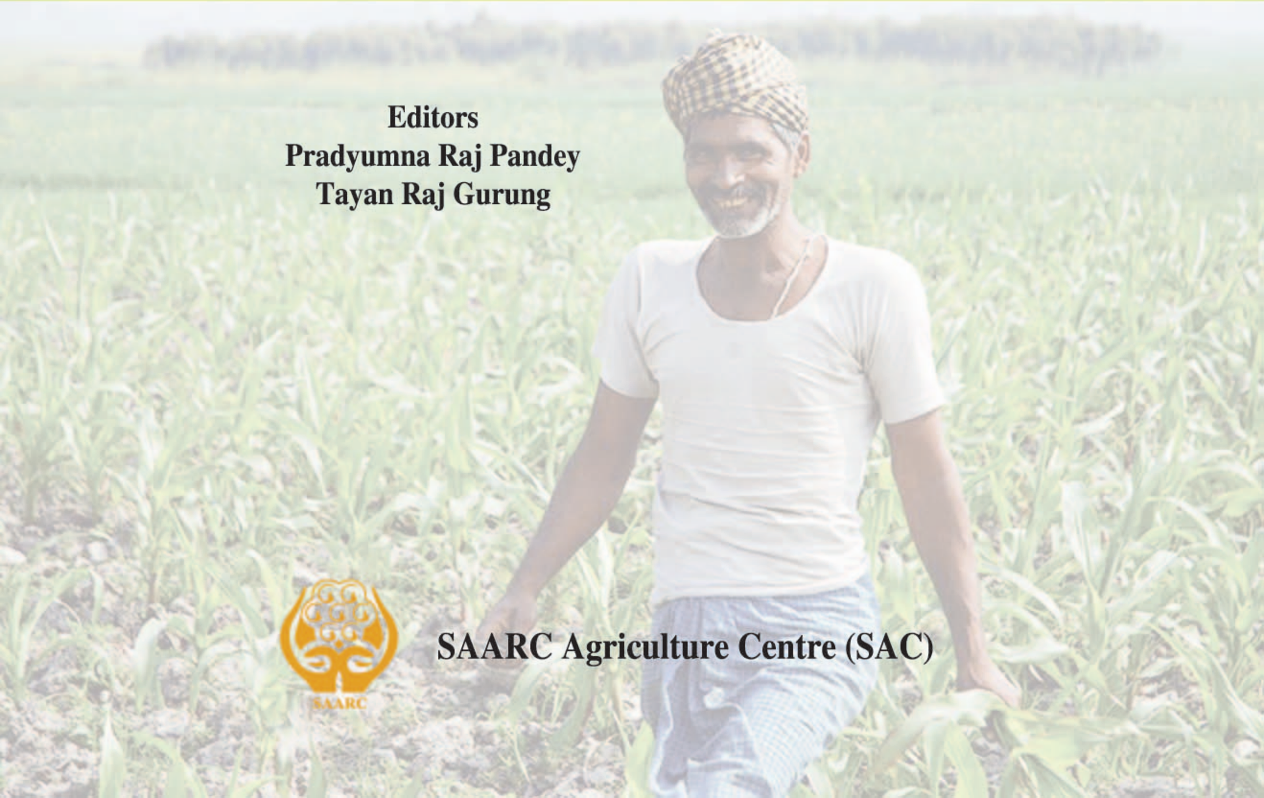
# Best Practices of Conservation Agriculture in South Asia




**Editors**
**Pradyumna Raj Pandey**
**Tayan Raj Gurung**



**SAARC Agriculture Centre (SAC)**

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**SAARC Agriculture Centre**

**Best Practices of Conservation Agriculture in South Asia**

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# Foreword

Conservation Agriculture (CA) holds great promise as the goal of agricultural sustainability, conserving, improving and making more efficient use of natural resources through the integrated management of available soil, water and biological resources, combined with judicious use of external inputs. CA has potential contribution in South Asia to reduce the negative impacts of intensive agriculture, minimizing soil degradation, build-up soil organic matter, improve soil physical and biological health; reduce use of fossil fuels and enhance input use efficiency contributing, thereby, reduction of emission of GHGs in the atmosphere. Therefore, it is urgent to utilize the CA for sustainable agricultural intensification that complies with the generally accepted ideas of ecological sustainability in South Asian farming system.

In South Asia, the area under CA is very small compared to the rest of the world. Currently, conservation tillage is being practiced on more than five million hectors. Problem-oriented research and training, provision of conservation machinery at specific sites at proper time at affordable rates, and aggressive extension campaigns help to boost the uptake of CA in South Asia. The mainstreaming of CA is prominent requirement in South Asian farming system through awareness of conservation agriculture technology, capacity development and exposure visit. Furthermore, the technology should be localized with improving the existing planning systems through value chain in local condition. To obtain this achievement networking the proven scientific technology to the global partners would be the prime priority of SAARC Agriculture Centre (SAC).

SAARC Agriculture Centre jointly organized with the College of Natural Resources and Department of Agriculture, Bhutan, a regional consultation meeting on "Conservation Agriculture in SAARC member countries". This book "Best Practices of Conservation Agriculture in South Asia" is a collection of papers contributed by experts from SAARC Member States.

I would like to take this opportunity to express my sincere appreciation to Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), and Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre for their hard work to put together the manuscript in this form. I am confident that this compilation will facilitate further research and development in conservation Agriculture in SAARC Region.

**Dr. S.M. Bokhtiar**
Director
SAARC Agriculture Centre

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# Executive Summary

In South Asia 42% of the 4.13 million square km total area is estimated to be affected by various kinds of degradation. Especially in India and Pakistan, 63 million ha of rain-fed land and 16 million ha of irrigated land have been lost to desertification. This lost land accounts to 7% of regional Agricultural Gross Domestic Product. The trend of land productivity in other SAARC countries is in decline. Further, with mounting pressure on land from other uses (urban infrastructure/ industrial expansion) and degradation of natural resources, agricultural land is shrinking rapidly, thus limiting the food production. As the arable land becomes limited, the conventional agriculture that capitalizes on manipulation of soil (or tillage) excessively coupled with mono-cropping (specialized farming) may further deteriorate the productive capacity of the land. Recently researchers in South Asia have identified several constraints to the adoption of conservation tillage among smallholders including: weed control; competitive uses for crop residues and uncontrolled grazing of residues left in the field; lack of dedicated forage and fodder crops and absence of machinery for crop establishment without tillage.

One technology that has prospects to conserve and facilitate improved and efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs is Conservation Agriculture. Emanating from three broad principles of minimum soil disturbance, permanent organic soil cover, and diversified crop rotations, conservation agriculture is often referred to as a resource- efficient or resource- effective agriculture (FAO) that contributes to environmental conservation as well as to enhance and sustain agricultural production. Conservation agriculture is founded on the principle of no-tillage or minimum tillage as a way of sustenance. It is gaining popularity among farmers throughout the world. Although it is difficult to get an accurate estimate of the total area covered, Derpsch and Benites (2003) calculated that CA is practiced in 72 million ha globally. One of the main reasons for this no-tillage revolution has been the greater profitability of CA over conventional systems as a result of lower input costs (less fossil-fuel use and more efficient input use) coupled in most cases with an increase in yield.

However, the limitation of conservation agriculture is a site specific, community- based and agro-ecological specific which may not have a blue-print for replication. The success or failure of conservation agriculture depends greatly on the flexibility and creativity of the practitioners and extension and research services of a region.

Conventional agriculture has put forth soil and crop sustainability to substantial soil degradation resulting in a concomitant decrease in the productivity of these systems. Conservation agriculture (CA) including minimum soil disturbance, permanent soil cover, and diversified crop rotations aimed to decrease and/or revert the effects of conventional farming practices like soil organic matter decline, soil erosion, soil physical degradation, and fuel use. However, in South Asia, the area under CA is very small compared to the rest of the world. The history of CA in South Asia starts when wheat plantation with zero tillage was first introduced in Indian and Pakistani Punjab in the 1980s. Currently, conservation tillage is being practiced on more than 5 M ha in Indo-Gangetic plains of South Asia. Conservation tillage reduced greenhouse gas emission and the production cost which improved the soil health and crop yields. However, challenges like cultural and economic entrenchment of tillage agriculture in this region, weeds, insect pests, diseases, crop residue management, and reduced availability of suitable seeding and planting equipment are hindering its uptake. In this scenario, problem-oriented research and training, provision of conservation machinery at specific sites at proper time at affordable rates, and aggressive extension campaigns may help to boost up the uptake of CA in South Asia. The limitation of conservation agriculture is a site specific, community- based and agro-ecological specific which may not have a blue-print for replication. The success or failure of conservation agriculture depends greatly on the flexibility and creativity of the practitioners and extension and research services of this region.

SAC in collaboration with the Member States organized a regional consultation meeting on Conservation Agriculture in SAARC Countries with the main objectives to identified the best practices of conservation agriculture and promote and sharing the best policies and technologies among the South Asian Coutntries. As a result of the consultation meeting following outline of the technological developmnet of conservation agriculture practices in South Asian Countries with major available conservation machinery in South Asian countries are found as highlighted below.

**Technological Developmnet of Conservation Agriculture Practices in South Asian Countries**

| Country | Major Available CA Technologies in South Asia |
| --- | --- |
| Bangladesh | • SRI system under permanent raised bed condition<br>• Unpuddled rice transplanting system by strip and raised bed method<br>• Permanent raised bed technology for wheat, maize, |

| Country | Major Available CA Technologies in South Asia |
| --- | --- |
| | pulse, oil seed and vegetable and cotton crops<br>• Strip tillage technology by same crops<br>• DSR under strip tillage and zero tillage methods<br>• Zero tillage technology especially chick pea, wheat and maize crops<br>• Unpuddled zero till rice transplanting system in boro rice season<br>• Rain water harvesting<br>• Crop residue incorporation<br>• Drip/ sprinkle/ gated irrigation<br>• Mulching- crop residues, paddy straw, green leaves<br>• Cover crops- Green manuring  and Pulse crops |
| Bhutan | • Fruit based cropping system<br>• Strip/hedgerow cropping system<br>• Individual pond water harvesting<br>• Bio-digester<br>• Improved tunnel forming<br>• Stone check dams and live check dams<br>• Integrated farming with livestock |
| India | • Double no till in Rice wheat and relay cropping of pulses<br>• Direct seeded no till rice –wheat<br>• Combo happy seeder<br>• SRI method of rice cultivation<br>• Permanent raised bed system for different crops like rice, wheat, cotton under irrigated conditions.<br>• Soybean – chickpea/wheat on permanent raised bed with Ready mix Chlodinofap + metasulfuron @ 400 gm/ha<br>• Brown manuring in direct seeded rice and irrigated crops<br>• Manipulation of harvesting for different crops like maize; pigeon pea<br>• Live mulch in rainfed crops<br>• Integration of soil moisture through permanent bed and furrow method or permanent conservation furrow as 4$^{th}$ principle |

| Country | Major Available CA Technologies in South Asia |
| --- | --- |
| Nepal | • SRI (System of Rice Intensification)<br>• DSR (Direct seeded Rice)<br>• Legume Intercropping in Maize based cropping system<br>• Zero tillage/ minimum tillage in maize and wheat<br>• Surface seeding in wheat<br>• Fertigation system in mid hills/ terai<br>• Drip/ sprinkle/surface irrigation<br>• Intercropping in fruits<br>• Laser land levelling<br>• Crop residue incorporation<br>• Green manuring in rice<br>• Crop rotation in rice and maize based cropping system<br>• Mulching in vegetables<br>• Agroforestry: *Uttis Nepalencis* with Large cardamom<br>• Multi storey cropping<br>• Composting/ use of urine<br>• Bio-digester<br>• Rain Water harvesting |
| Pakistan | • Crop specific bacterial strain based bio-fertilizers for N-fixation, P- stabilization,<br>• Plant growth promoter Rhizo bacteria for sustainable crop productivity<br>• Vermicomposting: using red wangler (earth worm) to decompose plant material and form high value compost for high value crops<br>• Direct seeded rice technology<br>• Crop residue incorporation |
| Sri Lanka | • Mulching- crop residues, paddy straw, green leaves<br>• Cover crops- Prenia, Mucuna, ealoporium, eintrosima<br>• SALT technology (Sloping Agricultural Land Technology), e.g. double tree hedge rows<br>• Soil conservation measures for sloping lands |

| Country | Major Available CA Technologies in South Asia |
|---|---|
| | • Rain water harvest<br>• Cultivation of multi-purpose trees<br>• Incorporation of crop residues, organic matter and charred paddy husk in rice based cropping systems<br>• Soil test based fertilizer recommendation<br>• On-farm water management<br>• Inter-cropping and mixed cropping in upland farming<br>• Home gardening and agro forestry<br>• Mulching for weed control |

**Major Available Conservation Machinery in South Asian countries**

| | Major Available Conservation Machinery in South Asia | |
|---|---|---|
| Countries | Conservation Machinery | Purposes |
| Bangladesh | Power tiller-operated seeder<br>Power tiller-operated bed planter<br>Power tiller-operated zero-tillage seeder<br>Power tiller-operated strip tillage seeder<br>Multi crop planter<br>Herbicide sprayer<br>Mechanical weeder<br>Urea applicator<br>High speed rotary drill | Less tillage, minimum cost and timely sowing of crops.<br>Bed making and sowing of crops on the top of the bed is done in single operation<br>Sowing of wheat, chickpea and maize in a single pass with residue of previous crop, utilize residual soil moisture.<br>Cultivate a targeted area and leaving the crop residue on the surface between the tilled strips, utilize residual soil moisture for crop establishment.<br>Cost effective due to seedings of various crops with utilize residual soil moisture.<br>Manual / power tiller driven<br>Manual / power tiller driven<br>Basal and top dressing of USG<br>Seeding of Jute, cotton and onion crop with other crops |

| | | |
|---|---|---|
| India | Raised bed planter | Bed making and sowing on the tip of the bed is done in single operation |
| | Zero-till drill | Sowing of seeds in the stubbles of previous crop |
| | Strip till drill | Cultivate a targeted area and leaving the crop residue on the surface between the tilled strips, retaining moisture and organic matter to improve the soil structure and fertility |
| | Happy seeder | Residue management and seed sowing in rice-wheat cropping systems. |
| | Direct-seeded rice drill | Drilling of rice seed after seedbed preparation |
| | Combo Happy seeder | Direct sowing of wheat under residues. |
| | Happy turbo seeder | 35 HP tractors |
| | Star wheel punch planter | seeding into loose residues 4 t/ha residue |
| | Rotary disc drill | seeding into loose residues and sugarcane ratoons Horizontal shaft straight discs |
| | Double disc drill | Seeding into loose residues light weight cutting |
| | CRIDA precision planter | Rainfed conditions to sow the crop, fertilizer application and herbicide application |
| | Permanent bed planter | To make permanent bed and furrow, sowing, fertilizer and herbicide application in a single operation under rainfed conditions |
| | Conservation furrow planter | Makes conservation furrow, sowing and fertilizer application |
| | Top dressing implement | Top dressing fertilizer on permanent beds |
| | Mechanical weeder | Weeding |
| | Disc residue cutter cum planter (Under validation) | Chopping of residues and sowing under rainfed conditions |

| | | |
|---|---|---|
| Nepal | Power tiller rotary tiller | Soil cultivation, aeration, weeding, fertilizer application, flower and seed bed preparation |
| | Strip till drill | Cultivate a targeted area and leaving the crop reside on the surface between the tilled strips, retaining moisture and organic matter to improved the soil structure and fertility |
| | Zero till drill | Sowing of seeds in the stubbles of previous crops |
| | Jap seeder | Hope making and seed dropping done simultaneously and there is on bending or squatting |
| | | Seed sowing |
| | Power tiller seed drill | Sowing<br>50HP tractor |
| | Mini tiller | Mechanical |
| | Turbo happy seeder | Zero till transplanting, power tiller driven |
| | Weeder | |
| | Rice trans planter | |
| Pakistan | Bed planter | Bed and furrow making plus seed drilling Four wheels' tractor |
| | Laser land leveller | Levelling of uneven land for water saving Four wheel tractor |
| | Pak seeder | Residue management and seed sowing in rice-wheat cropping system. 50 HP four wheel tractor |
| | Straw Chopper | Straw cut, chopping, and collects in the tractor, four wheel tractor |
| | Turbo seeder | Sowing of wheat in rice residue in residual moisture, four wheel tractor. |
| | Direct-seeded rice drill | Drilling of rice seed after seedbed preparation, four wheel tractor. |
| | | Useful in tunnel farming |
| | High efficiency Fertigation system | |

**Key Policy interventions for Conservation Agriculture in South Asia**

- Mainstreaming the conservation agriculture into the main agriculture development programme and plan.
- Awareness of conservation agriculture technology, capacity development and exposure visit through national Extension system.
- Localizing the CA technology, improving the existing planning systems through value chain in local condition.
- Networking the proven scientific technology to the global partners (joint research) and Regional networking of CA through SAARC level network.
- Public-private (NGO, INGO and Civil society) partnership (As UN declared SDG and we have to fulfilled these goals 1,2, 15 and 17) and establish Public and private partnership model for sustainable CA.
- Strengthen R&D on user and gender friendly tools, equipments.
- Review present subsidies and incentive schemes and analyze how it helps to CA. There should be easy process for subsidy and incentive to CA practitioneners and farmers. The incentive should be production based incentive system and cost sharing mechanism.
- Policy should be focused on skill development of farmers, LSP and operators and planned agricultural activities to promote CA.
- Pilot/demonstration farms in farmers' field and creating awareness on CA among all the stakeholders.
- Provision of inputs (seed, fertilizer, chemical, and training) and machinery through Agricultural Service Providers (ASPs) since land holding is small and farmers cannot afford to buy machinery.
- Establishment of SAARC information unit in each country to validate, exchange CA based technology among the member countries and networking all related stakeholders to improve integrated approach within the SAARC network consortium on CA for mutual benefit.
- Policy on promote agribusiness for pro-farmers to generate revenue, improve their traditional agriculture practices and livelihood improvement through PPP, that is best policy for CA and sustainable agriculture.
- Review present Acts and Regulations on soil and water conservation and land ownership and land use to find gaps and laps related to CA. Create legislation to prevent crop residues burning.

- Integrated sustainable conservation policy with inclusive endogenous technology.
- Implementation of CA through a dedicated scheme with components like technology demonstration, capacity building, awareness and supply of inputs.
- Incentivize CA farming by providing subsidy/soft loans and establishment of custom hiring centres and extending financial assistance during early two-three years (transition phase) for adoption of CA to compensate yield loss.
- Declaring tax holidays for CA machinery manufacturing units and waiving of custom duty on CA machineries to facilitate import.

**Implementation Modality of Conservation Agriculture in South Asia**

- CA should be implemented in line of Organic farming through dedicated scheme like technology demonstration, awareness and adoption with cluster approach in farmers participatory model, like organic farming adopting at least one village/ 20 ha cluster.
- CA should be implemented by involving, self help group, farmers field schools, service providers, agriculture cooperatives. A revolving fund may be created to take up various operations under CA.
- Identify areas and major cropping systems/crop rotations.
- DSR/SRI/Soybean/arhar/cotton/Bajra/ maize/ cotton-wheat/ kharif and rabi pulses/ oil seed/ vegetable/ intercropping of cereal and legumes cropping system.
- Permanent bed and furrow method/ strip till system should be preferred for multiple benefits.
- Cultivation of moong/black gram/cowpea(fodder)/GM/sesame in summer needs to be explored and promotion of Green leaf mulching and brown manuring to increase the residues.
- Providing subsidy/soft loans and tax holidays on machineries and declaring tax holidays for manufacturing machineries.
- Establishing custom hiring systems.
- Creating awareness by organizing FLDs and imparting training to farmers.
- Extending financial assistance @Rs 2500 per ha during early years for adoption of CA to compensate any yield loss.
- Developing and implementing legislation on prevention and

monitoring of on farm crop resides burning providing suitable machinery to farmers.

**Research Gaps**

- It should be developed crop cultivars suitable for CA.
- CA requires farmer/gender friendly multi-tasking machinery, manual operated/ animal power/ drawn by low horse power 2 and 4 wheel tractors for various farm operations.
- Development of zero till variable depth and multi seed cum fertilizer drill, crop specific zero till transplanter, zero till single rice transplanter, development of machines for mulching in between rows for control of weeds, moisture conservation weeders. These technologies should be easily adoptable for different eco-regions/ecosystem and irrigated/non-irrigated conditions. Developing multi task machinery, suitable for low horsepower tractor capable of harvesting of crop, recovery of grains, chopping, wind rowing and spreading of straw for uniform distribution of crop residues.
- Developing innovative package of practices for CA for major cropping systems in each agro eco-system.
- Developing CA based integrated farming system models and weed, residue management technologies under rainfed conditions.
- Assessing benefit: cost and environmental impacts including ecosystem services under CA vis-à-vis conventional practices to formulate future policies.
- Research plan of policy and implementation modality gap to identify the successful technology of appropriate farm machinery project for regional development of CA and policy intervention mechanism of conservation agriculture in South Asia.

**Key Recommendations and Way Forward for Conservation Agriculture for Upcoming Programs/Activities in South Asia**

- Government should consider at least two years of time period to shift the existing conventional farm to conservation agriculture. SAARC Agriculture Centre (SAC) will initiate to develop the SAARC regional project for Conservation Agriculture.
- South Asia region is rich in technologies; however, the existing sharing mechanism is very weak. Therefore, there should be urgent need to develop a regional level Conservation Agriculture Techhnology information sharing network.

- It is important to relate available technologies to the climate change prospects, especially it is needed to relate while developing the regional project.
- There should be strong policy for existing crop residues burning problem at farm, it is better to have partnership with the agencies who advocates bio-char technology. It is noted that crop residues burning destroy the 35% P and K and 30% sulphur and other stuffs, when it burnt at farm, these nutrients get lost to atmosphere with increased carbon in the atmosphere. Bio-char can be promoted, especially for forest litter which is difficult to compost while crop residue can be easily composted.
- CA is all about sustainable and efficient use of resource. This will reduce risks to farmers and can adapt to the changing climate context.

# Conservation Agriculture Practices in South Asia: Strategies for Achieving SDGs

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## Introduction

South Asia accounts for 25% of the global population (nearly 1.7 billion). Majority of the population is below the poverty line (SARDPS, 2013). The population will account for about half of the entire global population by 2050. Agriculture in this region is dominated by smallholders with 42% landmass is under agricultural operation providing employment to over 50% of the population in the region (HDSA, 2015) contributing to GDP of about 19%. South Asia accounts for 37% of world's poor and nearly half of the malnourished children. Nearly 80% of poor live in rural area and earn their living by agriculture and allied activities. Sustainable intensification of agriculture is a must to lift up them out of hunger and poverty. The present tillage based intensive agriculture being practiced has already shown negative effect on the quality of natural resources such as soil, water, terrain, biodiversity and the associated ecosystem services provided by nature (Dumansky *et al*., 2014). This is evident from loss of soil organic matter (SOM), accelerated soil erosion, deterioration of soil physical, chemical, and biological health, poor input (water & nutrient) use efficiency, groundwater pollution, declining water tables, salinization and waterlogging, loss of biodiversity and decline in factor productivity. Another challenge for agriculture is its environmental foot print and climate change as agriculture contributes about 30% of the total greenhouse gas emissions of $CO_2$, $N_2O$ and $CH_4$ with accelerating effects on global warming, air pollution (IPPC, 2014). There is also a need to enhance the resilience of productions systems to biotic and abiotic stresses, particularly those arising from climate change.

Agricultural intensification, therefore, must focus on achieving food, nutritional, environmental and livelihood security through improvement of farming systems of resource poor small farm holders without harming the environment and conserving natural resources for future generations. The new paradigm of "sustainable intensification" as elaborated in FAO (2011) recognizes the need for a productive and remunerative agriculture which at the same time conserves and enhances the natural resource base and environment, and positively contributes to harnessing the environmental services. Sustainable crop production intensification must not only reduce the impact of climate change on crop production, but also mitigate the factors that cause climate change by reducing emissions and by contributing to carbon sequestration in soils. Intensification should also enhance biodiversity in crop production systems above and below the ground to improve ecosystem services for better productivity and healthier environment.

The United Nations Millennium Development Task Force on hunger has made enhancement of agricultural productivity and profitability of resource poor farmers along with conservation of natural resources among the five recommendations to fight hunger. In this context, conservation agriculture (CA) holds great promise as the goal of agricultural sustainability, conserving, improving and making more efficient use of natural resources through the integrated management of available soil, water and biological resources, combined with judicious use of external inputs. CA has potential to reduce the negative impacts of intensive agriculture minimizing soil degradation, build up soil organic matter, improve soil physical and biological health; reduce use of fossil fuels and enhance input use efficiency contributing, thereby, reduction of emission of GHGs in the atmosphere. Thus, CA is a base for sustainable agricultural production intensification and complies with the generally accepted ideas of ecological sustainability. According to FAO (FAO, 2014), CA is an approach to manage agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. CA is a resource-saving agricultural production system that aims to achieve production intensification and high yields while conserving the natural resource base through compliance with following three interrelated principles, along with other good production practices of plant nutrition and pest management (Abrol and Sangar 2006, Bhan and Behera, 2014).

(i) ***Minimum soil disturbance:*** The soil biological activity produces very stable soil aggregates as well as various sizes of pores, allowing air and water infiltration. This process can be called "biological tillage" and it is not compatible with mechanical tillage. With mechanical soil disturbance, the biological soil structuring processes will disappear. Minimum soil disturbance provides/maintains optimum proportions of respiration gases in the rooting-zone, moderate organic matter oxidation, porosity for water movement, retention and release and limits the re-exposure of weed seeds and their germination (Kassam and Friedrich, 2009).

(ii) ***Permanent soil cover through crop residues or cover crops:*** Soil mulch protects the soil against water and wind erosion, increases water infiltration , reduces water evaporation, conserves moisture, and helps moderate soil temperature, improves soil structure and aggregation contributes to the accumulation of organic matter, reduces weed infestation, promotes biological soil tillage through their rooting but also by support for earthworm, arthropods and microorganisms belowground and improves soil structure and aggregation, soil biological activity and soil biodiversity besides carbon sequestration (Ghosh *et al*. 2010).

(iii) ***Crop rotations ensuring a balanced mix of legume and non legume crops :*** The rotation of crops is not only necessary to offer a diverse "diet" to the soil micro organisms, but also for exploring different soil layers for nutrients that have been leached to deeper layers that can be "recycled" by the crops in rotation. Furthermore, a diversity of crops in rotation leads to a diverse soil flora and fauna. Cropping sequence and rotations involving legumes helps in minimal rates of build-up of population of pest species, through life cycle disruption, biological nitrogen fixation, control of off-site pollution and enhancing biodiversity (Kassam and Friedrich, 2009; Dumanski *et. al*., 2006).

(iv) ***Controlled traffic (tramline) farming system:*** The system confines all machinery loads to the least possible area (~15%) of permanent wheel tracks where the crop zone and traffic lanes are permanently separated. It can improve profitability and sustainability with reduce soil compaction, water erosion, nutrient leaching and GHGs emission. It offers farmers to apply the herbicide/pesticides uniformly over the bed for control weeds, pests & diseases by driving down the furrow lanes. Similarly, this system offers an opportunity to band basal and top-dresses fertilizer applications too.

Conservation agriculture systems require a total paradigm shift from conventional agriculture with regard to management of crops, soil, water, nutrients, weeds, and farm machinery (Sharma *et al*., 2012). Some of the salient features of conservation agriculture vis-à-vis conventional system are given in Table 1.

Table 1. Salient features of conservation agriculture vis-a-vis conventional system

| Features | Conventional agriculture | Conservation agriculture |
|---|---|---|
| Cultivation | Ecologically unsustainable | Eco-friendly |
| Tillage | Excessive mechanical tillage | No- till or reduced tillage(biological tillage) |
| Crop Residue | Burnt or removed (bare surface) incorporated. | *in-situ* surface retention (permanently covered) |
| Manuring | No manuring/Green manuring (incorporated) | Brown manuring/cover crops (surface retention) |
| Crop rotations | Mono cropping/culture, less efficient rotations | Diversified rotations involving legumes |
| Farm operations | Heavy reliance on manual labor, uncertainty of operations | Mechanized operations, ensure timeliness of operations. Labour requirements are generally reduced by about 50%. Fuel savings in the order of around 60% or more |

Source: Sharma *et al*., 2012

**Benefits of Conservation Agriculture:** Conservation agriculture is generally a "win-win" situation for both farmers and the environment with following advantages (Hobbs *et al*., 2006):

***Resource improvement***

- Improves soil structure, reduces soil crusting, moderates soil temperature.
- Improved soil moisture regime (due to increased rain water infiltration, water holding capacity and reduced evaporation loss).
- Facilitates recycling and availability of plant nutrients.
- Helps build up soil organic matter in the surface layers.
- Improves biological activities/processes with abundant and diverse community of beneficial soil biota and associated eco system services.
- Due to controlled traffic, no compaction in crop area. Compaction only in tramline.
- Controls weeds.

***Economic benefits***

- CA technologies may have yield advantage up to 50%.
- Reduces cost of production on account of savings on diesel, labour, energy and inputs (water, fertilizers, pesticides, herbicides).

- Labour requirements are generally reduced by about 50%.
- Fuel savings in the order of around 60% or more.
- Impart greater resilience to biotic and abiotic stresses including climate change related aberrations, thus, lowering the risk of crop failure/yield losses.
- Improves water use efficiency, thereby, saves water up to 20% – 30%.
- Offers opportunities for crop diversification involving agroforestry to enhance natural ecological process and ecosystem services.

***Environmental benefits***

- Reduces soil erosion/degradation.
- Improves water quality due to reduced contamination levels from agrochemicals and soil erosion.
- Helps to sequester carbon in soil at a rate ranging from about 0.2 to 1.0 t/ha/year or more.
- Eliminate burning of crop residue which contributes to greenhouse gas emission, air pollution besides loss of plant nutrients.
- Mitigate Green House Gas emissions and improves environmental sustainability.

**Limitations and Opportunity**

*Machinery:* One of the major constraints to adoption of conservation agriculture is the availability of suitable cost effective equipments affordable by farmers. It is not true that CA requires heavy implements and large tractors. It can also easily be adopted by small and marginal holdings with machinery operated manually, drawn with animal power or low horsepower 2 and 4-wheel tractors. A strip-till system where a rotary blade cuts the residue and forms a narrow strip for planting seed and fertilizer can be tried as an attachment for 2-wheel tractors for this purpose. Happy Seeder which cuts and picks up the loose straw, chops and distributed evenly on the ground to form residue mulch ahead of the planter and subsequently sows the seed without tillage has great promise. A list of Conservation Agriculture machineries developed by different South Asian nations have been is documented by Rehman et al., 2015. This needs to be updated on regular basis.

*Crop residues Management:* Permanent crop cover with in situ retention of crop residues is a pre-requisite and an integral part of conservation agriculture. Although sowing of crop in presence of residues was a problem, new variants of zero-till seed-cum-fertilizer drill/planters such as Happy Seeder, Turbo Seeder, rotary-disc drill and easy seeder have since been developed to overcome the problem. In dryland eco-systems, where only a single crop is grown in a year, it is possible to grow a second crop with residual soil moisture in the profile under conservation agriculture with soil cover with crop residues. It is, however better to use the chopped biomass of semi-hard woody perennial plants instead of crop residues to cover the soil surface.

*Weed, pest and disease management:* Incidence of weed, pest and disease infestations has been reported a major threat for promotion of CA. However, if the CA is implemented in accordance with its principles following residue retention, use of cover crops, brown manuring, crop rotation with legumes, cultural and mechanical measures weed free seeds and integrated pest management, these problems can be reduced to a significant extent. Turbo seeder drill which places crop residues between rows proved to be extremely useful in controlling weeds.

*Compaction:* There are reports of increasing bulk densities under CA particularly when soils are wet and most prone to compaction. However, this can be minimized if farm operations are carried out manually or using animal/low powered tractor and/or by controlling traffic farming. Besides, infiltration of water in CA systems is greater than in conventionally tilled plots as long as ZT is combined with residue cover due to greater earthworm activity facilitating biological tillage.

*Yield reduction:* During the transition phase, there is fear of loss of productivity in the initial years. However, this can be overcome, if soil quality, pest and weed infestation is monitored and managed effectively using integrated nutrient and pest management along with residue retention and crop rotation. Success has also been achieved in zero till bed planting with multiple benefits. Water savings are in the order of 30-40% using beds. The beds permit more diversity in cropping systems during the summer season, as better drainage can be maintained for crops on beds during the wet monsoon period.

**Strategies and Way forward**

World-wide CA is being adopted on more than 147 million ha area (Kassam *et al*., 2015). However, only few countries i.e., USA, Brazil, Argentina, Canada and Australia share about 90% of this area. South Asian nations cover around 5.0 million ha under conservation tillage mostly in rice-wheat system. CA is often used synonymously with ZT. In South Asia, CA is practiced only in wheat with ZT. One should follow the principles of CA in totality throughout the year and not in piece meal. Following set of strategies including research, policy and development programme have to be formulated to achieve the goal of conservation agriculture.

***Developmental***

- CA needs to be implemented through cluster approach like organic farming in farmers' participatory mode adopting at least one village/20 ha cluster.
- Identify major cropping systems/crop rotations which could be readily taken up for conservation agriculture in different eco-systems namely irrigated, rainfed and dry land, arid, hill and coastal production zones. For example, DSR/soybean/arhar/cotton/Bajra - wheat/rabi pulses/ mustard/potato cropping system can be taken up under CA with bed planting.
- System of Rice Intensification (SRI) with zero till single rice transplanter may be promoted.
- Cultivation of moong/cowpea (fodder) in summer may be taken up.
- Vegetable crops for which zero till transplanters are available may be taken up.
- Permanent bed and furrow method/strip till system should be preferred due to multiple benefits.
- Involvement of NGOs in PPP mode may be explored to provide various services required under CA.

***Research***

- Developing suitable crop varieties for CA.
- Development of zero till variable depth and multi seed cum fertilizer drill, crop specific zero till transplanter, zero till rice transplanter, suitable bed formers-cum-planters may contribute heavily towards promotion of CA in South Asia.
- Developing gender friendly multi task machinery suitable for low horsepower tractor capable of harvesting of crop, recovery of grains, chopping, windrowing, and spreading of straw for uniform distribution of crop residues.
- Developing innovative package of practices for conservation agriculture for major cropping systems in each agro eco-systems.
- Assessing benefit: cost and environmental impacts including ecosystem services under conservation agriculture vis-à-vis conventional practices to formulate future policies.
- Developing CA based Integrated Farming System models.
- Residue management under rainfed conditions.

***Policy***

- Consider CA as one of the components of national Mission on sustainable agriculture.
- Launching of dedicated scheme on CA converging all the related components of various schemes being run by different Ministries/Departments.
- Supplying machineries for conservation agriculture on subsidized rates, promoting custom hiring systems and providing soft loans for purchase of implements.
- Declaring tax holidays for manufacturing machineries to be used for conservation agriculture.
- Creating human resources development and capacity building through training and teaching of graduate and post-graduate students of agricultural university.
- Creating awareness through organizing frontline demonstrations and imparting training to farmers.
- Extending financial assistance @ Rs. 2500/- per ha during early years (transition phase) for adoption of CA to compensate any yield loss.
- Legislation for prevention of crop residues burning.
- Introducing and providing carbon-credit to the farmers practicing conservation agriculture for carbon sequestration and greenhouse gas mitigation.
- Creating awareness on CA among all the stakeholders.
- Extending financial assistance during early years (transition phase) to compensate any yield loss.
- Waiving import duty on CA machineries.
- Encourage PPP (Public-Private Partnership) for promotion of CA.

**Conclusion**

The present high input based agricultural intensification is neither productive nor environmentally sustainable. We need a system resilient to both biotic and abiotic stresses with minimal impact on the environment to produce more per unit area through judicious use of inputs and efficient use of natural resources. Conservation agriculture has several benefits in terms of minimization of cost of production (through savings on fuel, labour, fertilizers, pesticides and water), enhancement of input use efficiency, improvement of soil health with greater biological activities, higher soil Carbon sequestration, reduction of land degradation, minimization of GHGs emissions, facilitation of ecosystem services besides extending sustainability to agricultural intensification and environment. Sustainable intensification of agriculture in South Asia through CA depends largely on farmer-friendly machinery to generate interest among the private manufacturers to invest. Moreover, CA requires a change in mind set, dedication, commitment, attitude, and behaviour of all concerned stakeholders viz. scientists, policy makers, extension workers, NGOs and farmers for its promotion. We must realized that C' in Conservation Agriculture stands for Carbon. Basically, CA is low carbon agriculture. Goal is to attain carbon neutral agriculture with ultimate goal of attaining carbon negative agriculture.

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# Best Practices of Conservation Agriculture in Bangladesh

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## Introduction

Conservation agriculture encompasses three management objectives: eliminating or significantly reducing tillage to minimize soil (less than 25%) disturbance; retaining crop residues on the soil surface and encouraging economically viable crop rotations that best complement reduced tillage and crop residue retention. It is important to note that conservation agriculture is not a fixed management system but rather a set of principles that have demonstrated value across a wide range of agro-ecological regions. The precise ways that conservation agriculture-based management strategies are implemented as well as the advantages derived from these management innovations are contingent on regional and site-specific cropping system characteristics.

One technology that has prospects to conserve and facilitate improved and efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs is Conservation Agriculture, which emanating from three broad principles as; (i) minimum soil disturbance, (ii) permanent organic soil cover, and (iii) diversified crop rotations. Conservation agriculture is often referred to as a resource- efficient or resource-effective agriculture (FAO, 2017)) that contributes to environmental conservation as well as to enhancement and sustenance of agricultural production. Conservation agriculture is founded on the principle of no-tillage or minimum soil disturbance as a way of sustenance. It is gaining popularity among farmers throughout the world. Although it is difficult to get an accurate estimate of the total area covered. Globally CA is practiced in 190 million ha. (Kassam *et. al*., 2017). One of the main reasons for this no-tillage revolution has been the greater profitability of CA over conventional systems as a result of lower input costs (less fossil-fuel use and more efficient input use) coupled in most cases with an increase in yield.

Benefits of conservation agriculture-based crop management often include as reduced production costs, labour and energy requirements; timely field operations and avoidance of terminal heat stress; improved soil quality and reduced erosion; enhanced rainfall infiltration and reduced evaporative losses; higher crop water productivity (kg of grain/$m^3$ of water); more stable and higher crop yields and lack of assured irrigation conditions; and many other environmental benefits. CA-based crop management can provide a buffering mechanism against many of the abiotic stresses that limit productivity in rain-fed conditions, especially with respect to conserving and maximizing the productive use of water.

For resource-poor farmers, there must be short-term payoffs from investments in climate risk management since the cost of adaptation can erode the asset bases of vulnerable groups and increase insecurity. In many circumstance, CA can be profitably adopted by farmers with little or no disadvantage because CA not only reduces production costs, but it also stabilizes and enhances crop yields, particularly against current climate risks as it builds resilience against climate changes and variability. This should significantly reduce production risks posed by climate factors and labour shortages, thereby enabling a higher level of investments in inputs and management intensity that, in turn, would lead to sustained increases in yields and more secure livelihoods for resource-limited farmers.

**Conservation Agriculture (CA) in rice-based system**

Rice–maize (R–M) systems are rapidly expanding in South Asia and Bangladesh due to higher yield and profit potential from rabi (winter) maize, it reduced water requirement as compared to rice–rice systems, and increasing demand from poultry and fish feed industries. The current practice of growing puddled transplanted rice and maize with conventional, repeated tillage degrades soil structure, delays maize planting, and reduces its yield potential, increasing energy and labour requirements, ultimately leading to high production costs. CA-based tillage and crop establishment options such as strip or reduced tillage, and raised beds, may hold potential to increase yield, reduce crop establishment costs, and increase income of the farmers. The objective of this study was to evaluate the productivity and profitability of R–M systems under CA-based tillage and crop establishment options across a gradient of 69 farmers' fields in Northwest Bangladesh. We evaluated four tillage and crop establishment options: reduced tillage; strip tillage; fresh beds; and permanent beds. Conventional-tilled (puddled) transplanted rice on flat followed by conventional-tilled maize on flat was included as a current practice. ANOVA for adjusted 4-year pooled mean revealed no significant treatment effects for yield and economic analysis parameters for rice ($P \geq 0.05$), but they were significant for maize and the R–M system ($P \leq 0.05$). Rice yields across tillage and establishment treatments over four years ranged from 4.6 to 4.9 t $ha^{-1}$

while maize and R–M system yields ranged, respectively, from 7.8 and 12.5 t $ha^{-1}$ under conventional tillage to 9.0 and 13.8 t $ha^{-1}$ on permanent beds. Compared to conventional tillage, the average maize and system yield across fresh beds, reduced tillage, and strip tillage, was greater by 9.1% and 6.1%, respectively. Maize production costs ranged from US \$922 $ha^{-1}$ with fresh beds to US \$1,027 $ha^{-1}$ for conventional tillage. Maize net returns and benefit cost ratio (BCR), however, ranged, respectively, from \$945 $ha^{-1}$ and 1.9 under conventional tillage to \$1350 $ha^{-1}$ and 2.4 under permanent beds. We conclude that while CA-based tillage and establishment options may not have significant yield advantage over conventional tillage in rice, they have significant advantages in terms of reduced production cost and labour use, and increased net returns. For maize as well as for R–M system, while most options can provide yield benefits similar to conventional tillage, permanent beds exhibit a significant advantage (yield, net returns, etc.) over conventional tillage. Profitability was consistently greatest and significantly different ($P \leq 0.001$) under permanent raised beds compared to all other treatments. Considering our assessment of the profitability distributions and risk analysis, we conclude that both rice and maize planted sequentially on permanent beds and strip tillage can result in higher net income and BCR compared to conventional tillage practice. Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice–maize systems:

Although, CA adoption is about 195 million ha globally mostly in non-rice based cropping systems. However, there is limited adoption of CA in rice-based systems which support predominantly smallholder farms (Johansen et al., 2012). The common rice establishment method in Asia involves transplanting following full tillage and soil puddling. Continuation of soil puddling for rice transplanting will negate the benefits of minimum disturbance in other crops in the rotation as is reported for the rice-wheat system (Singh *et al*., 2011). Conservation agriculture helps farmers to reduce production costs while improving soil health, crop diversity and timeliness of cultivation (Johansen *et al.*, 2012). Successful development of two-wheel tractor (2-WT) based implements like the BARI Multi-crop Planter for zero tillage, strip tillage, minimum tillage and raised bed planting have created new avenues for the pursuit of CA in rice-based smallholder farming systems that are common in South Asia (Hossain *et al.,* 2011). However, implementation of CA in the whole cropping sequence is hampered until there is a suitable alternative to transplanting of rice crops into fully puddled soils or a more reliable alternative to direct seeding.

The production costs for the transplanted boro (growing season from mid December to mid April) and aman rice (from mid June to November) (monsoon) rice cropping pattern increased by about 55 % in Bangladesh during 1996–2006 (BRRI, 2007a,b) due to increased wages and of the input prices including fertilizer, irrigation water, and pest control. Scarcity of farm labor and tillage for land preparation and puddled rice transplanting have emerged in recent times as a serious constraint for timely transplanting of rice in many parts of South Asia and South East Asia. Hobbs *et al*. (2002) described the emerging issues of sustainability of rice-wheat systems and stressed the need to improve water-use efficiency, soil structure, and weed management against the backdrop of increasing scarcity of labor and water. Bhuiyan *et al*. (2004) reported that the net profit from rice cultivation was static or had declined in some cases over the period which can be attributed largely to rising costs of crop production. Hence there are compelling reasons for decreasing the costs of rice production in South Asia and South-East Asia and preliminary evidence that unpuddled transplanting of rice seedling could provide such benefits (Haque *et al*., 2016).

**Advantages of Conservation agriculture in Bangladesh context**

**Fuel Savings:** Due to single pass planting, fuel costs are reduced by 30-85 % in strip till planting and zero tillage planting.

**Yield increases:** Significant yield increases on crop yield e.g., 8% for boro rice, 6% wheat, 8% mungbean, 38% lentil, 36% jute, etc.

**Fertilizer:** Mechanized sowing places seed and fertilizer close together which can boost early growth of crops. However, in sandy soils, *it* the fertilizer rate is too high and too close to the seed, toxicity may decrease plant emergence.

**Labor savings:** Due to single pass planting and mechanized seeding, labour costs are reduced by 30-70 % in strip planting and zero tillage.

**Savings of time:** Single pass planting reduces the time taken for crop establishment enabling crops to be planted on-time to achieve high yield potential

**Weed control:** Residue retention, herbicides and timely hand weeding can be effectively used to control weeds. More R, D&E and training of farmers on the safe and effective use of herbicides is essential.

**Seed placement:** Mechanized sowing can place seed precisely at the best depth for germination. Hence 20 % decrease in seed rate is commonly acceptable for good crop establishment.

**Sustainable intensification:** Unsustainable water use is evident in parts of Bangladesh where the rates of water extraction for irrigation exceed recharge rates to groundwater. In the Rajshahl Division, groundwater rates are reported be declining rapidly and Water use for crops can be decreased by CA practices. With wheat, research suggests that 36 % water savings are possible. With DSR, 50 % water saving is reported. Longer term changes in water balance under continuous CA practices need to be determined.

**Enabling Environment for CA and Mechanization**

Commercialization of the technology for adoption of CA is needed to spread the benefits to small farmers. The private sector is a key partner by supplying planters through dealer networks, by providing repairs and spare parts services and by continuously improving the stability of planters for the market. Local service providers are the key factor in enabling farmers to access mechanized minimum tillage planting with residue retention.

Policy initiatives from the Government related to machinery subsidies, fertilizer subsidies, and herbicide. Registration, extension priorities and mechanization can improve the spread of CA. Progressively, threatening the Boro rice production. The Government of Bangladesh through its funded R, D & E programme is well position to accelerate the spread of CA and its adaptation to the varied conditions across the nation. Subsidies ore available for a range of machinery but limited support is available for CA machinery. Carefully targeted and weighted price support can act as an incentive for LSP and farmers to take up mechanized CA planting, but care needs to be exercised in avoiding price distortions in the market. Credit is needed for LSP to be able to invest in planters under terms that allow repayment over 2-3 years.

### Soil properties

Bangladesh soils generally have low organic matter levels. Minimum soil disturbance and crop residue retention increases soil organic matter and improve soil health within 2-3 years under continuous CA.

### Reduced field preparation costs

CA reduces costs associated with tillage, whether manual or by machinery. In mechanized rice-wheat systems with both in Bangladesh and India, field operational costs were 25% lower under CA. In manual maize systems in Bangladesh, CA fields required 20% less labor than conventional ridge and furrow fields. The reduction in field preparations with CA also allows time timelier planting, which supports successful harvests (Hossain *et al*. 2012).

### Reduced soil erosion

Reducing tillage and maintaining soil cover with crop residues can reduce erosion by up to 80%. CA also generally increases soil organic matter in topsoil, as well as soil biological activity and biodiversity.

### Climate change mitigation

Under certain conditions, CA may contribute to climate change mitigation through carbon sequestration and reduced GHG emissions, but climate change adaptation rather than mitigation should be the main policy driver for its promotion.

### Agricultural scenario: Crops, Crop Production and Farming Systems

Agriculture plays an important role in Bangladesh economy. Morethan 70% people in the rural areas directly or indirectly are involved with agriculture (BBS, 2011). It employs nearly 47.5% of labour force and contributes one sixth of gross national product of the country (GoB, 2013). Different types of industries and farms have been developed in the rural areas based on agriculture. Agriculture supplies raw-materials to the industries especially agro-based industries. Rice is dominant among different subsectors of agriculture and accounting for roughly three fourths of gross crop area devoted to rice production (BBS, 2011). Most of the farming system is rice monoculture, as a result of continual cultivation of rice it is helpful to achieve self-sufficiency in rice production to some extent, and however, it has been created many problems. As a result, agriculture sector has been facing a number of problems like reduction of soil fertility, pests and diseases outbreaks and decline in water table in the crop fields.

Agriculture is the single most important sector of the economy in Bangladesh. It is the major source of livelihood in the rural areas, where some 80% of the populations live. Approximately two-thirds of the labour force is employed in agriculture. Although its share in the GDP is predictably declining, agriculture (crops, livestock, fisheries and forestry) contributes approximately one-third of the GDP and agricultural production accounts for 32% of the value of exports. The performance of this sector affects the overall economic growth. With irrigation covering only around 42% of the potentially irrigated area, agriculture is still weather dependent and has grown slower than was earlier expected, particularly because of the predominantly small farmer holdings in Bangladesh.

Bangladesh is one of the most densely populated countries in the world. Despite that, population is increasing @ 1.58%, but cultivable land is decreasing @ 0.78% per year due to rapid urbanization (@ 12%) & others. The demand of food production is increasing day by day along with the increasing of high population in Bangladesh. To meet up the food security, potential yield and cropping intensity should be increased. To increase wheat production in the country, adoption of the resource conserving technologies (RCTs), especially power tiller operated seeder and bed planter is very useful for quick finishing of planting operation and achieves crop diversification using less soil moisture. Barind tract is the region where 75,000 hectare of land is fallow after Taman harvest due to lack of germination soil moisture and irrigation water (BMDA, 2009). Farmers of this area kept 10-15 days of Taman straw on the same land for drying. After that there is no moisture there and farmers did not grow any Rabi crops after Taman harvest. They are also facing trouble doing agricultural operations due to labor shortage especially during planting season. As a result, they grow wheat in late and gets very low yield. Conserving tillage machinery such as bed planter and power tiller operated seeder (PTOS) are the alternate ways to ensure timely planting, meet up with labor shortage, keep crop production at economic level and enhance cropping intensity. These machineries are capable completing seeding operation in a single pass without any extra tillage. The adoption of reduce tillage methods can offer significant environmental benefits while providing energy savings (Hatfield and Karlen, 1992). Conventional tillage techniques increase the emission of $CO_2$ into the atmosphere. Grace (2003) reported that tillage operation contribute $CO_2$ through the rapid organic matter decomposition due to exposure of large surface area to increase oxygen supply. Raised bed cultivation facilitates more optimum planting time by providing timelier field access because of better drainage. This system has many advantageous such as reducing the seed rate, increasing crop yield, requiring less water imparting higher

N use efficiency, an*d red*ucing crop lodging over the conventional sowing systems (Hobbs *et al*,1997). Conservation farming provides important benefits to the environment and economic benefits for the farmer. It aims to conserve, improve and make more efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. Conservation farming is practice for the modernization of agriculture. It is commonly based on soil tillage. Conventional tillage techniques considerably increase soil degradation by compaction, erosion and river contamination with sediments, fertilizers and pesticides. In addition, conventional tillage techniques increase the emission of $CO_2$ into the atmosphere, contributing to global warning. It reduces the sustainability of agriculture by lowering soil organic matter and fertility, along with further negative environmental effects as decrease in biodiversity.

**Predominant conservation systems in predominant cropping systems**

**Major predominant cropping pattern in Bangladesh:**

Rice-rice, Rice- wheat-mungbean and Rice-potato-maize

On the basis of land type some predominant cropping pattern in Bangladesh are given below:

| Land Type | Cropping Pattern |
|---|---|
| High | 1. Boro - T.Aman – Fallow |
| | 2. Potato - Boro (HYV) - T.Aman |
| | 3. Pulses - Jute – Fallow |
| | 4. Wheat - Kaon - T.Aman |
| | 5. Tomato - Aus – Vegetables |
| Medium | 1. Potato - Boro - T.Aman |
| | 2. Wheat - T.Aman – Pulses |
| | 3. Oilseed - Boro - T.Aman |
| | 4. Boro - T.Aman – Mustard |
| | 5. Tomato - Aus – Vegetable |
| Low | 1. Potato - Boro B.Aman |
| | 2. Boro - T.Aman – Fallow |
| | 3. Wheat- T.Aman – Fallow |
| | 4. Wheat - Boro - T.Aman |
| | 5. Jute - T.Aman – Fallow |

Table 1. Existing Major Cropping Pattern in Drought Prone Rajshahi Region

| Sl. No. | Rabi | Kharif-1 | Kharif-2 |
|---|---|---|---|
| 1* | Boro | Fallow | T. Aman |
| 2 | Boro | Aus rice | T. Aman |
| 3* | Tomato/Boro | Fallow | T. Aman |
| 4 | Wheat | Mungbean | T. Aman |
| 5* | Mustard/Boro | Fallow | T. Aman |
| 6 | Wheat | Jute/Aus | T. Aman |
| 7 | Potato | Maize | T. Aman |
| 8 | Maize | Aus rice | T.Aman |
| 9* | Boro | Fallow | Fallow |
| 10* | Fallow | Fallow | T. Aman |

Source: BMDA, 2015 * Major cropping pattern

Table 2. Cropping Pattern Practiced in Drought Prone Area in Rajshahi Region

| Traditional pattern | Improved pattern |
|---|---|
| Fallow - T.aman - Fallow | Chickpea/ Lentil-Sesame -T.aman |
| Fallow - T.aman - Wheat | Wheat (Heat tolerant) - Mungbean-T.aman |
| Fallow - T.aus - Tomato | Lentil/ Maize - Taus - T.aman |
| Fallow-Taman- Boro | Wheat- Sesame/ Mungbean- Taman |

Source: BMDA 2015

**Major CA based Cropping patterns in Bangladesh**

- Rice-wheat-mungbean is favorable and profitable cropping pattern for RCTs machinery
- Rice-potato-maize looks promising
    a. Rice-based Cropping System

       Rice-wheat-mungbean, Rice-wheat-pulses, Rice-pulses-oilseeds

    b. Maize-based Cropping System

       Maize-rice-wheat, Maize-wheat-pulses, Maize-pulses-rice

    c. Vegetable based Cropping System

       Vegetables-pulses-oilseeds, Vegetables-rice-wheat, Vegetables-maize-rice

## Conservation Agriculture for sustainable intensification of agriculture

For sustainable intensification of agriculture on conservation agriculture needs policy, technologies and also extension to the farmers' field which are discussed as follow:

**Building partnership:** CA systems are complex and their efficient management needs understanding of basic processes and component interactions which determine the system performance. A system perspective is the best to build working in partnership with farmers, who are at the core of farming systems and best understand this system. Scientists, farmers, extension agents, policy makers and other stakeholders in the private sector working in partnership mode will be important in developing and promoting new technologies. As FAO (2005) reported that the challenge is for would-be advisers to develop a sense of partnership with farmers, participating with them in defining and solving problems rather than only expecting them to participate in implementing projects prepared from outside. Instead of using a top-down approach where the extension agent places CA demonstrations in farmer fields and expects the farmer to adopt, a more participatory system is required where the farmers are enabled through provision of equipment and training to experiment with the technology and find out for themselves whether it works and what fine-tuning is needed to make it successful on their land.

**Credit and Subsidy:** The other important thing for successful adoption of CA is the need to provide credit to farmers to buy the equipment, machinery, and inputs through banks and credit agencies at reasonable interest rates. At the same time government need to provide a subsidy for the purchase of such equipment by farmers. For example, in recent years the Chinese government adopted a series of policy and economic measures to push CA techniques in the Yellow River Basin and is providing a subsidy on CA machinery and imparting effective training to farmers (Yan et al., 2009). This resulted in a considerable increase in area under CA. Currently in Shanxi, Shandong and Henan provinces over 80% area under maize cultivation depends on no till seeder.

## Policy Intervention, Research and Extension on Conservation Agriculture Management

Conservation agriculture implies a radical change from traditional agriculture. There is need for policy analysis to understand how CA technologies integrate with other technologies, and how policy instruments and institutional arrangements promote or deter CA (Raina *et al.,* 2005). CA offers an opportunity for arresting and reversing the downward spiral of resource degradation, diminishing factor productivity, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. While R&D efforts over the past decade have contributed to increasing farmer acceptance of zero tillage for wheat in rice-wheat cropping systems, this has raised a number of institutional, technological, and policy related issues which must be addressed if CA practices are to be adopted in large scale in the region on a sustained basis. The following are some of the important policy considerations for promotion of CA.

**Scaling up conservation agriculture practices:** Efforts to adapt the CA principles and technological aspects to suit various agro-ecological, socio-economic and farming systems in the region started a few decades ago. Greater support from stakeholders including policy and decision makers at the local, national and regional levels will facilitate expansion of CA and help farmers to reap more benefits from the technology. However, its percolation to farmers is very limited. There is a need to think about the problems faced at the implementing level and devise a strategy involving all who are concerned. Most cases, where changes in favour of CA have occurred, are limited in success. FAO (2001) has reported that this is partly because policy environments are not favorable. One of the reasons for poor percolation of the technology to the farmers was the past bias or mindset about tillage by the majority of farmers (Hobbs and Govaerts, 2010). Under such situations, farmers' participatory on-farm research to evaluate/refine the technology in initial years followed by large scale demonstration in subsequent years is needed. In India, efforts are being initiated through a network research project for on-farm evaluation and demonstration of CA technology for its promotion.

Shift in focus from food security to livelihood security: Myopic "food security" policy based on cereal production must now replace a well-articulated policy goal for livelihood security. This will help the diversification of dominant rice-wheat cropping systems in Bangladesh, the cultivation of which in conventional tillage practice has overexploited the natural resources in the region. The nature of cropping patterns and the extent of crop diversification are influenced by policy interventions. The government policies that directly or indirectly affect crop diversification are: pricing policy, tax and tariff policies, trade policies and policies on public expenditure and agrarian reforms (Haque *et al.*, 2014).

CA technologies bring about significant changes in the plant growing micro-environment. These include changes in moisture regimes, root environment, emergence of new pathogens and shift in insect-pest scenario etc. The requirement of plant types suited to the new environment, and to meet specific mechanization needs could be different. There is a need to develop complementary crop improvement programmes, aimed at developing cultivars which are better suitable to new systems. Farmers-participatory research would appear promising for identifying and developing crop varieties suiting to a particular environment or locations.

There is a need for generating a good resource database with agencies involved complementing each others' work. Besides resources, systematic monitoring of the socio-economic, environmental and institutional changes should become an integral part of the major projects on CA.

Policy support for capacity building by organizing training on CA is needed. Availability of trained human resources at ground level is one of the major limiting factors in adoption of CA. Training on CA should be supported at all levels. Efforts to adequately train all new and existing agricultural extension personnel on CA should be made in relevant departments. Consideration of extension approaches such as the 'Lead Farmer Approach' should also be made as a way to mitigate extension shortages at the local level. In the long term, CA should be included in curricula from primary school to university levels, including agricultural colleges. Inclusion of conservation and sustainability concepts in the course curricula with a suitable blend of biophysical and social sciences would be important for sustainable resource management.

Institutionalize CA has to be mainstreamed in relevant ministries, departments or institutions and supported by adequate provision of material, human and financial resources to ensure that farmers receive effective and timely support from well trained and motivated extension staff. Key local, regional and national institutions should have dedicated CA champions among their staff who will help to ensure that relevant plans, programmes and policies embrace CA. In the short to medium term, policy makers could support activities of national and regional CA working groups to ensure that relevant thematic (research, technical, extension, training, education, input and output markets, policy) areas are covered by various CA programme. Institutionalizing CA into relevant government ministries and departments and regional institutions is required for sustainability of the technology. Local, national and regional policy and decision makers could spearhead and support the formulation and development of strategies and mechanisms for scaling up the technology. CA could be integrated into interventions such as seed, fertilizer and tillage and draft power support programme as a way of further enhancing productivity.

**Support for the adaptation and validation of CA technologies in local environments**: Adaptive research is required to tailor CA principles and practices to local conditions. This should be done in collaboration with local communities and other stakeholders. Issues that should be addressed include crop species, selection and management of crop and cover crop and rotations, maintenance of soil cover and CA equipment. The resource poor and small holder farmers in India do not have economic access to new seeds, herbicides and seeding machineries etc. (Sharma *et al.*, 2012). This calls for policy frame work to make easily available critical inputs.

**Support the development of CA equipment and ensure its availability**: While some countries produce CA equipment, most of the available implements and equipment are imported. In the short term, consideration could be made on removing or reducing tariffs on imported CA equipment and implements to encourage and promote their availability. In the medium to long run, local manufacture of these will increase availability, ensure that equipment is adapted to local conditions, increase employment opportunities and reduce costs. The larger and more complex equipment is expensive and users may have to hire it. There is an opportunity to develop a local hire service industry by providing equipment, and training on machine maintenance and business skills. Where governments support land preparation schemes using ploughs, there is scope to change the equipment to rippers or direct seeders to reduce the cost and align the schemes to CA approaches. In India, significant efforts have been made in developing, refining and promoting the second generation zero-till multi-crop planters, but quality control assurance on standards and their availability at the local level with after-sale services and spare parts is still an issue. The new machineries, viz. Strip till, Bed planter, Zero tillage and minimum tillage by PTOS etc. are found useful for CA practices, but these machines are more suitable for rich and medium to large farmers groups. These machines need more horse power (> 50) for smooth functioning in field conditions. Small and marginal farmers having small holdings and economic limitations are unable to afford for such heavy machines. They need smaller versions of these machines which needs **Bangladesh sustainable issue:** policy support for manufacturing at the local level.

Unsustainable water use is evident in parts of Bangladesh where the rates of water extraction for irrigation exceed research rates to groundwater. In the Rajshahi Division, groundwater rates are reported be declining rapidly and progressively threatening the Boro rice production. Water use for crops including paddy rice can be decreased by CA practices. With wheat, field, it is reported that 36% water savings are possible and with DSR 50% water can be saved. Minimum tillage un-puddled transplanting is another establishment technology for CA rice which decreases water requirements by avoiding the puddling operation.

Sustainable intensification on conservation agriculture, Bangladesh Government has taken some initiatives.

a) Given priorities to export incentive for some CA machineries like raised bed planter, thresher, combine harvester and two wheel tractor.

b) Given 30-50% subsidy on raised bed planter, thresher, combine harvester and two wheel tractor through DAE

c) Taken initiatives for carbon mitigation policy to attend world carbon mitigation meeting

d) Taken initiatives to make vermi-compost, tricho-derma and other composts mixed into soil

e) Taken initiatives to kept straw for added organic matter into the field

f) Taken initiative to machinery subsidies, fertilizer subsidies, herbicide registration, extension priorities and mechanization for improve and spread of CA.

g) Murdoch University has taken initiatives to given 30-50% subsidy for strip tillage planters, machinery manufacturers, local service providers with proper trainings

h) CA technologies are available for sustainable intensification

i) Government has taken some initiatives to adoption CA technologies through DAE with the help of agricultural scientists in the farmer's field.

For dissemination of conservation agriculture to sustainable intensification in Bangladesh needs CA based technologies and Farm Mechanization which are given below:

Conservation agriculture technologies are now developed for small farms in Bangladesh for a range of crops.

- Rice establishment in CA in now feasible.
- CA has water savings, labour savings, fuel savings and increases profitability of a range of crops.
- The commercialization of CA is being led by private sector actors (local service providers and manufacturers/importers).
- The enabling environment for CA spread can be developed by Government policies (R, D & E) and programmes (price support) and by the banking system (credit).

However, following points should be considered for sustainable intensification on CA in Bangladesh

- Commercialization of the technology for adoption of CA is needed to spread the benefits of small farmers.
- The private sector is a key partner by supplying planters through dealer networks, by providing repairs and spare parts services and by continuously improving the suitability of planters for the market.
- Local service providers are the key factors in enabling farmers to access mechanized minimum tillage planting with residue retention.
- The Government of Bangladesh through its funded R, D & E programme is well position to accelerate the spread of CA and its adaptation to the varied conditions across the Nation.
- Subsidies are available for a range of machinery but limited support is available for CA machinery.
- Carefully targeted and weighted price support can act as an incentive for LSP and famers to take up mechanized CA planting, but care needs to be exercised in avoiding price distortions in the market.
- Credit is needed for LSP to be able to invest in planters under terms that allow repayment within 2-3 years.

For sustainable intensification of agriculture needs advisory of Extension personnel and provided critical inputs among the technology and also needs proper training to the end users and added organic matter into the soil and change properties of soils.

Bangladesh soil generally has low organic matter levels. Minimum tillage and crop residue retention has been found to increase soil organic matter within 2-3 years and sustainable in long-term. Increase in soil carbon within 2-3 years under continuous CA (minimum tillage plus residue retention) improve soil health.

**Conservation Agriculture and Farm Mechanization in Bangladesh**

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- CA has water savings, labor savings, fuel savings and increases profitability of a range of crops.

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**Characteristics of Farming Systems in Bangladesh**

Aman rice is the anchor crop of most farm households in Bangladesh. At 350 kg of paddy consumed per person per year, the average family needs to grow 1750-2100 kg of paddy per year. Other cropping choices generally fit around this requirement for Aman rice, depending on the land type and the profitability of alternative crops. Field sizes are generally small (1,000 $m^2$). Farms often comprise several dispersed small fields. About 85 % of primary tillage is provided by the rotary tiller operated by two-wheel tractors (2WT). Small farms with small dispersed fields are not conducive to mechanization with tour-wheel tractors (4WT). The capital cost of mechanization is often too high for small farmers. Consequently, many farm operations on small farms including tillage, pumping and threshing are mechanized by hiring local service providers to carry out the work on a fee-for-service basis.

**Intensive Cropping**


The national average for cropping intensity is 1.91. However, in many areas cropping Intensity Is close to 3. Not only are most fields growing 2-3 crops per year but considering whole farms and the changing profitability of crops over time, numerous crops may be grown over a number of years on each farm. Hence, each farmer needs the skill, capability and machinery to grow a variety of crops. Costs of crop production are relatively high in Bangladesh reflecting inefficient use of Inputs and labor. This makes crop production vulnerable to collapses in market prices and to low cost imports.

The intensity of cropping results in periods of high labor demand, particularly around harvesting of one crop and establishment of the next. Family labor is often insufficient to meet these demands in a timely fashion. Lack of timely sowing will decrease the yield potential of crops. Service provision has been adopted to overcome labor constraints for threshing and tillage but not yet for planting.

**Emerging Trends**

Labor shortages have emerged as a major constraint to farming operations limiting farmers' capacity to carry out transplanting, weeding, harvesting and threshing in a timely fashion. The shortage of labor is reflected in the rising costs of day labor which has risen from 80 to 250 Taka per day. New technologies like herbicides have spread rapidly in Bangladesh to deal with labor shortages. Industry estimates and farmer surveys put the usage of herbicides in Boro rice at 80+ % of cropping area.

**Conservation Agriculture**

The form of cropping known as conservation agriculture (CA) involves minimum soil disturbance for placement of seed and fertilizer, retention of crop residues as a soil cover and diversifying crop rotations. Conservation agriculture is practiced on over 160 million hectares globally. There is still limited practice on small farms of CA especially in intensive crop rotations such as Bangladesh.

Since 2005, considerable research has been undertaken on developing CA for small farms in Bangladesh. Many research results confirm that for wheat, maize, pulses and oilseeds that sowing is feasible by mechanized planters with minimum soil disturbance. Even jute can be successfully established by machine sowing with minimum soil disturbance. Most of the planting has used strip planting where 3-5 cm width and similar depth of soil is disturbed to place seed and fertilizer while the remainder of the soil surface is undisturbed and crop residues are left standing.

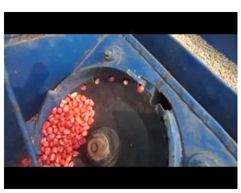
The most problematic crop to produce under continuous CA is rice. The traditional puddlings of soils for transplanting destroys soil structure and reverses benefits obtained when zero tillage or strip planting are used for the non-rice crops in the rotation. Direct dry seeding (DSR) of rice is a possible CA technology, but significant weed control constraints remain in the Aman season rice due to the variable rainfall in the early wet season that hampers the efficacy of weed control, in Boro season, cold temperatures hamper successful crop establishment of the early DSR.

Non-puddled transplanting (NPT) is an alternative minimum soil disturbance technology for CA rice establishment in Aman, Aus and Boro seasons. Minimum tillage NPT (MTNPT) may be practiced following strip tillage or by zero tillage on permanent beds or on flat land. In all cases, 18-24 hours flooding of soil needs to precede transplanting to soften soils.

Yields across a range of soils and seasons have shown that MTUPT with both manual and mechanized transplanting results in similar or higher rice yields than conventional puddling and transplanting.

**CA and Small Farm Machinery Development in Bangladesh**

Many types of 2-wheel tractor- operated CA planters have been developed or imported. Some of them are commercially available and in use by the Local Service Providers and small farmers.Several Bangladeshi companies are manufacturing the small farm machinery which shown in below.

| Planter type | | Main features |
|---|---|---|
| <br>BARI Bed planter | <br>BARI Minimum tillage planter | Strip till, Bed planter, zero tillage and PTOS :Value; Tk 60,000; weight 150 kg; vertical plate seed meter and fluted roller seed meter with fertilizer placement facility in single pass operation |
| <br>BARI Zero till planter | <br>BARI Strip Till planter | |

**Best Practices of Conservation Agriculture by Crop**

Best practices of conservation agriculture by crops in Bangladesh are as follows:

1. **Minimum Tillage Unpuddled Transplanting of T-Aman Rice Production**

This is a process of transplanting rice seedlings into soil with no or minimal disturbance. This rice seedling transplanting method is similar to puddled transplanting except that the soil is not fully tilled or puddled. Unpuddled rice transplanting can follow zero tillage, strip tillage, single pass shallow tillage or reshaping of permanent beds. The soil requires 18-24 hours inundation before transplanting. Unpuddled rice seedling transplanting is already practiced under zero or no tillage in many rice growing areas such as receding floodwater fields. However, the novel strip tillage-based unpuddled rice seedling transplanting system was first tested in Rajshahi, Bangladesh druing the boro season of 2008 More than 2,000 rice farmers have since evaluated and practiced the strip-tillage-based unpuddled transplanting of rice seedling in many districts of Bangladesh. Mechanized transplanting into minimum tillage unpuddled soils has been successfully demonstrated in different soil condition.

Establishment of rice with different minimum and reduced tillage unpuddled techniques:

**(i) Zero Tillage (ZT)**

a) In weed infested field, weeds should be controlled manually or by non-selective herbicide;

b) If the field is dry, apply irrigation water to inundate the fields for 24 hrs. to soften the soil sufficiently;

c) Apply all basal fertilizers prior to transplanting of rice seedlings;

d) Transplant rice seedlings raised in a nursery as in the puddled system, and

e) Subsequent management such as- weed control, application of irrigation water, fertilizer top dressing, disease and pest control, and other intercultural operations are similar to puddled rice transplanting.

**ii) Strip Tillage (ST)**

a) In weed infested fields, weeds should be controlled manually or by on-selective herbicide;

b) Use machine (such as VMP/STP/PTOS) to make 3-4 cm wide and 4-6 cm deep tilled strips. Adjust the strip distance based on recommended row spacing;

c) Apply the irrigation water to inundate the field before 24 hrs. of transplanting operation to soften the soil sufficiently;

d) Transplant rice seedling in the strip using same method of puddled system; and

e) Subsequent management such as-weed control, application of irrigation water, fertilizer top dressing, disease and pest control, and other intercultural operations are similar to pudddled rice transplanting.

**iii) Single Pass Shallow Tillage (SPST)**

a) In weed infested fields, weed should be controlled manually or by non-selective herbicide;

b) Use machine (such as PTOS/VSTP) to shallow-till entire field (up to 5 cm deep);

c) Apply the irrigation water to inundate the field before 24 hrs. of transplanting operation to soften the soil sufficiently;

d) Transplant rice seedling in the field using same method of puddled system; and

e) Subsequent management such as-weed control, application of irrigation water, fertilizer topdressing, disease and pest control, and other intercultural operations as used in the puddled rice transplanting.

**iv) Permanent Bed (PB)**

a) In weed infested fields, weed should be controlled manually, mechanically or by no-selective herbicide;

b) Use machine (such as VMP/Bed Planter) to reshape the PBs. Make 3-4 cm wide and 4-6 cm deep strips along both edges of the bed while reshaping the PB. Reshaping the PB could control some level of pre-transplanted weed.

c) Basal fertilizer can be banded in the strips of the PB by machine while reshaping.

d) Apply the irrigation water to inundate the beds for 24 hrs to soften the soil sufficiently;

e) Rice seedling transplanting method on top the beds is similar to puddled system;

f) Subsequent management such as – weed control, application of irrigation water, fertilizer topdressing, disease and pest control, and other intercultural operations as used in the puddled rice transplanting.

Following are the merits of minimum tillage unpuddled rice cultivation (comparison with conventional puddled rice seedling transplanting):

- Reduces cost of land preparation for rice cultivation up to 80%.
- Reduces diesel fuel use for land preparation up to 78%.
- Decrease labour requirements;
- Reduce turnaround time;
- Minimum tillage along with conservation agriculture (CA) practice, increases soil organic carbon in longer term.
- Decreases soil green-house gas emission by 16%.
- In most cases, rice grain yield is as similar or a bit higher compared to puddled transplanting; and
- Accelerates the adoption of CA in rice-based systems.

**Challenges of Minimum Tillage Unpuddled Rice Seedling Transplanting**

- Reluctance of farmers and labourers to transplant rice seedlings due to mindset, Some farmers do not believe that rice will grow in a minimum tillage unpuddled system until it has been demonstrated to them;
- Seedling transplanting by hand is more laborious and slower if the soil surface is hard;
- Weed infestation would be increased if weeds are not controlled before transplanting in which case labour requirement would be higher for post transplanted weed control.

### 2. Strip Tillage Planted in Rabi Crops and Cropping Pattern

Patterns are: Rice-wheat-mungbean, Rice-maize-mungbean, Rice-lentil-rice, Rice-wheat-jute, Rice-wheat- sesame.

Table 3. Differences of Crop Establishment between Conservation Agriculture System and Conventional Method

| Sl No. | Performance parameter | CA tillage system | Conventional system |
|---|---|---|---|
| 1 | Crop establishment | One pass direct seeding | Land prepared by 3-4 passes. Manual broadcasting |
| 2 | Seed rate | Optimum | More than recommended |
| 3 | Depth of planting | Uniform | Uneven |

| Sl No. | Performance parameter | CA tillage system | Conventional system |
|---|---|---|---|
| 4 | Irrigation water | Less water | Comparatively more |
| 5 | weeding | Comparatively easy | Difficult to control |
| 6 | Fertilizer application | During seeding operation | During land preparation and top dress application (2/3 split) |
| 7 | Turn around time | Minimum | 7-9 days required from first ploughing to seeding |

Source: Hossain *et al.* 2012

**Findings/ Benefit of smallholders' Conservation Agriculture in Rice-Based Systems**

Major advantages of the CA system are savings in labour, time, fuel and irrigation water. On-farm evaluations were carried out to test the implementation possibilities by farmers and to assess effects of yield, labour, input cost and profit (Haque *et al*., 2013b). Grain yield of wheat and mungbean was significantly higher in strip tillage compared to conventional full tillage (Table 4). Seed sowing in line at optimum moisture zone, banding basal fertilizers in strips, use of knock down herbicide (Roundup) ensured better crop stand and finally that contributed to grain yield in single pass strip tillage. Significantly higher grain yield (5.99 $tha^{-1}$of single pass strip tillage unpuddle boro rice and single pass strip tillage lentil (1.38 $tha^{-1}$ was recorded (data not shown) compared with CT puddled rice (5.74 t/ha) and CT lentil (1.00 t/ha). Tillage cost for land preparation was significantly lower in all crops where single pass strip tillage was used (Table 4). Although the use of Roundup in single pass strip tillage increased the total variable cost that was compensated by reduced cost of hand weeding in single pass strip tillage unpuddled rice (Haque *et al*., 2016b) and wheat. Significantly higher labour cost was recorded to transplant rice seedlings (Table 4) in single pass strip tillage unpuddled plots. The irrigation cost for all single pass strip tillage systems was significantly lower compared to CT. Total variable cost was significantly higher in rice under full tillage and puddled system. In single pass strip tillage wheat compared to full tillage; this variation was mostly due to excess use of tillage for land preparation in conventional methods.

Current on-farm practice of CA in Bangladesh is still limited. Rahman *et al.* (2017) reported that in 2013-14, about 440 hectares of crop was planted with strip tillage or zero tillage. Haque reported that Rabi season planting by CA principles using the VMP in the 2016-17 season was

1,500 hectares. In Durgapur Upazilla, where a concentration of effort on VMP promotion and extension has occurred in the last 5 years, 2016-17 Rabi season planting was 4.5 % of the total crop area. In three blocks, the CA planting reached 10-16 % of all Rabi season crops. Hence there is evidence of early adoption by farmers where there have been programme to build farmer confidence in the technology and the availability of the planters and LSP to provide planting services for farmers on a custom hiring basis.

A five-year field study was conducted at the Regional Wheat Research Centre, BARI, Rajshahi, Bangladesh to evaluate the performance of direct seeded rice (DSR) and transplanted rice in different tillage options. The minimum tillage unpuddled tillage treatments were i) zero in flat, ii) strip in flat, iii) strip tillage on top of the bed with transplanted rice (TPR), and compared to iv) single pass shallow tillage (SPST) with unpuddled transplanting and with puddled transplanted rice as conventional practice . In all treatments we used 30% straw retention (SR) from all previous crops. There was no significant grain yield difference among the treatments up to three years but after four years higher grain yieldwas found from 30% straw retention with strip till DSR and unpuddled TPR in raised bed system over other treatments. Lower yield was found from zero tillage with DSR due to lower plant population with seeding problem. Conventional tillage with 30% SR also produced similargrain yield compared to DSR strip and raised bed with 30% SR. In on-farm validation and up-scaling trials, we used four treatments like unpuddled TPR both strip and raised bed, unpuddled DSR with strip and conventional puddled TPR in three drought prone areas. Maximum rice grain yield was found from unpuddled TPR in strip tillage followed by unpuddled raised bed compared to conventional puddled. Lower grain yield was also found from DSR in strip tillage and farmers' practice. Soil organic matter in surface soil layers of the PRB had increased by 0.72% after 12 years (12 rice-wheat-mungbean crop cycles) with 30% straw retention. Compared with all on-farm trials, unpuddledstrip tillage TPR was the best performer compared to unpuddled TPR in raised bed and conventional puddled. But in on-station trials DSR in strip tillage was similar to puddled TPR in raised bed with both 30% residues over conventional puddled without residue retention. Considering all trials, unpuddled TPR on strip till with 30% residue retention appears to be a very promising technology for sustainable intensification of RW systems in Bangladesh.

A twelve years long term bed planting field experiment was conducted to study the productivity, soil fertility and N-use efficiency of intensified RW systems by adding a third pre-rice crop of mungbean. System productivity, fertility and N use efficiency were evaluated under five N fertilizer levels (0, 40, 80, 100 and 120 % N of recommended dose, two straw retention (SR) (0 and 30%) and two tillage options (raised bed and conventional tillage practice (CTP). Permanent beds with 30% straw retention produced the highest productivity for all three crops in the sequence. Within each N rate the total system (rice-wheat-mungbean) productivity was higher with 30% SR on PRB and least in CTP with 0% SR. At 80% of recommended fertilizer N rate, mean annual system productivity was 12.5 t/ha for PRB with 30% SR, 11.2 t/ha with PRB on 0% SR and 10.3 t/ha with CTP without straw. N uptake and use efficiency were increased with increasing N levels with bed planting up to 120% N application (120 kg N $ha^{-1}$) in wheat, both 100% (80 kg N $ha^{-1}$) in rice and (20 kg N $ha^{-1}$ ) in mungbean for all years. System productivity in N unfertilized plots increased when straw was retained due to increased supply and uptake of N. The results suggest that N fertilizer rates can be reduced when 30% straw is retained both from rice and wheat & full residue retention from mungbean. Soil organic matter in surface soil layers of the PRB had increased by 0.78% after twelve years (12 rice-wheat-mungbean crop cycles) with 30% SR. Straw retention is an important component of soil management and may have long term positive impacts on soil quality compared with conventional tillage with 0% SR. The combination of PRB with nutrients and residues retained appears to be a very promising technology for sustainable intensification of RW systems in Bangladesh.

**Long-term Impact of Conservation Agriculture**

Soil puddling for transplanting rice seedlings is the key obstacle to conservation agriculture (CA) for intensive rice-based cropping systems. A novel solution to this challenge is strip planted non-puddled rice seedling transplanting (NPT) (Haque *et al*., 2016b). Long term trends with CA following the use of NPT were assessed at two long-term experiments at Durgapur (E1) and Godagari (E2) in Rajshahi district since 2010, and another at Mymensingh district since 2012 (E3). Three tillage practices: strip planting (SP including NPT), bed planting (BP) and conventional tillage (CT) at E1 and E2; and either SP or CT at E3. All experiments had low current and increased residue retention levels. Cropping sequences were lentil/mustard-mungbean/jute/irrigated rice-monsoon rice (for E1); wheat /chickpea-mungbean/early wet season rice/jute-monsoon rice (E2; and wheat-mungbean-monsoon rice (E3). The VMP was used for establishing all upland crops (lentil, mustard, chickpea, early wet season rice & mustard) in single pass operation for SP and BP, however, 3-4 tillage operations by 2-WT followed by hand-broadcast seeding and fertilizing were done for CT. In case of irrigated and rainfed rice, NPT were practiced in SP and BP; and for CT conventional puddling was followed. Significantly higher grain yields and higher net return for all upland crops were recorded in SP in all sites compared to BP and CT. In the first two years, there had no significant variation in rainfed rice yield using NPT between the tillage systems. Thereafter, significantly higher grain yield of rainfed rice in NPT was recorded in SP. However, since beginning, the SP plots showed greater profit margin of irrigated NPT.

**Some research findings from long term CA experiment in rice-wheat-mungbean cropping pattern were discussed in the following:**

**1. Total system productivity (TSP)**

System yields on CA based technology consistently increased as straw retention (SR) increased from 0% to 30%, but the differences between 0% and 30% SR were always significant for all three crops. TSP increased about 10-12% for all crops in 30% straw retention with permanent bed planting system over conventional (Fig. 1). TSP of rice, wheat and mungbean (R-W-M) was 12 t ha/ year. Yields tended to be lower in lower levels of straw retention for all crops. Lower system productivity also occurred from 0% SR with CTP due to reduced crop growth. Similar observations were made by Singh *et al.,* (2003) in Mexico.

**2. Environmental impact**

RCTs perform better with minimum disturbance of soil. Soil erosion was comparatively less compare to conventional method. Fuel used both conventional and reduced tillage system was showed in Table 1. 54 litre/ha/year diesel used for PRB system where 96 litre/ha/year used in conventional method. PRB tillage system saved 42 litre/ha/year of costly diesel fuel which 44% less emission of $CO_2$ into the atmosphere (Witt *et al.* 2002).

**3. Changes of soil organic matter (SOM)**

After 13 years (2004 to 2015), increased organic matter by 0.78% (Table 2) from 30% SR both rice and wheat straw and full residue retention from mungbean crops with PRB system into the soil. Also P, K, S, Zn, B availability increased from 30% SR both rice and wheat straw and full residue retention from mungbean crops. Increase in soil organic C with 30% SR at 50-150% N was almost double that with 0% N. Kumar and Goh (2000) reported that, in the longer term, residues and untilled roots from crops can contribute to the formation of SOM. It is clear that further increases in the productivity of the RW system will depend on proper management of residue.

Therefore, in conclusion, 30% straw retention from wheat & rice and full residue retained from mungbean crops under permanent beds were the best combination for getting higher productivity as well as improve soil fertility with increase microbial activities. Compared with all treatments, the raised bed system with residue retained appears to be a very promising technology for sustainable intensification of RW systems in Bangladesh

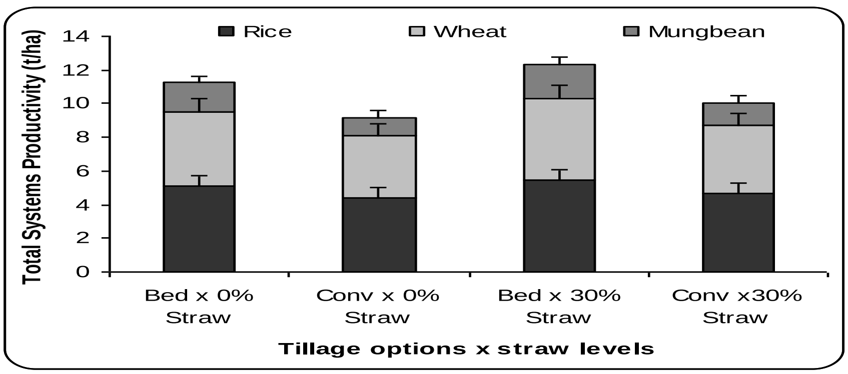



Table 4. Chemical properties changes after 12 years crop cycles

| Tillage options | Diesel used (litre/ha/year) | $CO_2$ emission (kg/ha/year) | Less $CO_2$ emission (%) | Fuel saved (litre/ha/year) |
|---|---|---|---|---|
| PRB | 54 | 140.4 | 44 | 42 |
| Conv. | 96 | 249.6 | - | - |

Table 5. Chemical properties changes after 12 years crop cycles

| Characteristics | Initial | Final | Difference |
|---|---|---|---|
| Organic Matter (%) | 0.90 | 1.62 | + 0.78 |
| Total N (%) | 0.12 | 0.19 | + 0.07 |
| Exch. K (ml eq/100g soil) | 0.26 | 0.48 | + 0.22 |
| Avail. P (mg / g soil) | 24.5 | 52.5 | + 38.0 |
| Avail. S (mg / g soil) | 25.6 | 38.9 | + 13.3 |
| Avail. Zn (mg/g soil) | 0.84 | 6.13 | + 5.29 |
| Avail. B (mg /g soil) | 0.19 | 0.37 | + 0.18 |

Table 6. Physical properties changes after 12 years crop cycles

| Tillage options | Bulk density ($mgm^{-3}$) | | | Infiltration rate ($cmh^{-1}$) | Total pore space (vol.%) |
|---|---|---|---|---|---|
| | 0-10 cm | 10-20 cm | 20-30 cm | | |
| Bed | 1.37 | 1.59 | 1.74 | 0.85 | 53-59 |
| Conv | 1.57 | 1.79 | 1.95 | 0.59 | 43-48 |
| LSD(0.05) | 0.037 | 0.025 | 0.034 | 0.032 | NS |

Source: Hossain *et al.* 2012

**Zero Tillage Unpuddled Boro Rice Transplanting**

Unpuddled transplanting (UPT) is an alternative minimum tillage technology for CA rice establishment in Aman, Aus and Boro seasons. Minimum tillage UPT (MTUPT) may be practiced following strip tillage or by zero tillage onto permanent beds or on flat land. In all cases 18-24 hours flooding of soil needs to precede transplanting to soften soils. Yields across a range of soil and seasons have shown that MTUPT results in similar or higher rice yields than conventional puddling and transplanting.

**Dissemination of CA based technology for sustainable crop production in Bangladesh**

The dissemination activities have been implemented in Regional Wheat Research Centre, BARI, Shyampur, Rajshahi from 2003 with the help of CIMMYT Bangladesh and Cornell University, USA with three objectives: (i) Assessment and prioritization of the constraints to, and opportunities for uptake of improved management options under raised bed systems, (ii) Conducting demonstration trials on raised bed system in farmers' fields and (iii) Dissemination of raised bed technology through capacity building and innovative extension methods. Under the objective 3, several on-farm trials on under strip tillage, bed planting system and conventional practices on different existing crops like rice, wheat, mungbean, potato, lentil, chickpea, black gram, maize, jute, okra, cabbage, cauliflower, red amaranth, reddish etc were produced with the principles of CA. These experiments are being continued in four district in Rajshahi region like Rajshahi, Natore, Pabna and Chapainababgonj district with 28 Upazila. From 2003-04 to 2018-09 seasons, 1275 farm trials are being conducted with 420 trainings of farmers and operator, and 42 tillage service providers. Power tiller with CA planter loaned 35 operators from RDA and 12 manufacturer assisted by RWRC, BARI. From 2009 to still up to 22750 farmers were exposed under CA based technology.  In the 2013-14 seasons, at least 16 crops were tested under raised bed system.

From 2003 to 2016 at least 6615 hectares land under CA based system among 22750 farmers. All dissemination trials compared with farmers own technology. Among them, all trials were significantly higher grain yield from farmers own practices. Grain yield of wheat was 10-25 % higher, lentil was 25% higher, other crops were at least 15-20% higher over farmers own technology. Some of these experiments are permanent while some are conducted for at least 13 seasons. Crop growth and development in these trials feedbacks are encouraging and farmers are expecting clear benefits from raised bed technology.

The dissemination activities have been implemented in RWRC, BARI, Shyampur, Rajshahi from 2003 with three objectives: (i) Assessment and prioritization of the constraints to, and opportunities for uptake of improved management options under raised bed systems, (ii) Conducting demonstration trials on raised bed system in farmers' fields and (iii) Dissemination of raised bed technology through capacity building and innovative extension methods. Under the objective 3, several on-farm trials on under bed planting system on different existing crops like rice, wheat, mungbean, potato, lentil, chickpea, black gram, maize, jute, okra, cabbage, cauliflower, red amaranth, reddish etc crops were produced with the principles of CA are being continued in four district in Rajshahi region like Rajshahi, Natore, Pabna and Chapainababgonj district with 18 Upazila. From 2003-04 to 2016-17 season conducted 2375 on farm trials, trainings of farmers and operator were 420, and tillage service provider was 42. Power tiller with bed planter loaned 35 operators from RDA and 12 manufacturer assisted by RWRC, BARI.  From 2009 to still up to 19750 farmers were exposed under raised bed technology.  In the 2016-17 seasons, at least 16 crops were tested under raised bed system.

From 2003 to 2016 at least 6375 hectares land under this system among 19750 farmers. All dissemination trials compared with farmers own technology. Among them, all trials were significantly higher grain yield from farmers own practices. Grain yield of wheat and maize were 10-25 %, mungbean&lentil were20-25% higher, other crops were at least 10-15% higher over farmers own technology. Some of these experiments are permanent while some are conducted for at least 5 crop seasons. Crop growth and development in these trials is good and farmers are expecting clear benefits from raised bed technology.

Table 6. Crop wise area coverage under bed planting system from 2003 to 2016

| Crops | 2003 | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wheat | 6 | 25 | 180 | 375 | 785 | 1020 | 1540 | 2160 | 2975 | 3545 | 3925 | 4260 | 4350 | 4470 |
| Mungbean | 6 | 25 | 75 | 120 | 155 | 210 | 375 | 575 | 625 | 675 | 710 | 785 | 854 | 890 |
| Maize | 6 | 10 | 45 | 120 | 210 | 240 | 350 | 450 | 475 | 525 | 595 | 645 | 720 | 785 |
| Sesame | | | | 2 | 5 | 15 | 25 | 30 | 40 | 45 | 50 | 60 | 75 | 82 |
| Lentil | | | | | 2 | 5 | 7 | 12 | 15 | 25 | 35 | 45 | 60 | 75 |
| Okra | | | | | | 1 | 3 | 5 | 15 | 21 | 30 | 35 | 40 | 45 |
| Radish | | | | | | 4 | 5 | 5 | 8 | 12 | 15 | 15 | 25 | 28 |
| Total | 18 | 60 | 300 | 617 | 1157 | 1495 | 2305 | 3237 | 4153 | 4848 | 5360 | 5845 | 6124 | 6375 |

They have several benefits from this technology, such as:

-yield increase up to 5-20% on cereal crops, 15-35% on pulse crops and 10-20% on other crops

-Save water 25-30%, nitrogen fertilizer save 10-15%, less rat damaged with less lodging, Management easy with less labor and less water logging and mitigate to help drought situation.

In keeping view of these observations and the objectives and goals of the project, more pulse crops will be designed and implemented in the coming seasons and years upon consultation with the project partners and farmers involved in the project.

In 2012, the project put special emphasis on improving the multi-crop planters with active involvement of BARI scientists and local manufactures, and by considering the feedback received from the innovative farmers. The new prototype of 2 WT operated multi-crop planter (with inclined plate seed metering system) is near to perfect and available for commercial production for multi-crop planting. After making significant improvements in the multi-crop planter the necessary modifications were made in the existing planters and seeders owned by the FFP project partners, and also new planters were purchased for some of locations and partners.


Figure1.Year wise crops distribution in Rajshahi region

Farmers got several benefits from CA base technology, such as;

- Yield increase up to 5-20% on cereal crops
- 15-35% on pulse crops and 10-20% on other crops
- Save water 25-30%
- Nitrogen fertilizer save 10-15%
- Less rat damaged with less lodging.
- Crop management easy with get border effect
- Less labor and less water logging and
- Mitigate to help drought situation.

In 2012, given special emphasis on improving the multi-crop planters with active involvement of BARI scientists and local manufactures, and by considering the feedback received from the innovative farmers. The new prototype of 2 WT operated multi-crop planter (with inclined plate seed metering system) is near to perfect and available for commercial production for multi-crop planting. After making significant improvements in the multi-crop planter the necessary modifications were made in the existing planters and seeders owned by the FFP project partners, and also new planters were purchased for some of the locations by stakeholders.

In objective 4, capacity building and training for the researchers and field staff of the project, and farmers and service providers has remained continuing the activities. The project organized several farmers' field days, farmers' motivational visits and training activities for farmers, service providers, extension workers, and researchers at the project districts as part of capacity building activities. From the year 2003 to current Rabi season, special emphasis has been given for the extension and dissemination of the promising CA based technologies.

**Challenges in Up Scaling Conservation Agriculture**

Major challenges are to encourage private sector investment scaling up these technologies for the end users. Build up a mechanism for available appropriate CA implements and tools at an affordable price to farmers. Training programs are needed for different level of workers, considering the advantages of conservation agriculture. Moreover, policy support is necessary for further acceleration of these technologies among the users.

Conservation agriculture as an upcoming paradigm for raising crops will require an innovative system perspective to deal with diverse, flexible and context specific needs of technologies and their management. Conservation agriculture R&D (Research and Development), thus will call for several innovative features to address the challenge. Some of the examples are:

(a) Understanding the system – Conservation agriculture systems are much more complex than conventional systems. Site specific knowledge has been the main limitation to the spread of CA system (Derpsch, 2001). Managing these systems efficiently will be highly demanding in terms of understanding of basic processes and component interactions, which determine the whole system performance. For example, surface maintained crop residues act as mulch and therefore reduce soil water losses through evaporation and maintain a moderate soil temperature regime (Gupta and Jat, 2010). However, at the same time crop residues offer an easily decomposable source of organic matter and could harbor undesirable pest populations or alter the system ecology in some other way. No-tillage systems will influence depth openetration and distribution of the root system which will influence water and nutrient uptake and mineral cycling. Thus, the need is to recognize conservation agriculture as a system and develop management strategies.

(b) Building a system and farming system perspective – A system perspective is built working in partnership with farmers. A core group of scientists, farmers, extension workers and other stakeholders working in partnership mode will therefore be critical in developing and promoting new technologies. This is somewhat different than in conventional agricultural R&D, the system is to set research priorities and allocate resources within a framework, and little attention is given to build relationships and seek linkages with partners working in complementary fields.

(c)Technological challenges – While the basic principles which form the foundation of conservation agriculture practices, that is, no tillage and surface managed crop residues are well understood, adoption of these practices under varying farming situations is the key challenge. These challenges relate to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance, developing crop harvesting and management systems.

(d) Site specificity – Adapting strategies for conservation agriculture systems will be highly site specific, yet learning across the sites will be a powerful way in understanding why certain technologies or practices are effective in a set of situations and not effective in another set. This learning process will accelerate building a knowledge base for sustainable resource management.

(e) Long-term research perspective – Conservation agriculture practices, e.g. no-tillage and surface-maintained crop residues result in resource improvement only gradually, and benefits come about only with time.

Indeed in many situations, benefits in terms of yield increase may not come in the early years of evaluating the impact of conservation agriculture practices. Understanding the dynamics of changes and interactions among physical, chemical and biological processes is basic to developing improved soil-water and nutrient management strategies (Abrol and Sangar, 2006). Therefore, research in conservation agriculture must have longer term perspectives.

(f) Weeds are a major challenge in smallholder cropping systems. Eliminating tillage sometimes increases weed pressure in the early years of CA adoption, but weeds decrease over time if controlled well. Many adaptations of CA use herbicides to control weeds.

Among farmers in Central Asia, researchers have identified several constraints to the adoption of conservation Agriculture among smallholders including: (i) weed control; (ii) competing uses for crop residues and uncontrolled grazing of residues left in the field; (iii) lack of dedicated forage and fodder crops and (iv) absence of machinery for crop establishment without tillage. Similar problems could be anticipated in the smallholder rain-fed systems of South Asia Region.

However, the limitation of conservation agriculture is a site specific, community- based and agro-ecological specific which may not have a blue-print for replication. The success or failure of conservation agriculture depends greatly on the flexibility and creativity of the practitioners and extension and research services of a region.

( g) Mind set up of high agricultural officials are not much favor convincing these CA tillage technologies. Limited investments of local manufacturers to scale-up production linked with uncertain CA machinery demand. The great numbers of resource poor smallholder farmers are not an attractive potential client group of machinery manufacturers; infrastructure and distribution channels of products are little developed. High price of machinery and low prices of agricultural produce discourage investments in agriculture, including machines and tools. Financial organizations are not much friendly to farmers in terms of reducing rate of interest and price installments. Absentee farmer and small landholder feel risk about crop failure with new technology. Additional learning is more comparing to conventional system. Research - extension- farmers linkage is not well established about these CA technologies transfer. Direct seeding rice is not yet in good shape in terms of weed management.

**Factors limiting the adoption of CA in Bangladesh**

So far, no studies have been identified the factors limiting adoption in Bangladesh apart from the practice of non-puddled transplanting.

However, from group discussions and informal discussions with key informants, the main factors are as follows:

- Rice establishment in puddled soil
- farmers' strong belief is the necessity of ploughing and leveling, based on conventional practices;
- peer pressure from neighbors to continue ploughing and/or puddling and leveling so that fields look well prepared;
- concern that machine planting will not produce satisfactory crop populations
- concern about lower yield;
- investment cost of machinery purchase;
- concern that residues from herbicides may harm following crops;
- integration of root crops in the cropping rotation requires tillage to plant and harvest;
- perceived difficulty of controlling hard-to-kill weed without soil disturbance; and
- Environmental and health concerns about the effects of herbicides on and off site.

**Potential for Future Conservation Agriculture Research and Development**

The direction that Asian countries take to meet their food and energy needs during the coming decades will have profound impacts on natural resource bases, global climate change and energy security for South Asia and the world. These challenges draw attention to the need and urgency to address options by which threats to Asian agriculture due to natural resource degradation, escalating production costs and climate change can be met successfully. A shift to no-till conservation agriculture is perceived to be of much fundamental value in meeting these challenges. Asian farmers/researchers will continue to need assistance to reorient their agriculture and practices for producing more with less cost through adoption of less vulnerable choices and pathways. The promotion of CA under Bangladeshi context has the following prospects

Reduction in cost of production – This is a key factor contributing to rapid adoption of zero-till technology. Most studies showed that the cost of wheat production is reduced by Rs. 2,000 to 3,000 (US$ 33 to 50) per hectare (Malik *et al*., 2005). Cost reduction is attributed to savings on account of diesel, labour and input costs, particularly herbicides.

Labor shortage- Labor shortage is increasing day by day in Bangladesh which is increasing production cost of any crops. This is burning issue now in Bangladesh and labor wages also high of field crop production. But CA practices reduce labor cost about 30-50% on crop basis.

Saving in water and nutrients – Limited experimental results and farmers experience indicate that considerable saving in water (up to 20% – 30%) and nutrients are achieved with strip-till planting and particularly in laser leveled and bed planted crops. Haque *et al.* (2007) stated that higher soil water content under no-till than under conventional tillage indicated the reduced water evaporation during the preceding period. They also found that across growing seasons, soil water content under no-till was about 20% greater than under conventional tillage.

Increased yields – In properly managed CA based planted wheat, yields were invariably higher compared to traditionally prepared fields for comparable planting dates. CA has been reported to enhance the yield level of crops due to associated effects like prevention of soil degradation, improved soil fertility, improved soil moisture regime (due to increased rain water infiltration, water holding capacity and reduced evaporation loss) and crop rotational benefits. Yield increases as high as 200 – 500 kg/ha are found with no-till wheat compared to conventional wheat under a rice-wheat system in the Indo-Gangetic plains (Hobbs and Gupta, 2004). Review of the available literature on CA provides mixed indications of the effects of CA on crop productivity. While some studies claim that CA results in higher and more stable crop yields (African Conservation Tillage Network, 2011), on the other hand there are also numerous examples of no yield benefits and even yield reductions particularly during the initial years of CA adoption.

Environmental benefits – Conservation agriculture involving zero-till and surface managed crop residue systems are an excellent opportunity to eliminate burning of crop residue which contribute to large amounts of greenhouse gases like $CO_2$, $CH_4$ and $N_2O$. Burning of crop residues, also contribute to considerable loss of plant nutrients, which could be recycled when properly managed. Large scale burning of crop residues is also a serious health hazard.

Crop diversification opportunities–Adopting a Conservation Agriculture system offers opportunities for crop diversification. Cropping sequences/rotations and agro forestry systems when adopted in appropriate spatial and temporal patterns can further enhance natural ecological processes. Limited studies indicate that a variety of crops like mustard, chickpea, pigeon pea, sugarcane, etc., could be well adapted to the new systems.

Resource improvement – No tillage when combined with surface management of crop residues begins the processes whereby slow decomposition of residues results in soil structural improvement and increased recycling and availability of plant nutrients. Surface residues acting as mulch, moderate soil temperatures, reduce evaporation, and improve biological activity.

Bangladesh is posed to begin adopting CA across a range of cropping systems, including those incorporating rice.

Research and development is needed to further refine CA packages and adapt them to different regions. Benefits from increased adoption of CA by farmers are primarily reduced cost of crop production (input-output), more timely sowing and water savings.

Government policies to create an enabling environment will accelerate the adoption by farmers and create incentives for the private sector to take a lead role in commercialization of CA through mechanization.

## Conclusions

Conservation agriculture offers a new paradigm for agricultural research and development different from the conventional one, which mainly aimed at achieving specific food grains production targets in Bangladesh. A shift in paradigm has become a necessity in view of widespread problems of resource degradation, which accompanied the past strategies to enhance production with little concern for resource integrity. Integrating concerns of productivity, resource conservation and soil quality and the environment are now fundamental to sustained productivity growth. Developing and promoting CA systems will be highly demanding in terms of the knowledge base. This will call for greatly enhanced capacity of scientists to address problems from a systems perspective; be able to work in close partnerships with farmers and other stakeholders and strengthened knowledge and information-sharing mechanisms. Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. "Conserving resources – enhancing productivity" has to be the new mission in Bangladesh.

Farmers accept conservation agriculture based tillage technologies considering the advantages of higher yields, reduced cost of tillage operation, and minimum turnaround time between the crops. Upland crops are more suitable under these tillage technologies. Most of the tillage implements are operated by imported Chinese two wheel tractor (power tiller). Minimum tillage seed drill, raised bed planter, zero till drill and strip till drills are being used in CA activities. Farmers started adopt the CA technologies, especially raised bed planting, strip tillage and minimum tillage technology. Weed management in rice cultivation is not yet in a good shape. Area coverage under bed planting, strip tillage and minimum tillage system are 6325, 4525 and 21850 ha, respectively. There is a big prospect accelerating the CA based tillage technology in the farmers' field as irrigation water availability becoming limited or more costly with labor shortage. Mind setup is the big issue for adopting CA tillage technology. Training and multi disciplinary approaches can push forward these tillage technologies ahead.

### Recommendations

Bangladesh is poised to begin adopting CA across a range of cropping systems, including those incorporating rice. Research and development is needed to further refine CA packages and adapt them to different regions. Benefits from increased adoption of CA by farmers are primarily reduced cost of crop production (input savings), more timely sowing and water savings. Government policies to create an enabling environment will accelerate the adoption by farmers and create incentives for the private sector to take a lead role in commercialization of CA through mechanization.

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# Best Practices of Conservation Agriculture in India

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## Introduction

Sustainable intensification of agriculture to meet food, nutritional and environmental security depends heavily on efficient management of natural resources mainly land and water. India, presently, supports 18% of the world's human and 15% livestock population with only 2.4% of the land mass and 4.2% fresh water resource. There is tremendous demographic pressure on finite land and water resources to attain the projected demand of 400 MT food grains by 2020 with required annual growth rate of 3 to 4 % in agriculture sector. Although Green Revolution has played a major role in increasing food grain production in the country by about fourfold, concerns has been raised about sustainability of crop production owing to widespread natural resources degradation,. Adoption of extensive tillage, faulty agricultural practices, imbalance use of chemical fertilizers, low addition of organic matter, burning of crop residue, over exploitation of groundwater resources have been identified as the possible reasons for such deterioration. It is, therefore, important to provide solutions to manage degradation of natural resources, especially soil and water with the goal of increasing resilience of the farming systems to sustain higher agricultural productivity in the country. It has been amply demonstrated that conventional crop production technologies are not cost effective (Jat *et al*., 2014), less water efficient (Bhushan *et al*., 2007) and cause decline in soil health (Jat *et al*., 2013). Conservation agriculture (CA) with its key principles (reduced tillage, crop rotations, permanent soil cover and controlled traffic) together with other best management practices (BMP) have immense potential to enhance systems productivity alleviating environmental and management constraints (Sommer *et al*., 2007; Hobbs *et al*., 2008). Earlier studies showed that CA based management practices are effective for increasing crop and water productivity, and economic sustainability in different cropping systems (Jat *et al*., 2013, 2014; Das *et al*., 2014). These factors forced to pursue diversified crops and cropping systems, which are not only environmental friendly, but also efficient in conserving natural resource pool (Aulakh and Grant, 2008).

## Agriculture Scenario in India

Agriculture plays a predominant role in the growth of Indian economy. Over 70% of the rural households depend on agriculture contributing about 17% to the total GDP and provides employment to over 60% of the population. Agricultural incomes are not only lower but the growth rate is also slower than in other sectors. The growth rate in agricultural sector is at a rate of 2.7%, as compared to about 10% in both service and industry sector, in the recent times. Furthermore, Indian population has tripled in the last 40 years but food grain production quadrupled and 78% of the farmers cultivate less than 2 ha. To meet the demands of increasing population most of the productive land and water is diverted to other uses like industries and residential. Hence, achieving food security and meet the increasing demand of meat, eggs, milk, fruits and vegetables for the burgeoning population with less land, water and labor is a gigantic task. In addition to meeting the food requirement the other major concern is to enhance the sustainability of natural resources and improve productivity.

India is blessed with diversified agro-ecology with as many as 127 zones under five agro-ecosystems such as rainfed, arid, irrigated, coastal and hill systems. The current net cultivated land area of India is about 142 million ha which produces 526 million MT of agricultural produce comprising food grains, pulses, oilseeds, cotton, jute, sugarcane, etc. The cropping intensity is around 133%. The total production of rice, wheat, coarse cereals, pulses and oil seeds in 2016-17 is estimated to be 108.86, 96.64, 44.34, 22.14 and 33.6 MT respectively and India is second largest producer of wheat, rice, sugar, groundnut and inland fish. India is largest producer for milk, pulses, cashew nuts, coconuts, tea, ginger, turmeric and black pepper in the world. The total horticulture production of the country is estimated to be around 286 million tonnes during 2015-16 which is 2% higher than the previous year. Production of fruits, vegetables, spices is estimated to be 90, 169 and 7 million tonnes which is 1%, 1.5%, 14% higher than the previous year. It may be noted that India is home to 10% of the world fruit production with first rank in the production of fruits like banana and sapota.

India ranks first among the rainfed agricultural countries of the world in terms of both extent and value of produce. Rainfed agriculture is dominated by small and marginal farmers with land holdings of ~ 0.6 ha. However, it contributes to nearly 40% of the national food basket and supports nearly 40% of population. In India, rainfed agriculture productions systems accounts for 55, 91, 90,85,65 per cent of rice, coarse grains, pulses, oilseeds and cotton respectively. This indicates the importance of rainfed agriculture in the country. The annual rainfall varies for 400 mm to 1000 mm. The rainfall is characterised by uneven distribution and highly uncertain and erratic. Hence a significant fall in food production is often noticed due to the low productivity of many rainfed crops which is about 1.0 t/ha although many studies have showed higher productivity up to 1.6 to 2.0 with the existing technologies. Besides droughts, land degradation (mostly affected due to water erosion), poor soil health (Stoorvogel and Smaling, 1990), nutrient stress (Srinivas Rao *et al*., 2009), and poor crop management contribute to low productivity in rainfed crops.

## Conservation Systems in Predominant Cropping Systems

According to current estimates, CA systems are being adopted in around 125 million ha worldwide, largely in rain fed areas and the area is expanding rapidly. While in India, CA is a new concept and its roots are only now beginning to find ground. Efforts to promote zero tillage in India were started in the 1980s by Imperial Chemical Industries Limited of U.K. in wheat. CA technologies in India are spreading mostly in the irrigated areas of the Indo-Gangetic Plains (IGP) where rice-wheat cropping system dominates. CA systems have not yet taken roots in other rainfed, semi-arid tropics, arid and mountainous agro-ecosystems. In India, the conservation agriculture practices with three principles are not being practiced in letter and spirit by the farmers. Few RCTs like zero tillage, mulching is independently followed by the farmers since past 6-8 years particularly in the IGP under the aegis of the Rice-Wheat Consortium. But there is potential to improve the crop productivity with CA technologies in the Northern and Eastern IGP, black soil belts of central plateau, Odisha-upland systems, Coastal high rainfall regions and rainfed regions Efforts are being made to develop location specific CA practices to popularize such technologies in those areas.

### *Rice based cropping system*

Rice, wheat and maize are the three important cereal crops in India. They are either grown as sole crops or in sequence. In irrigated and favorable rainfed lowland areas, rice-rice, rice-wheat and rice-maize are common cropping systems (Table 1). Rice-rice is also a predominant cropping system in south India and in subtropical areas with mild cool winter as in eastern India. The rice-wheat rotation is one of the largest rice based cropping system, occupying 13 million ha in the Indo-Gangetic Plains (Ladha *et al*., 2003). This system contributes to more than 30% of the area of both rice and wheat grown in the region and 70% of total cereal production in India (Singh and Kaur, 2012). This system meets the food requirement of more than one billion people. The major rice-wheat growing Indian states in IGP region are Punjab, Haryana, Uttar Pradesh, Himachal Pradesh, Bihar and West Bengal (Table 2). Some of the RCTs that are being promoted in the rice-wheat belt of the Indo-Gangetic

Plains are: laser land levelling, zero/reduced tillage in wheat, direct seeded rice, bed planting, rotary tillage, use of leaf colour chart, mechanical rice transplanter, system of rice intensification, surface seeding, new varieties that use nitrogen more efficiently. Presently 25% – 30% of wheat is zero-tilled in rice-wheat growing areas of the Indo-Gangetic plains of India. A few machineries namely zero-till seed-cum fertilizer drill, strip till drills, roto till drill, till planter, happy combo seeders have been developed for direct drilling of wheat after paddy. In addition to ZT, other resource conservation interventions like raised-bed planting systems, laser equipment aided land levelling, residue retention and crop diversification need to be introduced in the system to enhance and sustain agricultural productivity. Crop diversification in R-W system through intercropping with legumes, relay cropping, introducing mungbean or cowpea as a summer crop, brown manuring may be explored (Table 3).

***Maize based cropping systems***

In India, maize is grown in diverse ecologies and seasons on an area of 8.71 M ha with production of 22.26 MT (GoI, 2015). India rank is 4$^{th}$ in maize area in the world. Maize grain is mainly utilized for feed (63%), food (23%) and industrial purpose (13%) in the country. In the past, maize was tested as an alternate crop to rice with conventional management practices in rice-wheat system, but it was found uneconomical due to its lower yield and market price. However, in recent years, maize has witnessed increased production and productivity growth with the introduction of single cross high yielding and energy-use efficient maize hybrids. Presently Maize – wheat is the 5$^{th}$ dominant cropping system of India covering 1.8 Mha with 2.3% contribution in food basket (Jat *et al*., 2011). In the north-western Indo-Gangetic plains (IGP) maize is commonly grown in rotation with wheat, chickpea, mustard and winter maize. Rice-maize can be cultivated in all regions but is most popular in south Indian states namely Andhra Pradesh, Tamil Nadu, Karnataka and partly in Bihar and West Bengal with an-acreage of more than 0.5 Mha (Table 4). In Andhra Pradesh, zero till maize has picked up rapidly (Jat *et al*. 2009). The adoption of shorter duration maize hybrids compared to rice could be a better option under this situation to reduce over exploitation of natural resources, the production costs and minimize adverse environmental impacts (Ladha *et al*., 2009; Jat *et al*., 2009; Saharawat *et al*., 2012). Thus, maize – wheat cropping system can be a possible alternative of rice – wheat under IGP tracts of India mainly due to lower water requirement, higher productivity of wheat crop by its timely sowing and better soil health as compared to rice – based cropping system. The diversification of RW systems with maize-based systems with conservation agriculture practices could help to enhance the system productivity, sustain soil health, environmental quality, and save irrigation water and labour costs (Aulakh and Grant, 2008), provide palatable fodder and meeting increased demand of maize grains from piggery and poultry industries.

***Agroforestry systems***

Agroforestry and horticulture crops provide many value-added products, particularly in tropical regions. India has diversified climates right from temperate to tropical climates. Hence all kinds of perennial horticultural crops including tropical, subtropical and temperate fruits and nut, palms, beverage crops, tree spices and medicinal trees can be cultivated. However, the productivity of fruit crops is declining gradually in India. The major reasons for low productivity in fruits are decline in soil organic matter, increased weed and pest infestation and nutrient mining. Conservation agriculture can reverse this trend and bring back ecosystem stability. Growing legumes as intercrops and integrating livestock component in agroforestry system improves the productivity of tree crops. The establishment of legume cover crops/leguminous grasses in orchards is the most suitable soil management practice for soil conservation, preservation of environment, reduction of production costs and enhancement of quality of fruits. Alley cropping is one innovation that offers productivity, economic and environmental benefits to producers. Another intervention is the use of varying densities of "fertilizer trees" that enhance biological nitrogen fixation, conserve moisture and increase production of biomass for use as organic mulch. Combining agroforestry models along with CA is an important viable option to augment biomass supply particularly in rainfed arid and semi-arid regions (Table 5).

***Rainfed Systems***

In contrast to the homogenous growing environment of the IGP, the production systems in rainfed semi-arid and arid regions are quite heterogeneous in terms of land, water and cropping systems. The productivity of the rainfed crops is very low since these regions are characterised by 2-4 weeks of dry spells, low water use efficiency and nutrient use efficiency. Hence, conservation agriculture is very important for rainfed regions.

The rainfed cropping systems are mostly single cropped in fallow Alfisols and Vertisols. But, a second crop can be possible with residual moisture. In *rabi* black soils, farmers keep lands fallow during *kharif* and grow *rabi* crop on conserved moisture. Sealing, crusting, sub-surface hard pans and cracking are the key constraints which cause high erosion and impede infiltration of rainfall.

**Conservation Agriculture for Sustainable Intensification of Agriculture**

***Policy*:**

Conservation agriculture has a radical change from traditional agriculture and offers an opportunity for arresting and reversing the downward spiral of resource degradation, diminishing factor productivity, decreasing cultivation costs and making agriculture more resource use-efficient, competitive and sustainable. But this has limited success FAO (2001) have reported that this is partly because policy environments are not favorable. Hence there is need for policy analysis to understand the integration of CA technologies with other technologies, and the policy instruments and institutional arrangements promote or deter CA. These institutional arrangements must be based on a good understanding of the features that distinguish the principles and practices of CA from the conventional research and development approach. Policy indicators should be developed to assess the impacts of CA.

- *Appropriate legislation* may be implemented for preventing of on-farm crop residues burning through incentives and punishment. Campaigns may be launched to promote timely sowing of the crops, residue retention / avoid residue burning.
- *Provide tax break incentives* for CA farmers for water use efficient technologies and that build soil carbon (carbon credits).
- *Better understanding of the implications of CA by policy makers*. The policy makers often are not aware of the relevance of CA as a basis for sustainable intensification hence many existing policies work against the adoption of CA. Typical examples are commodity-related subsidies, which reduce the incentives of farmers to apply diversified crop rotations, mandatory prescription for soil tillage by law, or the lack of coordination between different sectors in the government. If the policy makers understand the advantages of CA it would be easier for them to justify the supportive policies, develop specific strategies and action plans for the promotion of CA which in the end are advantageous not only for the farming community but for every-one and hence for the policy makers and their constituency. Therefore, there is a need to sensitise policy-makers and institutional leaders. Policy makers often are not aware of the relevance of CA as a basis for sustainable intensification and thus many existing policies work against the adoption of CA. There are cases where countries have legislation in place which supports CA as part of the programme for sustainable agriculture, and yet within the same Ministry of Agriculture also have a programme to modernize and mechanize agriculture, introducing tractors typically equipped with

ploughs or disk harrows. This not only gives the wrong signal, but it works directly against the introduction and promotion of CA, while at the same time an opportunity is missed to introduce tractors with no-till seeders instead of the plough.

- *Developing, improving, standardizing machinery*: The equipment for sowing, fertilizer application, and harvesting that require least soil disturbance in crop residue management under different soil conditions is the key to success of CA. In hilly areas, small landholders' bullock-drawn equipment is highly important. The available CA implements like., happy seeder, turbo seeder, laser land leveller, etc., which are useful for CA practices need high horse power (>50 hp) tractors for better functioning in field conditions besides this the implements are very complex as well as expensive for a farmer to purchase it. Hence these are not suitable for small and marginal farmers with small land holdings as they cannot afford to procure such equipment. Hence manufacturing of low cost smaller versions of these machines at the local level is required. The local manufacturing of CA equipment becomes feasible if the import tax on the raw material might be reduced. Besides this the national or local government need to provide a subsidy for the manufacturing of low-cost implements or purchase of farm equipment such as laser land leveller, zero till drill, straw combine, strip till drill, roto-till, raised bed planters, straw combine, straw cutter cum spreader, straw baler etc. by farmers will help in the expansion of CA practices. For maintaining the quality standards of the CA machinery, there is a need to develop skill in the new and small scale local manufacturers. Hence the traders/dealers/local artisans should receive updated information and training on calibration, operation, repair and maintenance of CA machinery so that right services are provided to the farmers. ITIs and Cooperatives may be encouraged to set up service and repair centers for agricultural implements in each block. A course can be introduced in the ITIs to promote self-employment of the rural youths. Besides manufacturing of small equipment farmer may develop a local hire service industry by providing equipment to hire on custom basis. The banks and credit agencies should provide credit to farmers to buy the equipment, at reasonable interest rates.
- The success or failure of CA depends greatly on the flexibility and creativity of the farmer and extension and researchers of a location. Hence successful diffusion of CA can be done if KVKs, NGOs and research organizations work together in technology assessment and refinement (TAR) and develop FAQs database for easy and correct responses on toll free help lines. Cell phone based advisory services

should be made mandatory for each of the KVK and the DDA in the district and work in close collaboration with each other. Promote system based technical advisories to farmers using modern Information and Communication Technologies (ICT).

- CA is an investment into soil fertility and carbon stocks, which so far is not recognized by policy makers, but acknowledged by some farmers. Such farmers need to be paid incentives. Farmers who still plough know that by ploughing up these lands the mineralization of the organic matter acts as a source of plant nutrients, allowing them to "mine" these lands with reduced fertilizer costs. This allows them to pay higher rent for CA land than the CA farmer is able to do.
- *Convergence with various schemes:* Appropriate technology, policy and institutional supports are prerequisite for promotion of CA practices across different agro-ecologies. For the institutional support investment by the national government is not an issue but making best use of the allocated resources is important. Large investments were made on different schemes like NREGS, NHM, RKVY, NFSM, watershed programme, and for research programmes like RKVY, NAIP, national initiative on CA, climate resilient agriculture (NICRA), ICAR platform on water, etc. There is a need for convergence of these schemes; at the local level involving all major stakeholders would definitely contribute towards promotion of CA. Besides convergence there is a need for integration and complementarities in such schemes with appropriate monitoring and evaluation (M&E) for mid-course correction and greater impact at the field level.

***Technologies***

Conservation agriculture studies carried out by the different Institutes of the Indian Council of Agricultural Research and the State Agricultural Universities revealed that no-tillage and direct seeding results in saving in time, fuel (Table 6) and helps in adaptation and mitigation of climate change by reducing the GWP and increasing carbon sequestration (Table 7) (Chaudhary *et al* 2016, Pratibha *et al.;* 2015). The experiments carried out in different experiments on different methods of rice planting has indicated that Double no till system in rice – wheat system increased the yield and economics of the rice- wheat system. (Akther *et al*., 2015) (Table 6). However, there is a need to define location specific recommendation domains of different CA based crop management technologies suiting to various production systems, agro-ecologies and socio- economic conditions of farmers. The crop breeding programs need to focus to tailor varieties suited to system's needs and for large scale adoption of conservation agriculture.

The equipment plays a vital role for success of CA particularly for sowing, fertilizer application, and harvesting that require least soil disturbance in crop residue management under different soil conditions.The available CA implements like, happy seeder, turbo seeder, laser land leveller, etc., need high horse power (>50 hp) tractors and beyond the reach of resource poor farmers. Therefore, development of bullock/manual/ low power tractor drawn equipment suiting to small landholders is necessary.

Conservation of resources there are also significant environmental benefits of zero or minimum-till systems. Ploughing the soil has adverse effects such as contributing to soil erosion, soil compaction, the loss of organic matter and the degradation of soil aggregates.Whereas, CA (Zero tillage with residues) reduces the soil compaction and erosion. Experiments at CRIDA in pigeon pea and castor system has shown that zero tillage as recorded 20 and 70% lower soil and nutrient losses as compare to conventional and reduced tillage. Hence these practices have the potential of increasing agricultural yields and raising profits for farmers especially in wheat in rice - wheat cropping systems. Besides increasing crop productivity conservation agricultural practices increases the water use efficiency, reduce the weed seed germination, growth, evaporation and soil erosion.

In India, straw is burnt mostly in IGP regions to facilitate land preparation or sowing due to lack of proper implement to sow in the residue. Gupta et al., (2004) estimated that the burning of one ton of straw releases 3 kg particulate matters, 60 kg CO, 1460 kg $CO_2$, 199 kg ash and 2kg $SO_2$. With the introduction of multi operation zero-till machines capable of cutting, chopping and spreading crop residue, around 10 tons crop residues per hectare can be harvested instead of burning of straw which reduces the release of around 13–14 tons of carbon dioxide. Apart from this, zero-tillage on an average saves about 60l of fuel per hectare thus reducing emission of $CO_2$ by 156 kg per hectare per year (Grace *et al*., 2003; Gupta *et al*., 2004).

In India, livestock play a very important role in farming. Hence, long term basic and strategic research on CA in relation to crop-livestock interactions should be carried out to rationalize the residue needs for CA *vis-à-vis* livestock fodder under various production systems. Besides, a long-term basic and strategic research platform in different production systems and ecologies are needed for monitoring the impact of CA on resource/input use efficiency, soil health, pest dynamics, carbon sequestration, greenhouse gas emissions and environmental benefits including eco system services.

### *Extension*

CA experiments should be conducted in farmers' participatory mode involving other stakeholders as success or failure of CA depends greatly on the flexibility and creativity of all the stakeholders. In this process, farmers themselves will identify the benefits and help in fine-tuning the technology as per their resource availability to make it more cost-effective. The farmers are ingenious in problem solving, often innovative and adapt the practices to their own conditions if they pick up the conceptual part of CA. Hence practical knowledge and learning system through hands-on training for CA should be built up in the farming, extension and research community. Exposure visits of farmers from adjoining villages may be arranged for up-scaling CA through meaningful interactions and linkages. CA is knowledge intensive. Hence, capacity building for promotion of conservation agriculture is required to create awareness at all levels. Every agricultural university should have courses on conservation agriculture both at under and post- graduate levels.

## Policy intervention, Research and Extension on conservation agriculture management

### *Policy interventions*

In India, as such there is no specific policy intervention for conservation agriculture. But there were some developmental schemes in which provisions have been made for promotion of resource conservation technologies like DSR, SRI, zero tillage, Laser leveling, crop diversification etc. Similarly, to prevent soil erosion, the Government has massive integrated watershed management programme. The government, on the recommendation of National Green Tribunal (NGT) recently, issued stern regulations and guidelines on burning crop residues. Moreover, crop residue burning is punishable under the Air (Prevention and Control of Pollution) Act, 1981.

### *Research*

Agricultural universities, DOA, ICAR Institutions together with IARCs (CIMMYT, IRRI, RWC) have made significant efforts through on-station and farmers participatory research to develop best CA practices and customized solutions on conservation agriculture based technologies to address the issues of natural resource degradation, declining water tables, decelerating factor productivity, terminal heat stress and shrinking farm profitability. Recently, a Consortia Research Platform on CA have been initiated through in network mode with objectives to develop location specific CA technologies for sustainable intensification of cropping systems across agro-ecologies and validation of location specific CA packages in farmers' participatory mode involving all stakeholders. The studies were conducted in different cropping systems viz., Rice based cropping systems, Maize based cropping systems, Soybean – wheat, and sugarcane based cropping system and rainfed cropping systems.

***Extension***

Front line demonstrations of zero-till drills and other machines such as laser land leveler, raised bed planter, straw combine, and straw baler are being carried out by the State Department of Agriculture to promote CA. A RWC has also been formed by ICAR which is promoting CA technologies for rice-wheat systems.

**Best practices of conservation agriculture (by crop/by farming systems)**

**A. Agronomic practices**

***Unpuddled Minimum or zero tillage rice***

***Dry direct seeded rice:*** In India rice is grown usually by puddled transplanting method. The disadvantage of this method is high labour requirement and the physical changes which take place due to puddling are determentel to subsequent non- rice crops. Hence the need has been realized throughout India to explore rice production technologies that eliminate puddling, critical labour requirement, energy and facilitate timeliness in crop establishment. Dry direct seeded rice is an alternative method to transplanted rice in unpuddled soil without the adverse effect of greenhouse gas emissions like methane and without yield loss. Pre-germinated paddy seeders (4-6 rows) can be used for direct sowing of paddy in puddled soil with only 1 cm standing water. Use of these seeders resulted in higher yields and reduced labour requirement as compared to transplanted crop. But direct sown zero tilled rice (ZTDSR) is not competing with transplanted rice in respect of yield and economics due to heavy weed infestation in the rice fields and not a single herbicide is available which can be used to control multiple weed species. Besides the yield loss the $N_2O$ emissions are higher in direct seeded rice. Unpuddled mechanical rice transplanting is one of the solutions of these problems and it is coming up in a big way in India. On farm and on station demonstrations has revealed that unpuddled mechanical transplanting of rice is being preferred by farmers in India in a big way over zero tilled direct sown rice.

The CA practices in rice based cropping systems, can improve soil health, increase total productivity by 3-fold through diversification and 20% reduction in cost of production through tillage management. Apart from the above advantages DSR reduces overall water demand compared to transplanted puddled rice (TPR), saves labor (40-45%), fuel (55-60%), water (30-40%) and time and gives comparable yield with TPR, if weeds are effectively controlled. Therefore, DSR can be a technically, economically and environmentally feasible alternative to TPR. Weed pressure is the major problem in direct seeded rice. This problem is furthermore in dry direct seeded rice as compared to wet seeded rice. The other conservation agriculture practices for direct sown rice are bed planting and strip tillage system. To increase the adoptability of zero tillage/direct seeding of rice, there is a need to have suitable machinery, varieties and appropriate weed management strategies particularly to control *makara* grass in DSR system. At present, in DSR system, some hybrids and scented *basmati* rice cultivars are giving grain yield equal to that obtained in transplanting method. However, there is a great need to explore the potential of more varieties for this situation.

***SRI method of rice cultivation:*** In this method, soil is kept under saturation and young seedlings are transplanted. The seed rate and water required were lower in this method as compared to other method of rice cultivation. Efforts are being made to refine existing rice transplanter into a zero till rice transplanter capable of transplanting one/two seedlings.

***Zero till wheat:*** Zero till planting of crops after rice especially wheat was recommended and is picking up. In this technology the tillage intensity was reduced drastically. Zero tillage is not only a cost saving technology but it improves the crop yields. This Zero-till planting of wheat after rice is the most successful resource-conserving technology to date in the Indo-Gangetic Plains, particularly in northwest India (Erenstein and Laxmi, 2008). The interest in zero tillage in the Indo-Gangetic Plains was increasing due to time conflicts between rice harvesting and wheat planting in most of the rice-wheat cropping systems and due to number of advantages like alleviating several constraints in the rice-wheat system. This helps in early wheat planting, control of obnoxious weeds like *Phalaris minor*, cost saving and water saving (Erenstein and Laxmi, 2008). The increased yield and reduction in weeds is due to advancement of sowing.

***Laser Land levelling:*** A properly levelled land with the required inclination based on the irrigation method is required. The traditional farmers' methods of levelling by eyesight, is not precise particularly on larger plots and lead to inefficient water use, poor crop stand. With laser levelling, the levelling of the field is done up to ±2 cm, resulting in better water application, distribution efficiency, improved water productivity, better fertilizer efficiency, and reduced weed pressure. Hence the laser-guided equipment for the levelling of surface-irrigated fields is more economically feasible. In this method there is saving of water up to 50%

and 68% in wheat and rice respectively (Jat *et al.,* 2006). Laser land leveler consists of a laser source (transmitter) which emits a parallel laser beam to a laser receiver attached to a scraper bucket behind a tractor and the vertical movement of scraper bucket is controlled by a hydraulic jack in a control box for levelling the field.

***Brown manuring (for cover/mulch):*** In brown manuring, rice is sown in lines with a seed drill and Sesbania (Sesbania aculeata L.; Dhaincha) is broadcasted on the moist soil. Sesbania plants can grow with rice for 25-30 days, and then, knocked down by applying 2,4-DEE @ 0.50 kg/ha or bispyribac-Na @ 20-25 g/ha. Bispyibac-Na is broad-spectrum and more effective than 2,4-D. Sesbania while growing with rice smothers weeds, reduces herbicide use and irrigation water, and supplies 15-20 kg N/ha with a fresh biomass of 10-12 t/ha. It facilitates better emergence of rice where soil usually forms crust, conserves moisture with brown mulch, improves soil C content and increases farmers' income. This practice can be followed in crops like maize, pearl millet, sorghum. In broad-leaved crops, 2,4-D cannot be used, but Sesbania can be cut manually and spread as mulch between crop rows at 25-30 DAS for controlling weeds, and conserving moisture and nutrients.

***Relay cropping of mungbean in wheat:*** CA-based direct-seeded rice (DSR) with mungbean or other plants residue retention has great potential for minimizing the cost of production, soil health hazards and the negative impacts on the succeeding crops. A summer mungbean crop can be sown without delay in sowing of rice crop. It gives grain yield of 8-10 q/ha and usually adds 40-60 kg N/ha in soil, reducing the requirement of N of the subsequent crop. In recent times only, marginal adoption of double no-till systems with full CA is being adopted. The Rice-Wheat Consortium has developed tested and promoted technologies which allow the application of conservation agriculture in rice-based cropping systems (RWC-CIMMYT, 2003) these technologies include laser leveling, permanent bed planting and the retention of residues (including rice straw).

***Permanent bed with residue retention:*** In Bed planting system, crops are sown on raised beds (narrow or broad) alternated by furrows, using a bed planter. First, the beds of 60 -100 cm width are made after tilling soil, and the same beds can be used for subsequent years, but reshaping of beds are required once in a year, preferably at sowing of kharif crops. Crops are sown in 2-3 rows on the beds and irrigation water is applied to the furrows. As a result, weed population is reduced on the top of beds. The furrow irrigated raised-bed system (FIRBS) usually saves seed by 25%, water by 28 % and nutrients by 25%, in wheat without affecting the wheat grain yield (Jat *et al* 2012). Whereas in rice water saving is by 42% further, it reduces lodging owing to less physical contact of irrigation water with wheat culms, and vacant spaces in the form of furrows, facilitating easy air movement. Bed planting can be adopted in other crops like cotton, pigeon pea, maize, soybean, vegetables, sugarcane etc. The furrow acts as a drainage channel during high rainfall conditions in Vertisols where as it acts like conservation furrow in rainfed regions.

Similar permanent bed and furrow method can be used under rainfed conditions also. This method has several advantages such as it helps in timely sowing of the crop, requires low fuel and labor costs, improves soil health and quality, reduces erosion and conserve soil moisture with higher water use efficiency (15-20%) and yield enhancement. In permanent bed and furrow planting through furrow acts as a drainage channel in high rain fall/waterlogged areas and provides better microclimate for plant growth and root development and acts as a conservation furrow in low rainfall areas. A bed planter was fabricated at CRIDA to prepare bed and furrow method in rainfed regions. With this bed planter, 100 cm and 35 cm wide beds and furrows respectively and 15-20 cm deep furrows are prepared. After preparing the fresh beds, during the first year, these beds can be kept as permanent beds for subsequent year with the retention of crop residue, and reshape the beds, if required, during the sowing of the next crop. Depending on the spacing, 2-3 rows of crops can be sown on the beds. This planter can be used both in irrigated and rainfed conditions. The implement can do four operations simultaneously i.e. reshaping of the bed, sowing, herbicide, and fertilizer application.

***Surface Seeding in Water Logged Area*:** This is the simplest form of zero-tillage system and is sustainable for excessively moist conditions of poor textured, poorly drained soil commonly found in the low-lying areas of eastern IGP in Nepal, The lowlands of Bihar, West Bengal in India and Bangladesh. In these areas, soils generally cannot be tilled for normal planting. In this method, wheat is broadcasted in the wet soil surface either before or after rice harvest. The seeds germinate and the roots follow the saturation fringe as the water recedes. As the soil is wet, no machine can go inside the field, so surface seeding is very appropriate system for resource poor farmers as no equipment is needed. This system allows the farmer to take one more crop instead of keeping the field fallow and get 3-4 tons/ha of grain.

***Permanent conservation furrow:*** In this method, a conservation furrow of 45 cm wide and 20 cm deep is made in different rainfed crops like maize, pigeon pea and castor are sown. This furrow can conserve around 250 $m^3$ water. This furrow is reshaped every year. The inter spaces between two pairs can be effectively utilized by sowing legume crops.

***Strategies to increase residue retention:*** In rainfed agriculture, moisture stress is common, moreover, the rainfall is unimodal and erratic with high variability both within and between seasons, and droughts are common, due to which the crop yields and residue production are low. Besides low residue production, competing uses for crop residues also exist (e.g. fodder, fuel or construction material). In the tropical rainfed regions, crop and livestock production are closely integrated in mixed smallholder farming systems. A crop residue, particularly cereal Stover, provides high value fodder for livestock in smallholder farming systems in rainfed agriculture. Indeed, feed is often in critically short supply, especially under typical small farm sizes, and limited common lands for grazing.

In these situations where competition for crop residue use is strong, intercropping with grain legumes can be a viable strategy to achieve surface cover because the legume will cover the area between rows of the main crop and help conserve moisture. Apart from this manipulation of harvest height of the crop increase the residues in case of cereals like maize and sorghum the crops can be harvested at 60 cm since the crop residue above 60 cm is nutritious and 30 cm height for crops like pigeonpea and castor (Pratibha *et al.*, 2015). Legumes like horsegram (Macrotyloma uniflorum) can be grown if the rainfall is around 70 mm between October–December.

***Alley cropping:*** It is one innovation in rainfed areas that offers productivity, economic and environmental benefits to producers. A different agroforestry model along with CA is an important viable option to augment biomass supply particularly in rainfed arid and semi-arid regions. Intercrops or cover crops with legumes can be sown in between widely spaced tree species.

**B. Implements**

***Zero till seed drill (Direct seeding equipment):*** The conventional seed drill generally has seed and fertilizer boxes, wide shovel type furrow openers, seed metering device, seed and fertilizer delivery tubes and seed depth control wheels. While zero-till ferti-seed drill has all these parts except that the wide furrow openers are replaced with chisel or “inverted T” type openers to place seeds and fertilizers in narrow slits with minimum soil disturbance. To facilitate seeding into loose residues, zero-till seed-cum-ferti-drill planted crop does not require planking. In fact, zero-till performance of rabi season crops improves if seeds are not covered/planked. As the dew received in significant amounts facilitates germination of Rabi crops, usually this direct seeding equipment can be used to sow different crops into residues under zero tillage either on flat fields or raised beds (PAU, 2006). The primary focus of developing and promoting CA practices in India has been the development and adoption of zero tillage cum fertilizer drill for sowing wheat crop in the rice–wheat system. Apart from happy seeder other implements were double disc coulters, punch planter/star wheel, Rotary disk drill, Turbo happy seeder , combo happy seeder etc.,

***Double disc coulters:*** This is one of the second-generation machines having double disc-coulters fitted in place of tines to place the seed and fertilizer into the loose residues. This machine may efficiently work up to a residue load of about 4 to 5 tonnes/ha. The problem with this machine is that being lightweight it fails to cut through the loose residues and the seed and fertilizer is dropped on the top of it, part of which reaches on the soil surface. For proper germination after seeding irrigation is required immediately.

***Punch planter/Star wheel:*** It works under low residue load of up to 3 tonnes/ha. This machine is suitable for small and marginal farmer due to low cost and easy handling. Farmers also came with innovations of this type of machine now days to make CA more successful in Andhra Pradesh.

***Rotary disk drill (RDD):*** This machine was developed by Directorate of Wheat Research, is based on the rotary till mechanism. The rotor is a horizontal transverse shaft having six to nine flanges fitted with straight discs for cutting effect similar to the wooden saw while rotating at 220 rpm. The rotary disc drill is mounted on the three point linkage system and is powered through the power take-off (PTO) shaft of tractor. The rotating discs cut the residue and simultaneously make a narrow slit into the soil to facilitate placement of seed and fertilizer. This machine can also be used for seeding under conditions of loose residues as well as anchored and residue free conditions. It can be used as a zero till drill, straight blades or discs can be used for minimal soil disturbance. It is newly designed to seed under diverse situations depending upon the presence and condition of crop residues.

***Turbo happy seeder*:** This is a modified, advanced and light weight version of the PAU- ACIAR developed ‘Happy Seeder’ to plant a crop in presence of loose and or anchored residues. Turbo seeder differs from happy seeder in type of the cutting blades, provision for adjustment of the rows, seed metering system and is lighter in weight. This seeder/planter can be operated with a 35HP tractor unlike the happy seeder which required a double clutch heavier duty tractor. Turbo seeder has been found to work satisfactorily in combine harvested fields. This machine has been field tested extensively in Punjab, Haryana and other states. This machine chops the residues in a narrow 5-6 cm wide strip in front of the tines, places seed and fertilizer in the slit opened for placement of seed and fertilizer. This machine is capable of seeding into the loose residue load of up to 8-10 tonnes/ha, distributed uniformly across the field.

***Combo happy seeder:*** It is a compact, lightweight, tractor mounted machine with the capability of managing the total loose straw and anchored crop residue in strips just in front of each furrow opener. It consists of two separate units a straw management unit and a sowing unit. This machine cuts, lifts and throws the standing stubble and loose straw and sows in one operational pass of the field while retaining the crop residue as surface mulch in the field. This PTO driven machine can be operated with 40-60 HP tractors and can cover one hectare in 2.5-5 hours.

***Implements for rainfed Agriculture:*** The implements required for rainfed and irrigated agriculture differ as the implements used in irrigated agriculture may not suit the rainfed regions since the rainfed regions have undulated topography. The seed does not require any covering mechanism in irrigated regions because of the high quantity of residues but in rainfed regions of India the residue load is lower than the irrigated region hence covering of seed is required besides this the depth of placement of seed is also different from irrigated agriculture. Thus, the requirement of implements in rainfed regions differs. CRIDA precision planter (zero till planter with herbicide and fertilizer applicator) was designed and developed at CRIDA. This planter, like in the conventional planters has seed, fertilizer boxes, seed metering device, seed and fertilizer delivery tubes and seed depth control wheels in addition to herbicide tank. But the wide furrow openers are replaced with inverted T type openers to place seeds and fertilizers in narrow slits with minimal soil disturbance. The advantage of this implement is that the seed has better seed-soil contact as compared to traditional disc openers, and germination was better when this planter was used for sowing the crop. Apart from the CRIDA precision planter, bed planter and CRIDA paired row planter were developed at CRIDA for integration of soil moisture with other three principles of CA. These planters can be used to reshape the bed and furrow every year and sow the crop without disturbing the beds and furrows.

### Challenges in Up Scaling of Conservation Agriculture

Although the importance of CA has been increasingly recognized, the key limiting factors for its widespread adoption and up-scaling are attitude, small farm sizes, lack of knowledge, expertise, lack of suitable equipment and machines, lack of diverse CA technologies, high opportunity cost of straw/residues, inadequate financial resources and infrastructure and poor policy support. The more common barriers for widespread adoption of CA are as under:

***Social barriers:*** One of the possible reasons for limited adoption of the technology by the farmers was mind-set of a large group of farmers about tillage; apprehension of lower crop yields and/or economic returns, negative attitudes or perceptions, and institutional constraints about zero tillage. In addition, farmers have strong preferences for clean and good looking tilled fields' vis-à-vis untilled shabby looking fields. The barrier of mental change remains the main obstacle to the diffusion of this new approach in agricultural practices. The lack of knowledge on how to begin is often a reason for failure. Indeed, farmers need to acquire the basic knowledge before attempting to try the technology on their individual farms, and plan the change well in advance.

***CA skills and knowledge barrier:*** These conservation agriculture systems are much more complex than conventional systems and site-specific knowledge is required to the spread of CA system. This learning process will accelerate building a knowledge base for sustainable resource management. To manage components of CA practices, understanding of basic processes and component interactions is required for the whole system. Conservation agriculture should be considered as a system to develop management strategies.

***Technological barriers:*** CA is complex, knowledge intensive and relatively new concept therefore problems can arise for which locally-based experience and knowledge does not exist. Hence the research should aim at developing multi-disciplinary multi-stakeholder partnerships for developing site specific, need based and problem-solving technologies for better CA adoption and dissemination. Permanent crop cover with crop residue recycling is a prerequisite and an integral part of conservation agriculture. However, sowing of a crop in the residues of preceding crop is difficult. The key challenges relate to the development, standardization, scaling up and adoption of site specific, crop and soil specific seeding and harvesting implements suiting to small and marginal farmers. The wide variety of soil types, high investment of no-tillage equipment, and the intensive hands-on management are the main constraints for adoption of CA system.

***Barriers of farm power, equipment & mechanization:*** The equipment for sowing, fertilizer application, and harvesting that require least soil disturbance in crop residue management under different soil conditions is the key to success of CA. In hilly areas, small landholders' bullock-drawn equipment is highly important. The available CA implements like., happy seeder, turbo seeder, laser land leveller, etc., which are useful for CA practices need high horse power (>50 hp) tractors for better functioning in field conditions besides this the implements are very complex as well as expensive for a farmer to purchase it. Hence these are not suitable for small and marginal farmers with small land holdings as they cannot afford to procure such equipment. Therefore, manufacturing of low cost smaller versions of these machines at the local level is required. The local manufacturing of CA equipment becomes feasible if the import tax on the raw material might be reduced. Besides, government need to provide a subsidy for the manufacturing of low-cost implements or purchase of farm equipment such as laser land leveller, zero till drill, straw combine, strip till drill, roto-till, raised bed planters, straw combine, straw cutter cum spreader, straw baler, etc. by farmers will help in the expansion of CA practices. For maintaining the quality standards of the CA machinery, there is a need to develop skill in the new and small scale local manufacturers. Similarly, to provide after sale service to farmers, ITIs and Cooperatives may be encouraged to set up service and repair centers. A course can be introduced in the ITIs to promote self-employment of the rural youths. The banks and credit agencies should provide credit to farmers to buy small equipment at reasonable interest rates. Heavy CA machineries may be promoted through custom hiring centers.

In India the implements are available only for sowing of crops in zero tillage rice-wheat and rice-maize system. Furthermore, many times farmers lack skills to operate the implements, local artisans, and machinery manufacturers for repairing and maintenance are not available. Appropriate policies that support quality machinery and open access to quality machinery are limited since subsidies are available only to limited vendors.

***Policy and institutional barriers***: Conservation agriculture has a radical change from traditional agriculture and offers an opportunity for arresting the (i) downward spiral of resource degradation and diminishing factor productivity, (ii) reversing decreasing cultivation costs and (iii) making agriculture more resource use-efficient, competitive and sustainable. But so far, this has limited success. According to FAO (2001) this is partly because of lack of appropriate policy environments. Existing policies are not favourable for the adoption of CA. The policy makers often are not aware of the relevance of CA as a basis for sustainable intensification. Policy makers should understand the advantages of CA to enable them to frame supportive policies and specific strategies with action plans for the promotion of CA. There are cases where countries have legislation in place which supports CA as part of the programme for sustainable agriculture. Appropriate policies for technology adoption, production and supply of machineries/equipment’s and institutional support are prerequisite for promotion of CA practices across different agro-ecologies.

**Potential for Future Conservation Agriculture Research and Development**

The CA is not a panacea to all agricultural problems, but it is a new paradigm for farming which intensifies agricultural production, sustains environmental quality, decreases of cultivation costs, making agriculture more resource use efficient, competitive and sustainable. This calls for special emphasis to be placed on the need for a change in mindset amongst farmers especially in traditional farming communities and the importance of involving all stakeholders to apply a holistic approach in CA promotion that is just as much farmer driven as it is science and technology driven and supported by public and private sectors and national agriculture development policies.

In this endeavor, identification of CA enabled viable crop rotations is essential to arrest land degradation, maintain soil health, arrest pest and weed infestation and to boost crop productivity. Zero/minimum till sowing/planting should be standardized for a variety of crops. Development of low-price CA machineries particularly direct seeders/ planters suiting to small and marginal farmers for sowing/planting into crop residues (loose and anchored crop residues) is also needed. New concepts of integrated soil fertility management and integrated weed, disease or pest management in zero tillage with crop residue retention need to be developed.

The weed infestation is one of the major discouraging factors for the farmers to adopt CA. Research should be conducted on weed dynamics to develop integrated weed management techniques to keep the yield loss due to weeds to minimum. Other research areas include understanding herbicide performance under heavy load of crop residues, nutrient dynamics under residue cover, etc.

It is also essential to investigate long term impact of CA on crop yield, soil health, weed and nutrient dynamics, carbon sequestration, GHG emissions under different production systems. Adopting CA may, in the short term, involve costs and risks. Switching to CA quickly may appear too risky. Farmers may start with 10% of their land under CA, and move forward with the rest of the land as they gain experience with the new management system. If CA is to be a national priority, governments need to recognize the public good value of the environmental benefits generated by widespread adoption of CA practices. Appropriate technology, policy and institutional support is prerequisite for promotion of CA practices across different agro-ecologies. This means that appropriate policies and incentives need to be put in place to share costs and risks. Large investments are being made on various components under different schemes. There is a need for convergence of these schemes for promotion of CA.

Like other revolutionary concepts conservation agriculture is prone to an overlay of dogma. Researchers and practitioners should keep an open mind to avoid steering the local evolution of conservation agriculture away from its optimal form. The previous studies pertaining to comparing the effect of NT/RT relative to CT, and their effect in relation to rainfall and duration of the experiment has revealed that the yield decline in NT/RT was significantly greater in dry climates (11%) than that in humid climates (3%) irrespective of duration of the experiment. Previous studies indicated that the major limitation for success of CA is the availability of soil moisture. Whereas studies in rainfed agriculture has indicated that in-situ moisture conservation increased the yields to a tune of 10 to 20 % by conserving soil moisture and reducing soil loss. Hence, the implementation of moisture conservation technologies like in-situ moisture conservation practices along with the CA principles increases the crop yields besides resource conservation.

## Conclusions

Sustainable intensification involves increasing the agricultural production from the same area of land with low negative environmental impacts. CA fits within the sustainable intensification paradigm of producing more as "Conserving resources – enhancing productivity" is the mission of CA. Conservation agriculture offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource – use-efficient, competitive and sustainable. The conservation agriculture based technologies, with all the three principles, would enable the farmers to cope with rapidly growing demand for labor, to conserve and improve natural resources, and to mitigate adverse impact of climate change which will improve the productivity of major crops and cropping systems. Hence, out scaling of CA for large scale benefits and impact on soil health is a must in the present context. However, concerted policy initiatives and reorientation of research and development agenda will be required for large scale adoption and popularization of conservation technologies for sustainable agriculture in India. Therefore, further investment into technical research, machine design, demonstration and extension, and substitutes for fuel and forage are important for a breakthrough on CA adoption in both irrigated and rainfed ecosystems of India.

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**Annexes:**

Table 1. Predominant rice based cropping systems in India

| Cropping system | States |
| --- | --- |
| Rice-Wheat | UP, Punjab, Haryana, Bihar, West Bengal, Madhya Pradesh, Maharashtra, Jammu and Kashmir, Assam and Bihar |
| Rice-Rice | Odisha, Tamil Nadu, Gujarat, Andhra Pradesh, Karnataka, Kerala, Assam |
| Rice -Mustard | Bihar, Madhya Pradesh, Odisha, West Bengal, Madhya Pradesh |
| Rice-Groundnut | Odisha, Tamil nadu, Andhra Pradesh, Telangana, Maharashtra, Karnataka, Gujarat |
| Rice-Pulses | Odisha, Andhra Pradesh, Bihar, Maharashtra, Chhattisgarh |
| Rice-fallow | Bihar, Madhya Pradesh, Maharashtra, Jammu and Kashmir, |
| Rice -Vegetables | Gujarat, Maharashtra, Odisha, West Bengal, Tamil Nadu |

Source: Gangawar 2011

Table 2. Area under Rice -wheat cropping system in India.

| State | Area (m ha) |
| --- | --- |
| UP and Uttarakhand | 4.522 |
| Bihar and Jharkhand | 1.936 |
| Punjab | 1.614 |
| MP +Chhattisgarh | 1.064 |
| Haryana | 0.462 |
| West Bengal | 0.274 |
| Jammu and Kashmir | 0.228 |
| Assam | 0.182 |
| Himachal Pradesh | 0.093 |
| Orissa and AP | 0.042 |
| Total | >10 |

Source: Sabia Akhter 2015

Table 3. Effect of crop diversification of rice wheat systems on productivity and economics.

| Cropping system | System productivity (REY ton/ha) | Net return (Rs/ha) | Returns per Re invested(Rs) | Land-use efficiency (%) | WUE (Kg REY/ha-cm) |
|---|---|---|---|---|---|
| Rice –wheat-fallow | 7.85 | 20448 | 1.58 | 63.01 | 10.92 |
| Rice-wheat-green gram | 12.45 | 47639 | 2.09 | 83.56 | 12.97 |
| Rice-sorghum-green gram | 9.43 | 45091 | 2.09 | 71.23 | 14.30 |
| Rice-castor | 9.72 | 28481 | 1.80 | 72.60 | 15.19 |
| Rice-mustard-green gram | 12.79 | 48415 | 2.19 | 76.71 | 15.23 |
| Rice-sorghum-groundnut | 10.21 | 42817 | 1.94 | 83.56 | 13.09 |
| Rice-chickpea-cowpea | 11.18 | 44207 | 2.09 | 78.08 | 14.72 |
| Rice-fenugreek-okra | 25.73 | 96286 | 2.83 | 68.49 | 32.99 |
| Rice-onion-cowpea | 24.15 | 84511 | 2.06 | 78.08 | 23.00 |
| Rice-chickpea-sesame | 10.28 | 31147 | 1.81 | 80.82 | 10.72 |

Source: Jat etal

Table 4. Sources of biomass production

| Biomass source | Qty of Biomass (kg/acre/yr) | Remarks |
|---|---|---|
| Biomass produced at farm level | | |
| Gliricidiaa/Cassia Siamea (200acre) | 15,000 | 30kgs/plant/year- from 5th year planted on bunds and around compost pits after planting (three lopping) |
| Sun hemp on Bunds | 1750 | 1.3 kg/ m2 total area of bunds per acre is 560 $m^2$ (100m×40m) and 2m wide bunds |
| Weeds | 2000 | |
| Crop Residue | 2500 | |
| Neem trees on farm (min-3) | 2000 | 300 kgs per tree per year (2 lopping) |
| Pongamia trees on farm (min-3) | 2000 | 300 kgs per tree per year (2 loppings) |

Table 5. Effect of different establishment techniques on yield and economics of Paddy

| Treatment | Paddy yield | Cost | Income | Profit | Cost: benefit ratio |
|---|---|---|---|---|---|
| Double zero tillage | 4.8 | 59660 | 114000 | 35643 | 1.91 |
| Direct seeding | 3.36 | 55057 | 79800 | 5793 | 1.14 |
| Brown manuring | 4.23 | 60402 | 100462 | 21310 | 1.66 |
| Bed planting | 4.43 | 60452 | 105212 | 26010 | 1.74 |
| Conventional | 4.72 | 61045 | 104975 | 25180 | 1.72 |

Source: Akhter et al., 2015

Table 6. Fuel consumption time taken and $CO_2$ emission in different implements

| Particulars | No till drill | Cup type zero till planter | Happy seeder | Turbo seeder | Raised bed planter | Conventional |
|---|---|---|---|---|---|---|
| Time taken, h $ha^{-1}$ | 3[73] | 4[64] | 4[64] | 5[55] | 13 | 11 |
| Fuel used, 1 $ha^{-1}$ | 12[72] | 14[68] | 18[59] | 19[57] | 55 | 44 |
| Operational Energy MJ $ha^{-1}$ | 687[73] | 804[68] | 1029[60] | 1089[57] | 3173 | 254 |
| $CO_2$ Emission Kg C-$ha^{-1}$ | 30[74] | 40 [65] | 45[61] | 50[57] | 140 | 115 |

Source: Personal communication

Table 7. Effect of conservation agriculture practices on NGWP and GHGI in pigeon pea-castor system in rainfed regions

| Tillage | | Pigeon pea | | | | Castor | | | |
|---|---|---|---|---|---|---|---|---|---|
| Tillage | Residue (cm) | NGWP crop | NGWP soil | GHGI crop | GHGI soil | NGWP crop | NGWP soil | GHGI crop | GHGI soil |
| CT | 0 | 337 | 1026 | 0.32 | 0.97 | 1109 | 1082 | 0.58 | 0.57 |
| | 10 | -596 | 296 | -0.47 | 0.23 | -188 | 265 | -0.09 | 0.13 |
| | 30 | -3368 | -149 | -2.7 | -0.12 | -1663 | 62 | -0.77 | 0.03 |
| RT | 0 | -444 | 243 | -0.41 | 0.22 | 580 | 382 | 0.32 | -0.21 |
| | 10 | -436 | -582 | -0.37 | -0.50 | -367 | -397 | -0.18 | -0.19 |
| | 30 | -2588 | -752 | -2.1 | -0.60 | -1543 | -721 | -0.76 | -0.35 |
| ZT | 0 | 289 | -167 | 0.33 | -0.19 | 373 | -97 | 0.23 | -0.06 |
| | 10 | -230 | -1220 | 0.22 | -1.17 | -417 | -1120 | -0.24 | -0.65 |
| | 30 | -1502 | -1380 | -1.5 | -1.38 | -541 | -1907 | -0.36 | -1.2 |

Source: Pratibha et al., 2016

# Best practices of Conservation Agriculture in Nepal

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**Introduction**

Federal Democratic Republic of Nepal is a landlocked country in South Asia situated at the southern lap of Hindu-Kush Himalaya. The country is located between China in the north and India in other directions with an area of 147,181 square kilometers. Though Nepal occupies 0.03% total land area of the world and 0.3% of Asia, the country has diverse climate from hot tropical in the south to cool arctic in the north. Population of Nepal stands at 26,494,504. Overall literacy rate (for population aged 5 years and above) in Nepal is 65.9%. Estimates of life expectancy at birth for urban and rural areas stand at 70.5 and 66.6 years respectively in 2011. The population below the poverty line is 23.8% in the year 2014. On an average, households own 0.68 hectares of land, but the majority (45%) own less than 0.5 hectares (CBS, 2011).

***Physiography***

The country has five distinct physiographic regions divided along south-north direction; the Tarai, Siwaliks, middle mountain, high mountain and high Himalayas. Each of these regions has typical bio-cultural and agro-ecological set up and livelihood patterns. The Tarai region has suitable climate for crop and fruit cultivation and good accessibility to market whereas high mountain region has cold climate and limited accessibility to produce the crops. Despite small in size, due to vast topographical variations even within a short physical distance, Nepal has remarkable climatic differences ranging from hot monsoon to tundra type arctic climate.

***Overview of agriculture sector in Nepal***

Agriculture is the mainstay of Nepalese economy. Agriculture contributed 29.4 % of the total GDP in the country in 2016. It is a source of food security, income generation, employment and a way of livelihood for more than 60% of the Nepalese population. Agriculture shares more than 50% in Nepal’s total exports to India and third countries. However, the growth rate of agriculture has been limited to 1.3% in the fiscal year 2014/2015 with the decade average growth of 2.9% only. The labor force has been characterized by very low productivity. The adoption of improved technology is still at very low level and there is huge gap between current and the potential productivity of agricultural produces across the various geographical domains. More than 30 districts of the country are suffering from the food insecurity situations and issue of poverty has always been stood as matter of serious concern of the day. The major reasons for current level of low agricultural development are insufficient investment in infrastructure and agricultural research, low level of input use, insufficient adoption of modern technology, fragmented land, monsoon dependence, inadequate availability of improved seeds and quality fertilizers, lack of basic infrastructures and transportation, warehouses and assured markets, etc. In spite of the low development stage, there are some positive dynamics in the agricultural sector. The per capita income and productivity of labor have increased, poverty has reduced and malnutrition has declined gradually. The irrigation cover has increased and several villages have been connected through agricultural road networks. Production of vegetables, vegetable seeds, fruits, honey and other consumable products have been accelerating and significant achievement has been received in the sector of agribusiness and commercialization. Realizing the central role of agriculture sector in the economy, Government of Nepal has promulgated several policies like National Agricultural Policy 2004, Agri-Business Promotion Policy 2006, National Seed Vision (2013-2025) Agricultural Development Strategy (2015-2035) to institutionalize the effort of commercialization and agribusiness development. In addition, specific policies for seeds, fertilizer, land use, irrigation, trade and other key areas have been revised and harmonized with agriculture sector priorities.

***Farming system in Nepal***

The farming system of Nepalese agriculture varies according to the agro ecological zones. As long as we move toward north wards, the farming system seems to be dominated by agro-forestry whereas when we move towards southwards, cereal crops dominate the farming system. Among cereals, paddy is number one food crop in Nepal in terms of area, production, value, contribution to GDP and AGDP as well as in Nepali people’s food basket. In Nepal, there are typically three types of farming system (FS); Mountain FS, Hill FS and Tarai or Plain FS, as discussed in brief below.

***Mountain Farming system:*** High mountains that remain covered with snow year round is considered as the mountain farming system where human settlements is up to 3500 masl and the climate is very cold. The main crops grown in high hills are barley (hulled and hull-less), buckwheat, potato, finger millet, amaranths, prosomillet (chino), maize, apples, walnut and herbs. People keep chouri cow for milk and sheep for wool production.

***Hill Farming system:*** The hill region (Pahad) comprises of hills ranging from 800 to 4,000 masl. The climate of hills climate is pleasant and subtropical in river valleys to temperate in upper hills. In mid-hills, maize, millet, wheat, rice are grown as major cereals and citrus fruit dominates in most of the hilly areas. Animals like cows, buffaloes, goats are also raised in hilly areas. Generally, maize based system is popular in the hills.

***Tarai Farming system:*** Tarai, the southern plain area with subtropical climate, is the granary of Nepal. Inner Tarai and river basins also have the same type of climate. Inner Tarai is the broad low valleys in the north of Shiwalik foot hills (700-1000 m). The rice-wheat cropping pattern is predominant in the Tarai belt. In addition to rice and wheat, sugarcane, maize, jute, potatoes, and tropical fruits like mango, banana, guava, litchi, and animals like cattle, buffalo, goat and milk and milk products are mainly produced in Tarai, inner Tarai and river basins. The Tarai dominates national agricultural production

**Crop Production in Nepal**

The climatic diversity in Nepal has allowed production of various types of crops across the various geographical domains. Cereals, vegetables, pulses and fruits are major crops produced in Nepal. Among them, rice is the major staple crop of Nepalese people. The production detail of crops in Nepal is presented in the table below:

Table 1. Production status of crops in Nepal

| SN | Crops | Area (Ha) | Production (MT) | Yield (MT/ha) |
|---|---|---|---|---|
| 1 | Paddy | 1552469 | 5230327 | 3369 |
| 2 | Maize | 897789 | 2259445 | 2517 |
| 3 | Millet | 263101 | 306215 | 1164 |
| 4 | Buckwheat | 10890 | 11847 | 1088 |
| 5 | Wheat | 745823 | 1736849 | 2328.8 |
| 6 | Barley | 28366 | 32806 | 1156 |
| 7 | Pulses | 327321 | 363693 | 1.08 |
| 8 | Tea | 20747 | 23821 | 1.148166 |
| 9 | Oilseeds | 217867 | 208291 | 0.956 |
| 10 | Vegetables | 280807 | 3929034 | 13.99 |
| 11 | Beehives | 232000 | 3500 | |
| 12 | Mushroom | | 9300 | |

Source: MoAD, 2015 and MoAD, 2016

**Cropping Systems in Nepal**

Whether irrigated or rain-fed, rice is the staple crop of the lowland. This is because of rice being the staple food crop of the Nepalese people. In the lowlands wheat is another important food crop. Both these crops are consumed by majority of population. Similarly, maize is the second most important food crop in the hills. Millet, buckwheat, potato, vegetables are also the major components of cropping system in Nepal. The general cropping pattern of Nepal is presented below:

**Tarai (<1000 masl)**

**Rice and Maize Based cropping pattern**

| Irrigated area | Rainfed area |
|---|---|
| Rice-Wheat-Rice | Rice-Fallow-Fallow |
| Rice-Wheat-Fallow | Rice-Wheat-Fallow |
| Rice-Wheat-Dhaicha | Rice-Lentil-Fallow |
| Rice-Wheat-Mungbean | Rice-Rapeseed –Fallow |
| Rice-Maize-Rice | Rice- Fallow-Tobacco |
| Rice/Lentil-Rice | Jute-Rapeseed-Fallow |
| Rice-Chickpea, linseed | Jute-Wheat-Fallow |
| Rice-Wheat-Maize | Maize-Chickpea, Lentil |
| Rice-Potato-Dhaicha | Rice/Lentil |
| Rice-Peasonpea (in bund)- Wheat | Maize-Chickpea + Rapeseed |
| Rice-Potato-Maize | Rice- Fallow- Jute |
| Rice- Wheat- Jute | Rice-Vegetables-Fallow |
| Rice – Potato- Jute | Potato-Fallow-Potato+Maize |
| Rice- Rapeseed, Pulses- Jute | Rice - Potato -Maize |
| Rice-Vegetables-Vegetables | |
| Rice-Vegetables-Spring Rice | |

**Mid-hill (1000-2000 masl**)

| Irrigated area | Rainfed area |
|---|---|
| Rice-Wheat-Fallow | Maize/Millet-Wheat |
| Rice-Wheat-Rice | Maize/Millet-Fallow |
| Rice-Wheat-Maize | Maize + Soybean-Rapeseed-Fallow |
| Rice-Black Gram (in bund)-Wheat | Maize-Wheat |

| Irrigated area | Rainfed area |
|---|---|
| Rice-Barley | Maize-Oat |
| Rice-Maize | Maize + Upland Rice |
| Rice-Rapeseed-Maize | Maize + Upland Rice- Wheat |
| Rice-Rapeseed-Rice | Maize-Vegetables-Rapesseed |
| Rice-Potato-Maize | Maize- Vegetables- Vegetables |
| | Vegetables-Vegetables-Vegetables |
| | Maize-Ginger-Fallow |

**High hill (>2000masl)**

| Irrigated area | Rainfed area |
|---|---|
| Rice-Barley | Maize –Fallow |
| Rice- Necked Barley (Uwa) | Maize –Wheat |
| Rice-Wheat | Wheat- Finger Millet (2 years cropping pattern) |
| BuckWheat- Necked Barley (Uwa) | Maize- Necked Barley (Uwa)-Finger Millet (2 years cropping pattern) |
| Potato + Necked Barley (Uwa) – Fallow (2 years cropping pattern) | Maize-Wheat-Finger Millet 2 years cropping pattern) |
| Rice-Fallow-Finger Millet-Barley-Wheat (2 years cropping pattern) | Potato-Fallow, Potato-Buck Wheat, Maize-Rapeseed, Uwa-Fallow, Maize-BuckWheat |
| Wheat-Vegetables-Fallow | |

**Cropping pattern involving pulses**

| SN | Pulses | Cropping pattern | |
|---|---|---|---|
| 1 | Lentil | Rice/Lentil, Rice-lentil, Rice-lentil+Pea+Linseed+Mustard, Rice/lentil+Grass pea | Southern flat plain (Tarai) |
| | | Summer Maize -Lentil, Maize-Lentil+Mustard | Low hills/mid hills |
| 2 | Chick pea | Rice-Chick pea | Mid Western and central Tarai |
| 3 | Soyabean | Maize+Soyabean-Fallow, Soyaabean on rice bund, Summer maize/Soyabean | Mid hills/high hills |
| 4 | Black gram | Upland rice-Black gram | Mid hills |
| | | Maize-Blackgram+Niger | In warm low hill area |
| | | Maize/black gram | in mid hills, Tarai or inner tarai |
| | | Rice+blackgram (on paddy bunds) | |
| 5 | Pigeonpea | Pegionpea-Fallow | Mid western Tarai |
| | | Pegionpea+Maize | |
| | | Pigeonpea on rice bund | Central and eastern Tarai |
| | | Maize/Pigeonpea | Central Tarai |
| 6 | Mungbean | Rice-Wheat-Mungbean | Tarai/inner Tarai |

Source: CDD 2015

**Intercropping in fruits**

- Fruits+Legumes-Fallow
- Fruits+Legumes+Cole crops-Fallow
- Fruits+Ginger/Turmeric-Fallow

**Aagricultural practices leading to the Conservation Agriculture in Nepal**

***The Integrated Pest Management (IPM)***

**IPM FFS**

The Integrated Pest Management (IPM) is a leading complement and alternative to synthetic pesticides and a form of sustainable intensification. The IPM is a system of farming designed to be sustainable, it involves using a combination of cultural, biological and chemical measures, including plant biotechnology. Jha (2008) found that IPM-FFS (integrated pest management-farmer's field school) trained farmers used 36% lesser amount (1.82 kg / ha) of active ingredients of pesticides than the non-trained farmers (2.85 kg / ha). Similarly, another report (GC, 2011) stated that the pesticide application reduced up to 40% in FFS implemented areas as compared with non-FFS areas. IPM helps farmers to raise their crops yield and increases their income by improve returns on investment. In Nepal program carried out by FAO for Community IPM in Asia, the GCP/RAS/172/NOR has shown that IPM trained farmers increase their rice yield by about 15 to 25 % and reduce the use of pesticides by about 40 %.

Figure 1: IPM in Vegetable in Nepal

***Incorporation of legumes in cropping system***

Cultivation of legumes between rice-wheat crops short period e.g. vetch, clover etc. can increase grain yields of main crops. Crop rotation with Sesbania (Dhaincha) can increase 10-13% rice grain yield i.e. 450-750 kg/ha (Chen 1993). Some of the legume based cropping patterns recommended by Regmi (1987) are Rice-Vegetable-Legume, Rice-Legume-Vegetable, and Leguminous vegetable-Wheat-Vegetable (Cucumber). Likewise, incorporation of legumes into cropping system is found as a beneficial practice. It is reported that legumes at about a yield of 1 t/ha can provide a residual 20-40 kg N/ha to succeeding crops depending on the quantity of biomass returned to the soil.

### *Use of bio-fertilizers*

Bio-fertilizers are the biological active product called microbial inoculates containing active strain of selective micro-organisms like bacteria, fungi, algae or in combination. However, there are several bio-fertilizer companies are established in Nepal, the use of FYM, compost is in practice but the use of bio-fertilizers, green manures and other waste has yet to become popular as a cost effective and eco-friendly nutrient supply. Majority of the Nepalese farmers are not capable of applying recommended dose of fertilizers. Blue Green Algae (BGA) are alternative source of nitrogen to the chemical fertilizers. Experiments conducted on different legume crops grown under varying agro-ecological conditions proved the potentiality of bio-fertilizer and organic wastes as important source of plant nutrients. Patel et al. (1980) have reported while summarizing the responses of rice to azolla inoculation that the rice yields obtained from azolla inoculated plots are higher than that of 60 kg N/ha. Prasad and Prasad (2004) recommended some suitable strains of Cyanobacteria as a source of bio-fertilizer for rice productivity in Bagmati and Narayani Zones of Nepal. Gurung (2004) reported 5.26% increase in soil N due to BGA inoculation in rice field of Kathmandu which ultimately increased the yield of rice.

### *Integrated Plant Nutrient Management System (IPNMS)*

The aim of Integrated Plant Nutrient Management System (IPNMS) is to integrate the use of natural and man-made soil nutrients to increase crop productivity and preserve soil productivity for future generations (FAO, 1995a) In Nepal, Soil Management Directorate (SMD) has launched many programs that include soil analysis, fertilizer analysis, micronutrient analysis, Integrated Plant Nutrient Management System (IPNS), nutrient deficiencies study, soil fertility maps of different districts, training related to soil management and laboratory procedures, FYM and Compost Management programs etc. Chapagain and Gurung (2010) reported that maize yields under improved and farmers' management systems were found to be very similar to the research station yield, and were higher than the average productivity in the average farmers' field. Average maize yield using the local cultivar under Farmers' management was 3.5 t/ha which was nearly 2.3 tons lower than the yield obtained with IPNS management and improved cultivar. Efficient use of all nutrient sources, including organic sources, recyclable wastes, mineral fertilizers and bio-fertilizers should therefore be promoted through Integrated Nutrient Management (Roy et al, 2006).

### *The conservation agriculture (CA)*

The conservation agriculture (CA) is characterized by three linked principles, namely: continuous minimum mechanical soil disturbance, permanent organic soil cover and diversification of crop species grown in sequences and/or associations. Global warming has become the major threat across the globe; hence resources can be available in CA, since it minimizes the emission of green house gases. Nepal has been involved in testing and promoting CA based technologies under maize based system in the western Tarai and adjoining hills of Nepal. Marahatta (2014) reported that Farmers from Chitwan, Nepal saved the production cost by 31.98, 33.85 and 34.44% as well as increased benefit- cost ratio by 51.55, 29.19 and 54.11% respectively through the adoption of zero tilled wheat, reduced tilled-wheat and dry direct seeded rice.

**Need of Conservation Agriculture in Nepal**

Repeated tillage, removal or burning of the crop residues and absence of crop rotations are the fundamental causes of unsustainable conventional agriculture system in Nepal. Stagnation of agricultural productivity, degrading soil (soil losses ranges from 0.2 to 105 t/ha by erosion on barilands of Nepal) and water resources are the major problems of the agricultural production system in Nepal. Since, rice needs approximately 3000 liters of water to produce one kg of grain. Agriculture impacts climate change causing green house gas emissions, and is at the same time impacted by effects of climate change as well. Increase uncertainness in availability of water due to increasing frequency of drought and or excess water events resulting in uneven water availability in time and space. Lack of technologies that impart greater resilience to the production system are the great threat to all; researchers, policy makers and alike.

Although agriculture is main stay of rural economy people employ different livelihood strategies like labor migration. More than a million Nepalese youth are working each year abroad. Unfortunately, present day agriculture has not been the profession of attraction for educated youth in the country. CA is an approach to managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. The zero tillage, along with other soil conservation practices, is the cornerstone of CA (Dumanski et al, 2006). Conservation agriculture is not a prescriptive approach and business as usual, but is a scientific response to the questions of sustainability that agriculture is facing today. Its approach is based on three elements. First, farmers should keep the soil covered as far as possible - either by leaving the crop residue after the harvest or by letting something else grows on the soil. Two, tillage of fields should be kept to a minimum. If possible, the soil should not be tilled (plowed) at all and they should rotate crops spatially and temporarily (Karki and Shrestha 2014).

If these broad concepts are followed, significant improvements can be made in water conservation, enhancing soil quality and improving soil fertility. Nepal receives rains very ferociously within the short period of the rainy season. The high velocity raindrops break up the surface of the soil and carry the fragments away. When soil is covered, the residues absorb that impact, more water is absorbed by the soil and runoff is reduced. Similarly, tillage is a harmful practice, it accelerates erosion and emission of greenhouse gases and also energy-intensive. Tillage-based operations are costly and impart unsustainability. Essentially, resource conservation issues have become a prerequisite for agriculture and conservation agriculture enables farmers to improve their resource base using their own resources. Through such steps, we can reverse the degradation of soils and move towards more sustainable agriculture (Karki and Shrestha 2014).

**Conservation Agriculture for Sustainable Intensification in Nepal**

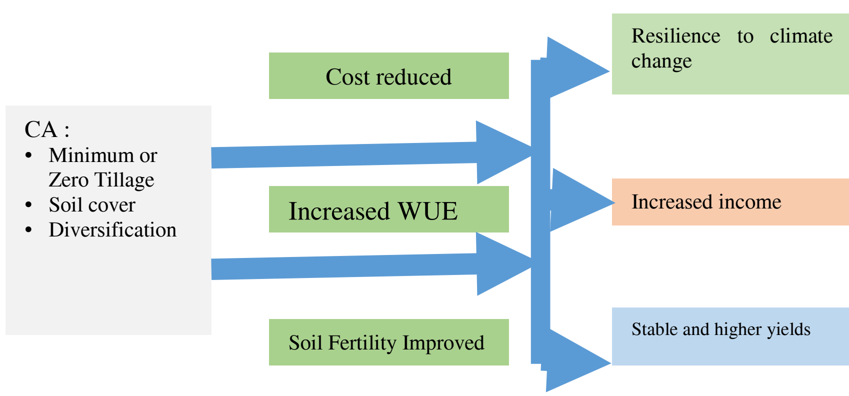



Figure 2. Conservation agriculture for sustainable intensification
Source: Conceptualized by author

**Policy arrangements for Conservation Agriculture in Nepal**

*Constitution of Nepal 2015*

**Fundamental rights in Constitution of Nepal**

- Right relating to food
- Right to clean environment

**Economic Objective of state:**

- The economic objective of the State shall be to achieve a sustainable economic development, while achieving rapid economic growth, by way of maximum mobilization of the available means and resources

- ✓ **Policies relating to protection, promotion and use of natural resources:**

  Protect, promote, and make environmental friendly and sustainable use of, natural resources available in the country

*National Agriculture Policy 2004*

- The negative impact of the use of agro chemicals on the condition of soil and reservoirs, and other environmental problems resulting there from, shall be minimized
- The production, use and promotion of organic fertilizers shall be encouraged.
- A conservation-oriented farming system shall be gradually developed by managing watersheds and controlling erosion of soil by rivers on the basis of local participation.
- Organic farming shall be encouraged. Necessary support shall be provided for the certification of the standard of exportable agricultural products produced in production areas based on organic farming.

*Rangeland Policy 2010*

- Soil erosion from the rangelands with steep slopes will be controlled with the adoption of appropriate technology
- Value chain of the rangeland based organic products will be developed and strengthened
- Rangeland based water sources will be conserved and utilized. Wetlands in the rangelands will be properly managed
- Conservation of rangeland will be embedded with the environment conservation and rangeland related studies/ research and technology dissemination will be regulated by developing operational guidelines and standards.

*Agriculture Development Strategy (ADS) 2015-2035*

Under heading Sustainability (One of the Key elements of the vision) ADS focuses on :

- Intercropping systems, conservation tillage, organic farming and agro-forestry
- Efficient water use management including non-conventional irrigation,
- Integrated plant and soil nutrient management to contribute to an environmentally sustainable agriculture.

**Best Practices of Conservation agriculture in Nepal**

Practice of adopting conservation agriculture in Nepal is not a new concept. Farmers have been continuously adopted CA based principles, like use of crop residue, maintaining soil cover, reduced tillage since many years. Currently, Government of Nepal has started doing formal research in CA and developed many CA based technologies that are applicable to Nepalese people. Among many CA based technologies; adoption of direct seeded rice and minimum or zero tillage are the widely adopted conservation agriculture practices in Nepal. Broadly, best practices/technologies of CA in Nepal are listed below:

Table 2. Best practices/technologies of CA in Nepal

| | |
|---|---|
| 1. SRI | Mulching in vegetables |
| 2. DSR | Agroforestry: *Uttis Nepalensis* in Large cardamom |
| 3. Legume Intercropping in Maize based cropping system | Multi storey cropping |
| 4.Zero tillage/ minimum tillage in maize and wheat | Composting/ use of urine |
| 5. Surface seeding in wheat | Bio-digester |
| 6. Fertigation system in mid hills/ tarai | Rain Water harvesting |
| 7. Drip/ sprinkle/ gated irrigation | Green manuring in rice |
| 8. Intercropping in fruits | Crop rotation in rice and maize based cropping system |
| Crop residue incorporation | |

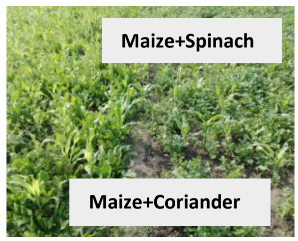
Some of the research outputs of CA based technologies in Nepal is presented below:

- *Maize Soya bean intercropping*

Sole crop of maize and soybean recorded significantly higher grain yield than corresponding yields under intercropping systems. Planting maize+soybean at 1:1 ratio recorded highest maize grain yield (4.58 t/ha) and 2:2 ratio recorded the highest soybean yield (1.70 t/ha). Higher net return was obtained in ZT (NPRs 110.4 thousands/ha) than CT (NPRs 105.8 thousands/ha). Intercropping of maize and soybean at 2:2 ratio recorded maximum benefit (NPRs 132.7 thousands/ha) and land equivalent ratio (1.47) than sole and intercropping treatments. It was found that paired rows of soybean between two rows of maize under ZT system could achieve higher productivity and profitability (Paudel et. al., 2015).

- *Coriander+maize and Spinach+Maize intercropping*

Coriander+ Maize and Spinach+ maize intercropping resulted the extra income up to USD 450/ha, better weed control and less damage by disease/insect.




- *No tillage*

Grain yield and related parameters of two hybrids Rampur Hybrid-2 and RML-32/RML-17 under various tillage methods and planting geometries in Rampur, during winter, 2013 showed higher yield in No tillage practice in comparison to conventional tillage practice (Karki et al 2015).

Table 3. Grain yield under conventional tillage and No tillage

| SN | Tillage | No of cobs/ha | Grain yield (t/ha) |
|---|---|---|---|
| 1 | Conventional Tillage (CT) | 62120 | 8.35 |
| 2 | No Tillage (NT) | 64962 | 8.36 |

Source: Karki et al, 2015

Karki and Shrestha (2015) found higher B/C ratio under No tillage as compared to Conventional tillage as shown below;

Table 4. B/C ratio under conventional tillage and No tillage

| SN | Factors | Grain yield (t/ha) | Harvest index (%) | B/C ratio |
|---|---|---|---|---|
| 1 | CT | 5.39 | 39.65 | 2.43 |
| 2 | NT | 6.64 | 41.71 | 3.30 |

Source: Karki and Shrestha 2015.

Yield gains of 200-500 kg/ha are found under rice-wheat system with no-till wheat against conventional-till system (Hobbs and Gupta, 2004). The benefit cost ratio of 1.7 in conventional tillage with residue removed and 2.5 in no tillage with residue kept were recorded in the second year. Since, it reduced significantly the cost of production without severe yield penalties; farmers are interested to scale-up the conservation agricultural practices in the hills of Nepal (Karki, 2014). Karki et al (2014) found higher yield of maize under No tillage in comparison to conventional tillage.

Table 5. Yield of Maize under Conventional Tillage and No Tillage

| SN | Factors | Grain yield (t/ha) |
|---|---|---|
| 1 | CT | 4.7 |
| 2 | NT | 5.2 |

Source: Karki 2014.

In maize- rapeseed cropping system B/C ratio was higher in conservation tillage with residues than in conservation tillage without residue (Karki et al 2014)

Table 6. Yield Comparison in Maize-Rapeseed Cropping System

| SN | Factors | total cost nrs/ha | B/C ratio |
|---|---|---|---|
| 1 | Conventional tillage without residue | 84480 | 1.7 |
| 2 | Conservation tillage with residue | 67650 | 2.5 |

Source: Karki et al 2014

- *Zero tillage technology*

The research result has shown great impact of zero tillage method over conventional tillage consistently in both the years (Tripathi, 2010).

Table7. Yield Comparison in Zero Tillage and Conventional Tillage

| SN | Tillage | Yield t/ha |
|---|---|---|
| 1 | Zero Tillage | 2.8 |
| 2 | Conventional tillage | 2.04 |

Source: Tripathi, 2010.

- *Reduced tillage (RT)*

Two methods of reduced tillage (RT) technology: power tiller seed drill (PTSD) and power tiller rotary (PTR) were tested against conventional tillage (CT) practice along with two popular varieties for two consecutive years 2006/2007 and 2007/2008 in wheat. Statistical analysis of grain yield data showed that all three methods of wheat planting performed differently as

**ZT-DSR Vs Un-TPR**
Figure 4. DSR in Sunsari district, Nepal

they produced significantly different amount of grain yield. Both reduced tillage methods: PTSD and PTR proved superior to that of CT however, performance of both the RT methods also differed greatly with each other proving PTSD the best practice among all (Tripathi, 2010).

- *Surface seeding in wheat*

Over all surface seeding produced 2684 (kg/ha) grain yield of wheat against 1982 kg/ha which is more than 35% higher over conventional tillage with almost no land preparation and planting costs (Tripathi, 2010).

- *Direct Seeded Wheat and Rice (DSR)*

On an average, the RT-wheat had lower productivity as compared to the ZT and conventional wheat. ZT-wheat produced 2.47% more while RT-wheat had 14.84% lower grain yield compared to the conventional wheat. ZT-wheat had 20.33% more yield as compared to the RT-wheat. Rice yield in DSR was lower than the conventional rice farming. On an average, yield of DSR was 2.92 t/ha and which was only 2.01% lower than the conventional practice. Conventional wheat farming required NRs. 33195.25 per hectare which is 47.03 % more than in ZT - wheat and 51.18 % more than in RT - wheat. In rice cultivation, cost of cultivation for DSR was NRs. 22021.75 which was 57.34% lower than the conventional rice farming (Marahattha, 2014).

- *No Till Garlic Cultivation*

No till garlic cultivation in Kailali district of Nepal has resulted in increased crop yield, decreased workload, reduced risk of production failure, diversification of income sources, reduced labor cost

*Results of B/C analysis in CA practices in Nepal*

A research on adoption of conservation agriculture (zero tillage) conducted Sunsari district of Nepal showed higher benefit cost ratio in CA based practices compared to conventional agriculture (conventional tillage) practices as shown in graph below.

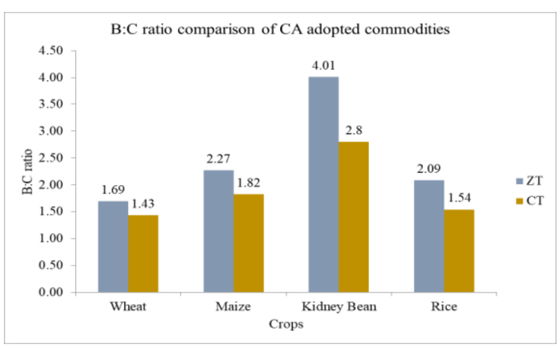



Figure 5. Cost Benefit Analysis in CA Adopted Commodities
Source: SRSSI (2017)

### Tools and Equipment used for Conservation Agriculture in Nepal

There are so many farm equipment used for practicing CA based technologies in Nepal. Some of them are presented below:

Table 8. Tools and Equipment Used for CA in Nepal

| Farm machines | Uses |
|---|---|
| Power tiller-operated seeder | Timely sowing of wheat |
| Zero-till drill | Zero-till drill |
| Sowing of seeds in the stubbles of previous crop | Sowing of seeds in the stubbles of previous crop |
| Happy seeder | Seeding |
| Power tiller-operated bed planter | Creates a trapezoidal raised bed and can perform seeding operations on the top of the bed simultaneously |
| Power tiller-operated zero-tillage seeder | Sowing of wheat and maize in residue of previous crop |
| Herbicide sprayer | Manual |
| Mechanical weeder | Manual / power tiller driven |
| Urea applicator | Basal and top dressing of USG, Manual |
| Combine harvester | by 50 HP tractor |
| Rice Transplanter | Zero till rice |

Source: Various publications of NARC

### Challenges of CA in Nepal

Despite the tremendous opportunities of CA, very limited research and development activities have been undertaken in Nepal. The primary restriction to CA adoption is the assumption that soil tillage is essential for agricultural production. Other restrictions include those of intellectual, social, technical, environmental and political characteristics. Key restrictions with mainstreaming CA systems relate to problems with up-scaling which is largely due to the lack of knowledge, expertise, inputs (especially equipment and machinery), adequate financial resources and infrastructure, and poor policy support (Friedrich and Kassam, 2009). The area under zero-tillage of wheat and direct seeding of rice has been increasing across the Tarai region. Mainly the socioeconomic constraints are competing uses of crop residues, lack of appropriate machinery, changes to pest dynamics especially weeds, knowledge-intensive adjustments to standard agronomic management practices, uncertain land use rights, poorly developed infrastructures like market, credit and research and development services. Larger areas in the hills and mountains where crop ecologies are entirely different than the Tarai are not being explored for the CA. Nepal Agricultural Research Council and Department of Agriculture are the main drivers to develop, verify and disseminate the CA based technologies in Nepal. A major requirement of this system is the development and availability of machines and equipments that promotes good germination of crops planted into soil that is not tilled and where residue mulch occurs on the soil surface. It should also be able to place bands of fertilizer for increased efficiency. In Tarai, several such machines are tested and improved, however still not perfectly executed. Whereas, in the hills cultivations are done mostly in sloppy terraces, scope of crop residue incorporation is limited since it is used for livestock fodder, no or limited roads to transport the heavy machines/equipment, poor affordability of the farmers for machines and rainfed agriculture that may limit the promotion of CA based technologies. No implements and equipment are being tested in the hills for reduced and zero-till condition. Similarly, none of the tools are for no-till weeding and mowing in the hills. There is challange of enhancing technical capacity and a complete shift from intensive tillage to zero or minimal tillage, which needs extensive educational programme by demonstrating the benefits accrued by conservation agriculture. Another problem is related with the high cost of machines and implements. Farmers in Nepal are small and poor thereby may not immediately shift from the existing or available machines to the conservation agriculture machines. There is less access to information about the conservation agriculture. Farmers need complete information related to tillage practices, cultivation methods and improved varieties. Another problem is related with the skills development, new machines (zerotill machine) and cultivation practices need skills development of the farmers. Agro ecological based conservation agriculture technologies are available, which need capacity of farmers to adopt and implement those in their production environment. Most of the farmers lack of skills in using zero-till machines and cultivation practices that prevents adoption of conservation agriculture practices.

Appropriate institutional arrangements are needed to be evolved so that small and marginal farmers, who may not afford to maintain the machines and other equipment for practicing conservation agriculture. In addition, a massive training program for capacity development of farmers needs to be developed.

### Potentiality of CA Based Technologies in Nepal

Precision land leveling, no-till systems, furrow irrigated raised bed planting systems, crop residue management and crop diversification are potential areas of CA in Tarai and plain areas of Nepal. Similarly, no-till, residue incorporation, strip cropping, intercropping and crop rotation with legume species, introduction of high yielding varieties of crops are few of the potential technologies to be tested, verified and promoted in the hills. In order to minimize the cost of intercultural operation especially for weeding and minimize the intensity of nutrient mining, integrated weed management strategy consisting of mechanical, manual, herbicide, cover crops, trap crops can be adopted in both hills and tarai, multi crop, zero till ferti seed drills fitted with inverted-T openers, disk planters, punch planters, trash movers or roto-disk openers are being used into loose residues in Tarai. Laser land leveling machines are also being used in these areas. Mini-power tiller along with fitted seed drill, punch and jab planter having drill for both seed and fertilizer, weed mower and chopper are some of the tools and implements that require less labor and fuels appropriate for the hills. The critical scientific manpower in CA is also available in the country. NARC as an apex body of country's agricultural research is presently working through 56 different research stations/ programs/divisions and DOA as an apex body of agricultural extension is working with 75 District Agricultural Development Offices across the country can be fully utilized. Global warming has become the major threat across the globe; hence resources can be available in CA, since it minimizes the emission of green house gases. Presently, many organizations have been promoting CA based technologies under rice based system in the country. Nepal has been involved in testing and promoting CA based technologies under maize based system in the western Tarai and adjoining hills of Nepal.

### Lessons Learnt

- Difficult to operate ZT machines in undulating and fragmented land thus promotion of two wheel tractor (Power tiller) is useful,
- Difficulty in Laser Land Leveling (LLL) promotion due to low HP tractor (need >50 HP),
- Lack of/limited irrigation facilities coupled with uncertainties in rainfall causing poor crop establishment thus low production,
- Promote drought and flood tolerant varieties (Rice-Sukha1-6; S. Sahawang; heat tolerant maize),
- Limited no. of tractors and their use in non-agricultural purposes creating difficulties for use of ZT machines and low income.

### Way Forward

For adoption of CA it is not only enough to find any progressive farmer who will prove the concept to work, but the farmer must have a socially important role, and be respected and integrated in the community. Wider adoption of CA technologies require concerted effort of all the stakeholders in the expanded partnership and participatory approaches in which farmers experiment and provide rapid feed-back. This would need to be supported by institutional changes that promote knowledge-sharing, flexibility and decentralized decision-making for rapid adoption of technologies to maintain production and productivity, increased food security and livelihood of the farmers. However, in order to sustainably adopt the Conservation agriculture, the farmers must markedly alter their cropping systems, to diversified crop rotations, including the use of green manuring crop. This necessitates the learning and mastering of an array of new crop management skills. Farmer's cooperatives need to be upgraded with the support of public and private sector. The experiences of various organizations involved in promoting CA based technologies can be capitalized. In order to formulate CA based agricultural policies, a task force consisting of researchers, extensionists, farmers and private sectors along with private sector (machine manufacturers) need to be formed urgently. As per the recommendations of the task force short, medium and long-term strategies for research and development need to be formulated and implemented soon in Nepal.

Moreover, the followings can be the future strategies for promoting conservation agriculture in Nepal:

- Direct seeding of rice and wheat in light to medium light soil is recommended for higher nitrogen use efficiency, enhanced soil physical health and reduced cost of cultivation.
- For timely planting using recommended ZT wheat varieties?
- Long term impact of CA based technologies should be studied/reviewed on diseases, insects and weed incidence and soil properties.
- Government should facilitate credit to farm machinery manufacturer at low interest rate and exemption of custom duties of imported products as well as raw materials.
- Provision should be made for subsidies on machinery purchase by the farmers.
- Government should give priority to promote agricultural mechanization to address the high production cost and labor scarcity.
- Farm mechanization with power tiller for small land holders should be promoted.

- Laser land leveling should be promoted on a large scale.
- Large plot demonstrations should be conducted on conservation agriculture in Tarai region.
- Networking to sharing the best practices of CA among the SAARC countries.

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# Best Practices of Conservation Agriculture in Pakistan

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## Introduction

Conservation agriculture (CA) is a set of soil management practices that minimize the disruption of the soil's structure, composition and natural biodiversity. It endeavors to make a judicious use of land, water and natural resources to maximize crop yields and arrest their deterioration to make agriculture sustainable. It aims to increase input efficiency to reduce cost of crop production and harmful effects of chemicals and fossil fuels on environment. CA has sprung to forefront in importance due to climate change impacts. Industrial growth, expanding agriculture and massive energy use are all spewing out harmful gases and chemicals into environment. The composition of atmosphere is changing and water aquifers are polluting. Accumulating $CO_2$, nitrogen, sulfur oxides and methane in the air are obstructing escaping heat from the earth surface into the space and so raising earth temperature. The rising heat is harmful to life; crops and livestock. Crop yields and livestock productivity would suffer. Heat would affect adversely in many other ways. Current favorable crop production zones would be rendered less favorable; glaciers feeding rivers would shrink and rising heat would increase insect and pathogen activity. So humanity is facing a dilemma; rising food needs and deteriorating food base.

Future agriculture, therefore, should produce abundant food at low rates, conserve natural resources, use inputs efficiently and reduce energy use to arrest environmental degradation. Room for free will is shrinking and man needs to act in unison with nature to avoid catastrophe. Biodiversity is nature’s means to maintain health of planet and is man’s free but tool to attain his goals. These are the ingredients of CA. CA package is in making but time is not man’s side. So the two international agricultural research organizations - CIMMYT and IRRI – have reviewed the available knowledge and put together a package of practices that can go a long way in adding efficiency, reduce energy and input use and make agriculture sustainable. These practices have, over time, proved their efficacy and so are gaining acceptances worldwide.

**Agricultural Scenario: Crops, Crop Production and Farming Systems**

The total cropped area of Pakistan was 11.07 million hectares (mha) at the time of its inception in 1947. It increased to 22.11 mha in 2003-2004 almost 100 per cent. Its population also went up from 34.3 million to 144.4 million during this period an increase of 346 per cent was recorded. Presently, the country is in the grip of population explosion of severe intensity, and has experienced a greater population growth compared to other developing countries. The population of Pakistan is increasing at the rate of 2.65 per cent and the gap between the supply and demand of agricultural products is widening day by day. The population was about 33.82 million in 1951 and just after 20 years it increased to 65 million. The current population of Pakistan is above 180 million but, it may touch 345 million in 2050. Increasing population pressure on quantity and quality in food supply and dwindling land and water resources forces the agriculture to steadily increase the productivity of the land through higher yields and crop intensity. To meet the challenge of food supply to the rapid increasing population, there is an urgent need to boost up crops yield. The issues in developing countries are growing population, fragile food security, and low agriculture inputs like fertilizer, poor yields, degrading soils and dependence on imports from the developed world. On the other hand, the land availability per capita will decline. Thus, the country faces great challenge to increase crop productivity per unit of land to ensure national food security in the wake of growing population.

The total land area of Pakistan is 796,096 sq.km. Most of the areas in the Punjab and Sindh provinces are comprised of plain land, formed by the River Indus. Pakistan is known for its excellent network of irrigation canals and rich agricultural lands, with three major reservoirs Tarbela, Mangla and Chashma, 23 barrages, 12 huge inter-river irrigation canals, 63,200 kilometers irrigation canals and more than 106 kilometers of water courses and 107,000 numbers of field channels. About 1.6 million km (1 million miles) are covered by water courses, farm channels and field ditches. In addition, the irrigation infrastructure is supplemented by 48 MAF groundwater extractions. The huge network of irrigation serves 43 command areas with 75,000 villages, covering 16.22 mha of the nation cultivated and cropped area of 22 mha. Pakistan had a remarkable 82 per cent of its agricultural area covered by irrigation. The economy of the country is basically agrarian and is heavily dependent on irrigation largely confined to the Indus Plain. Country is part of the sub-continent south of Himalayan mountains situated between longitude 61$^{o}$ and 76$^{o}$ E and latitude 24$^{o}$ and 37$^{o}$ N. The climate in Pakistan is arid to semi-arid with temperatures ranging between 2$^{o}$C and 50$^{o}$C. The mean annual precipitation ranges from less than 10 cm to more than 75 cm. There are great variations in the soils of Pakistan.

Pakistan is an agrarian economy. Agriculture is a vital sector of Pakistan's economy contributing 21 percent of GDP and employing 43.7 percent of the labor force. Sixty percent of the rural population is directly involved in agriculture to derive their livelihoods (GoP, 2014). It is the biggest sector of the economy and earns about 40% of the national income from it. Pakistan like many developing countries of the world is faced with the problem of low agricultural productivity. In spite of the fact that our country is blessed with a galaxy of climate, soil condition and irrigation water. The country is totally dependent on agriculture for the supply of food and fibre. Therefore, it is imperative to increase food and fibre production to cope up not only with ever growing requirements of the country, but for the sake of foreign exchange earnings and to attain self-sufficiency. Rapid agricultural growth can stimulate and thus sustain the pace of industrial growth, thus setting into motion a mutually reinforcing process of sustained economic growth. It contributes about 65 per cent to total export earnings derived from raw and processed agricultural commodities. Apart from the sectors immediate economic contribution it also has indirect linkages with various parts of the economy. Any changes in agricultural productivity, therefore, send a ripple effect throughout the rural population of Pakistan. It provides food, feed and raw materials for major industries, such as textile, sugar and to several other medium and small scale industries which account for about 50 per cent of total value of industrial production.

The yields of crop in Pakistan are comparatively lower than those of agriculturally advanced countries. The general problems associated with agriculture of this region are scarcity of water, floods, water logging, alkalinity, soil erosion, low yield per unit area, low yield per acre unit and traditional and old methods of cultivation. The most fundamental constraint in Pakistan is water availability which, limits further expansion of agriculture, therefore its efficient use must be given high priority apart from the general problems, other include poor quality seeds, poor soil management, low yielding varieties, lack of crop protection methods, shortage of irrigation water, credit facilities and non-application of modern technology in raising crops, contribute to the low yield and poor quality of crops.

The land of the country is classified as arid to semi-arid because rainfall is not sufficient to grow agricultural crops, forest and fruit plants and pastures. The cultivable? area of Pakistan is 35.4 mha, forest land 3.5 mha, cultivable (cultivable waste mean the area can be brought under cultivation but not being cultivated presently) waste 8.6 mha, cultivated area 22 mha, waterlogged and salt affected area in the Indus Basin is 6.8

mha, salt affected area outside Indus Basin is 6.3 mha. The hot deserts extend over some western areas and Thar, Cholistan and Thal. The Thar and Cholistan are part of the Great Indian Desert and cover the area east of the southern half of the Indus plains. The Thal area is between the Jhelum and Indus Rivers. Agricultural production in Pakistan is still three to four times less compared with some developed countries like USA, Japan, Holland, France, UK, etc. The total cultivated area increased from 19.2 million ha in 1965 to 22.0 million ha in 2000. Since area under cultivation cannot be increased significantly, therefore, due attention has to be paid to mechanical as well as other inputs in order to meet the problems of food, fibre and shelter for the growing population of Pakistan.

Fertility of soil is decreasing day by day due to intensive cropping in order to fulfill the needs of rapidly growing population. To maintain the fertility status of soils in order to supply adequate nutrients for plants, application of different fertilizers are recommended by the agriculturist scientists. Like many other parts of the world, salinity and water logging are the major constraints limiting crop production in Pakistan. Of the 22.2 mha of the total cultivable land, 6.3 mha are salt-affected. Soil salinity may be robbing, Pakistan of about 25% of its potential production of major crops. A major part of salt-affected soils (about 3.5 mha) are presently cultivated to rice, wheat, cotton, sugarcane, rape seed and other crops with substantial reduction in yield. Water is a unique natural resource. In Pakistan, conservation and management of water supplies is crucial as the demand for water continues to rise because of burgeoning population. Pakistan agriculture is predominantly irrigated. Water is one of the most limiting constraints for agricultural production in Pakistan. Water shortage is a major factor impeding growth of the agricultural sector. Fluctuations in weather conditions, deficient in storage capacity and poor use of available water, culminate in water acting as a major constraint to agricultural growth.

Water available at the farm gate after accounting, farm losses and run offs is 98.4 MAF during 2015-16 (Economic survey, 2016). During Rabi season 2015-16, water availability remained 32.9 MAF which 0.6% lower than rabi 2014. While kharif 2015 stood at 65.5 MAF showing a 5.5 % decrease over 2014 kharif season. Water available from ground extraction is 46 MAF. So, the total water available for 22.5 mha land is 144 MAF of which 97% is used in agriculture and the remaining 3% for domestic and industrial purposes. Out of 144 MAF, around 106 MAF is annually diverted into one of the largest irrigation system.

Agricultural sector of Pakistan is usually divided into four main sub-sectors: crops, livestock and fisheries. The crop sector accounts for about 65 per cent of agriculture share in the GDP. Blessed with abundantly available national resources and favourable climate, Pakistan stands as an ideal place for crop, animal, forestry and fish production. Of these, crop sector accounts 69 per cent of agriculture's GDP, while livestock accounts for 30 per cent. Forestry and fisheries make up less than 2 per cent of the total. Agriculture is therefore, the leaching sector and backbone of our economy. There are about 65 large and small institutes and over 62 sub-stations, etc. in the country. All research activities undertaken today's in the country pertaining to agriculture are being carried out by both provinces, (numbering four) and federal government. The Federal government plays a defined role in policy making, inter-provincial coordination, and foreign trade of agriculture related commodities. There are two growing seasons of crops in Pakistan, i.e. Kharif (summer) and Rabi (winter). In Kharif season, mostly rice, cotton, sugarcane, maize, etc. crops are grown, while in Rabi, the crops like wheat and vegetables are grown. Other crops grown in the country are bajra, jawar, barley, tobacco, sugar beet, guar, gram, mung, mash, masoor, bean, peas, rapeseed, mustard, groundnut, sesamum, linseed, castorseed, onion, garlic, chillies, turmeric, ginger, potato, tomato.

Table 1. Production of important crops (000 tons)

| Years | Cotton 000 bales | Sugarcane | Rice | Maize | Wheat |
|---|---|---|---|---|---|
| 2009-10 | 12,914 | 49373 | 6883 | 3261 | 23311 |
| 2010-11 | 11,460(-11.3) | 55309 (12) | 4823 (-29.9) | 3707 (13.7) | 25214 (8.2) |
| 2011-12 | 13,595 (18.6) | 58397 (5.6) | 6160 (27.7) | 4338 (17.0) | 23473 (-6.9) |
| 2012-13 | 13,031 (-4.1) | 63750 (9.2) | 5536 (-10.1) | 4220 (-2.7) | 24211 (3.1) |
| 2013-14 | 12,769 (-2.0 | 67460 (5.8) | 6798 (22.8) | 4944 (17.2) | 25979 (7.3) |
| 2014-15 | 13,960 (9.3) | 62826 (-6.9) | 7003 (3.0) | 4937 (-0.1) | 25086 (-3.4) |
| 2015-16 P | 10,07 (-27.8) | 65475 (4.2) | 6811 (-2.7) | 4920 (-0.3) | 25482 (1.6) |

Source: Pakistan Economic Survey, 2015-16

## Predominant Conservation Systems in Major Cropping Systems

### Rice-based Cropping System

The rice-wheat growing areas in Pakistan are primarily situated in central Punjab (main districts include Gujranwala, Sheikhupura, Narowal and Sialkot) followed by Sindh (Table or Figure 1). The rice-wheat cropping system in Pakistan is the major one with an estimated area of 1.6 mha. In the system, rice is traditionally grown by transplanting 25-35 days old seedlings in well-puddled and continuous flooded field. This method of rice establishment is a time-consuming, tedious and inhuman and involves high cost of labour, water, and land preparation. Wheat sowing after the paddy harvest is delayed, resulting into poor crop stand and low grain yield. Wheat crop is also badly affected by flood irrigation due to poor drainage of paddy soils. Consequently, the productivity of the system remains far below the potential yield levels of modern cultivars.

The rice-wheat system, one of the major cropping systems of the South Asia and parts of East Asia, requires special management. Rice grows well on puddled compacted soil, whereas wheat grows best on well-drained soils. The hardpan developed with puddling operation is important for water retention and weed control in rice, but compacted soil creates problems of water logging for wheat. In addition to this, the traditional land preparation after rice harvest results in later wheat sowing dates than optimum. Due to these management differences and traditional cultural cultivation practices, the productivity of the rice-wheat system is stagnating and its sustainability threatened.

This can only be possible if the planting techniques of rice or wheat crops are improved resulting to saving of time, cultivation cost and irrigation water. Resource conserving technologies (e.g. zero-tillage, bed planting or direct seeding of rice) can be helpful in the achievements of major goals.

**Maize-based Cropping System**

Maize is one of the major crops and is ranked third among the cereals after wheat and rice in production and achieves the highest-yield in Pakistan. There is an increasing trend in maize production which mainly comes from productivity enhancement. The contribution of maize to the total value added in agriculture remained at 2.1 percent and to the GDP at 0.4 percent during 2013 to 2014. It was planted at an area of 1.12 million hectares (ha) (65% irrigated, and 35% rainfed) resulting in a production of 4.53 million tons.

Pakistan has already been on the list of the top 30 producers of the world during 2012. The country ranked 31st in area under maize cultivation, 29th in total maize production and 68th in yield among the maize growing countries of the world (FAOSTAT, 2013).

Maize, the highest yielding cereal crop in the world, is of significant importance for countries like Pakistan where demand from a rapidly increasing population has already out-stripped the available food, (Memon et al., 2012, Memon et al., 2011, Ullah et al., 2011, Durrishahwar, 2008) feed and fodder supplies (PARC, 2013). Maize is traditionally a summer crop grown mainly in the two provinces, Khyber Pakhtunkhwa (KPK) and Punjab. The introduction of hybrid maize, particularly planted in the spring season in Punjab, with yields averaging 8–9 tons per hectare (t/ha) has revolutionized maize production (Salam, 2012). Since 1991, maize area, production and yield depicted a positive growth. The growth in production of maize (9.43%) largely came from productivity gains (8.82%) with a very slow growth in area (0.61%) during the last decade (2001-2010). Being a multipurpose crop, maize provides raw material to industry and feed for livestock and poultry production as well. It contributes more than 10 percent of all agricultural production and 15 percent of agricultural employment in the country (Khaliq et al., 2004). It is equally important for subsistence as well as commercial farmers.

The use of maize in Pakistan, for direct human consumption, is declining, but its utilization in the feed and wet milling industry is growing at a much faster pace than anticipated (Tariq and Iqbal, 2010). The major demand for maize comes from the feed sector followed by wet milling (Shah et al., 2014). Demand for maize, largely from the poultry and livestock subsectors, is expected to increase and more can be done to add value to Pakistan's maize crop (USAID 2009). The wet milling of maize produces an array of products, by-products and value addition (GoP, 2014). The growth in poultry and livestock sector, in addition to other industrial uses and human consumption, further triggered the demand which helped the food and feed industry to offer competitive prices to maize growers (SMEDA, 2008). Based on inter- market price data (Shah et al. 2014) reported that maize markets were integrated and price signals were well communicated from the Lahore market located in the maize production hub in Punjab. They also highlighted that the maize trade depicted a fluctuating trend in the past, but since 2008 to 2009, Pakistan has been a net maize exporter. Increase in production coupled with the stability in prices of maize helped to increase the income of the farmers due to the increased adoption of hybrid maize. This also helped to increase maize productivity.

### Fruit based cropping system

Pakistan is blessed with many horticultural crops, which are highly important in the economy of Pakistan. They include fruits, vegetables, flowers and ornamental plants. The fruit industry in Pakistan has made remarkable progress during the last four decades. The important fruit crops of the country are: i) Citrus - Kinno, Mandarin, Red Blood, Musambi; ii) Mango - Langra, Sindhri, Dusehri, Chaunsa, Anwar, Ratol, Begun Pali; iii) Grapefruit - Marsh seedless Shambler; iv) Lemon - Kagzi lemon; v) Date palm - Asil, Begum Jungi, Dhaki, Halini Fasli; vi) Apples - Golden delicious, Red delicious, Mashdi, Amri; vii) Pomegranate - Behi-dana; viii) Guava - sufaida; ix) Apricots - Char Maghzi; ix) Peaches - Florida King, Early grand; x) Plums - Santa Rosa, Stanley; xi) Almond - Kaghzi, Besta; xii) Banana; xiii) Papaya; ixv) Ber;

xv) Custard Apple; xvi) Coconut; xvii) Jamun; xviii) Sweet Orange; ixx) Pear; xx) Custard apple; xxi) Phalsa; xxii) Tamarind; xxiii) Groundnut; ixxv) Walnut.

### Vegetable based cropping system

Vegetable production in Pakistan is diversified and more than 36 species are grown and consumed in summer and winter. Pakistan possesses diverse climatic zones, making it possible to cultivate many kinds of vegetables. There is substantial inter-provincial trade of vegetables and presently, large quantities of winter vegetables are transported to different markets. Vegetable Program, HRI**,** National Agricultural Research Centre (NARC) trained a large number of male and female members of the community for capacity building at various locations. Moreover, various interventions have been designed and proposed to address the issue of food security

### Off-Season Vegetable Production Using Plastic Tunnel

Before 1990 in Pakistan, especially in Punjab & Khyber Pakhtunkhwa mostly vegetables were grown in two seasons i.e. summer and winter. In winter season, acute shortage of summer vegetables like tomato, cucumber, pepper is experienced and their prices goes very high. On the otherhand during main growing season prices are very low due to glut in production and sometime farmers could not even cover their expenses. Off-season vegetable production technology was initiated by Vegetable Programme, NARC in 1984-88 under the expert guidance of Turkish, Dutch and Italian consultants.

| Technology/ product | Year | Adoption (% Area) | Diffusion Area | Farmers Benefited | Impact |
|---|---|---|---|---|---|
| High Plastic Tunnel | 1984-88 | 80-90 | Punjab & Southern Khyber Pakhtoon Khawa | >200/ year | 45,000 Thousand acres |
| Methodology | Modified protected vegetable production technology according to indigenous requirements/resources. | | | | |
| Process | Through research/development activity. | | | | |
| Mechanism | On-farm demonstration and feedback from progressive farmers for more productivity and profit. | | | | |
| Knowledge generated | Production of summer vegetables in winter season to fetch higher price. | | | | |
| Information generated | Year round availability of summer vegetables. | | | | |

### Early Production of Cucurbits through Seedlings

In Pakistan, cucurbit crops: vegetable marrow, bitter gourd, cucumber, muskmelon, long melon, water melon, bottle gourd and sponge gourd etc are being grown over a larger area. Mostly the farmers are growing cucurbits in the normal growing season (mid-February to mid- March) by sowing of direct seeds and when such vegetables are harvested, the markets are flooded with these vegetables and the growers sometimes not even getting back their cost of production. Whereas the prices of the early season cucurbits are always two to three times higher than their normal season. Early crop by 20-25 days can fetch better price than the normal. Nursery of cucurbit crops can be raised in polythene bags/glasses under very simple and low cost protected structures like walk-in tunnels. Seedlings of the desired cucurbits are raised in the last week of December up to mid of January and 40-60 days old seedlings are transplanted in the open field from mid-February to first week of March. The technology is very effective for producing early crops.

| Technology/ product | Year | Adoption (% Area) | Diffusion (% Area) | Farmers Benefited | Impact |
|---|---|---|---|---|---|
| Early Production of Cucurbits through Seedlings | 2000 | 25 | Punjab/ Khyber Pakhtoon Khwa | >200/ year | 1 thousand acres |

| | |
|---|---|
| Methodology | Experimentation (Research trial) |
| Process | Research experiments on NARC field. |
| Mechanism | Raising seedlings in polytubes/multi-pots/poly glass. |
| Knowledge generated | Early production of cucurbits to get more return. |
| Information generated | Prolonged availability period. |

### Autumn Onion Production

Onion is grown throughout Pakistan in varying volumes and with different harvesting periods. However, supply of onion falls in short of requirements from December-January and prices soar to more than five times compared with normal season. The traditional method of producing autumn season crop is through seedlings which are raised in first week of July. It is difficult to manage nursery seedlings of autumn crop because of high temperature and monsoon rains. This difficulty can be overcome through direct planting of onion sets and to eliminate the step of nursery raising. Size of onion set is closely related to subsequent bulb yield. Set size in the range of 17-21 mm diameter produced the highest marketable bulb yield of onion.

### Onion Bulb Production through Sets

The autumn crop of onion through sets is planted from mid-August to first week of September. About 550 kg sets of 17-21 mm diameter are required for planting one acre of land. Onions are usually planted in the field at 10 cm plant-to-plant and 25 cm apart in rows on flat beds.

| Technology/ product | Year | Adoption (% Area) | Diffusion (% Area) | Farmers Benefited | Impact |
|---|---|---|---|---|---|
| Autumn onion | 2002 | Slow less than 10% | Limited- Southern Punjab & Balochistan | >100/ Year | <500 acres |

| | |
|---|---|
| Methodology | Production of mini-bulbs/onion sets during summer and plantation in Autumn season |
| Process | Raising of onion seedling at narrow spacing to get mini-bulbs for planting in August. |
| Mechanism | Comparison of growing onion crop through seedling and onion sets. |
| Knowledge generated | Off-season production of onion for better economic return. |
| Information generated | Avoid nursery raising issues during hot and rainy season. |

### Vegetative Propagation of Tomato

Growing hybrid tomato through seed is very much expensive due to high prices of the hybrid seeds (Rs. 3-4/seed) which a poor farmer can't afford for each crop; therefore, there was a dire need of exploration of an efficient method of vegetative propagation of tomato seedlings for its cheaper multiplication and cultivation. For off-season crop of tomato, indeterminate hybrids are used which require regular pruning of lateral shoots for single stem maintenance. The use of cuttings to raise tomato crops has fundamental importance for farmers, mainly due to high cost of seeds. The vegetative propagation technology of tomato via lateral shoots will be an alternative for the commercial cropping. Vegetative propagation through lateral cuttings is often faster, easier and cheaper than that of crop raised from seed, as it takes 5 to 6 weeks to grow a tomato seedling of transplanting size.

| Technology/ product | Year | Adoption (% Area) | Diffusion (% Area) | Farmers Benefited | Impact |
|---|---|---|---|---|---|
| Vegetative Propagation of Tomato | 2011 | Newly introduced | In progress | >50/ year | Adopted by some P.F. |

| | |
|---|---|
| Methodology | Experimentation (Research trial) |
| Process | Vegetative propagation of tomato (indeterminate) |
| Mechanism | Comparison of vegetative propagated plants with seedlings of tomato. |
| Knowledge generated | Availability of cheaper tomato hybrid plants. |
| Information generated | More profit due to less expenses on hybrid tomato plants. |

**Vertical Vegetable Production**

| Technology/ product | Year | Adoption (% Area) | Diffusion (% Area) | Farmers Benefited | Impact |
|---|---|---|---|---|---|
| Vertical Vegetable Production | 2012 | less than 10% | Punjab & Khyber Pakhtoon Khawa | >100/ year | <200 acres |

| | |
|---|---|
| Methodology | Experimentation (Research trial) |
| Process | Vertical vegetable production through staking |
| Mechanism | Comparison of growing vegetables horizontally. |
| Knowledge generated | Yield enhancement through increase in plant population |
| Information generated | More profit due to higher yield |

**Fisheries based system**

Fishery and fishing are important means of food in Pakistan’s economy and is considered to be a source of livelihood for the coastal areas.. During 2015-16 (July-March), total marine and inland fish production was estimated 501,000 m. tons out of which 368,000 m. tons was marine production and the remaining catch came from inland waters. Whereas the production for the period 2014-15 (July-March), was estimated to be 499,000 m. tons in which 365,000 m. tons was marine and the remaining was produced by inland fishery sector. A total of 91,965 m. tons of fish and fish preparations was exported during 2015-16 (July-March).

Pakistan's major buyers are China, Thailand, Malaysia, Middle East, Sri Lanka, Japan, etc. Pakistan earned US $ 240.108 million.Whereas, the export of fish and fish preparations for 2014-15 (July-March) was 99,203 MTs amounting US $ 253.497 million. The exports of fish and fish preparations have been decreased by 7.30 percent in quantity and in value have been decreased by 5.28 percent during 2015-16 (July-March). Government of Pakistan is taking a number of steps to improve fisheries sector. Further number of initiative are being taken by MFD and provincial fisheries department which includes inter alia strengthening of extension services, introduction of new fishing methodologies, development of value added products, enhancement of per capita consumption of fish, up-gradation of socio-economic conditions of the fishermen's community.

**Pasture based cropping system**

The total pasture area in different parts of Pakistan is 45.2 million hectares. Due to misuse and centuries of overgrazing, the productivity of rangelands has been adversely affected. At present, rangelands are producing only 10 to 15% of their potential. This low productivity can be increased by adopting various management practices such as periodic closures, re-seeding, and improved grazing management etc. Small-holders raise ruminants in limited numbers in conjunction with food and cash crop production. Although cropping patterns vary from region to region, they dictate forage quantity and quality throughout the year. Pasture resources in the ruminant production systems are presented below.

**Pastures resources in irrigated areas**

In this system, cut-and-carry feeding plays a vital role in ruminant production. Every farmer allocates a piece of land for planting fodder crops in irrigated areas of Pakistan. Usually milking buffaloes and cows are stall-fed with green fodder and concentrates. The non-milking and draught animals are maintained on straws, maize stovers, and community grazing lands. During summer, most land is planted with sorghum, maize, cotton, rice, and sugarcane. Forage sorghum, millet, and maize provide the bulk of fodder for stall-feeding. Most of the area after rice and cotton harvest remains fallow and is used for grazing of volunteer species. During winter every farmer plants mixtures of Egyptian clover (Trifolium aegyptium) and oats (Avena sativa) according to the land holding and herd size. Mixtures of berseem (Trifolium alexandrinum) with rice and wheat straw also provide feed during winter. Other crop residues such as dry maize and sorghum stalks, sugar cane tops, and rice stubble are also a component of livestock diets. With the increased demand for milk, meat, and other dairy products, some farmers cultivate large areas with lucerne (Medicago sativa), berseem, oats, maize, and sorghum around the big cities and sell green fodder to farmers raising buffaloes and dairy cows. Urban cattle also graze on vegetable and fruit wastes. Community and government wastelands are utilized to some extent.

**Pasture resources in rainfed areas**

Nearly 24% of the rainfed tract of the country is unfitting for agronomic or forestry crops due to unfavourable soil or climatic conditions. These large areas of land produce grasses and bush. Livestock alone are capable of utilizing this extensive and renewable natural resource. Animal husbandry thus occupies a vital place in the economy of the rainfed areas. Natural grazing on the vast rangelands provides about 20% of the nutritional requirements of cattle and 60% of that of sheep and goats. The flocks and herds of the land-less farmers subsist almost entirely on the rangelands. However, they have been badly over-grazed, and palatable species of grass have perished and been replaced by vegetation that livestock do not relish. The carrying capacity of rangelands has thus been greatly reduced to 10 to 50% of potential.

**Conservation Agriculture for sustainable intensification of agriculture**

- Policy - The ministry of National food security and research, government of Pakistan prepared a draft on Agricultural policy recently. The resource conservation is mainly focussed in the policy.
- Technologies

**Bed and furrow planting of crops**

It is sowing of crops on the raised leveled surface. Crop is sown on beds in lines Size of bed and furrow depth depends on the type of crop and soil. Bed planter is used for making beds and/or sowing seeds. Using either Dry or Wet sowing method crop can be sown. Irrigation is applied in the furrows. For the sowing of wheat, University of Agriculture Faisalabad has developed a university bed planter machine. It makes two beds and three furrows in the same operation; bed width is 2 feet with four rows of wheat sowing on it, and furrow width is 1 foot. The first row of wheat on bed is sown 3 inches away from either side of furrow, and 2$^{nd}$ row is sown 5 inches away from first line from either side; between these two lines there is a buffer zone with width of 8 inches for the accumulation of any salt. In this planting geometry of crop, plant population is not reduced in any way. This technology saves 40-50%

water, reduces the seed rate upto 10%, better weed control and 20% increase in the yield of the crop has been achieved. Similarly, other crops can also be grown successfully on beds such as cotton etc.

**Crop residue management**

Evidence is now appearing that the productivity of rice-wheat system is stagnant and total factor productivity is declining because of a fatigued natural resource base and, therefore, sustainability of rice-wheat cropping system is at risk. A huge amount of crop residues (7-10 t/ha) is produced annually in this cropping system. Recent mechanization in harvesting paddy through combine harvesters leaves a sizeable amount of rice straw in the field. About 40 per cent nitrogen (N), 30-35 per cent phosphorus (P), 80-85 per cent potassium (K), and 40-50 per cent sulfur (S) acquired by rice during its growth remains in vegetative plant parts at crop maturity. Rice and wheat exhaustively feeds the nutrients and the rice-wheat system is heavily depleting the soil of its nutrients. A rice-wheat system yielding 7 t/ ha of rice and 4 t/ha of wheat removes more than NPK 300:30:300 kg/ha from the soil. A 10 t/ha crop removes more than 730 kg NPK/ ha that is rarely returned under the current cultural practices.

The malformed practice of straw removal in case of wheat, and burning for rice crop, has posed serious edaphic and ecological problems. A farming system that does not take in to account of proper residue management may result in mining the soil of major nutrients leading to net negative balance and multi-nutrient deficiencies in such a system. Declining soil fertility due to poor crop residue management has been acknowledged as a major agricultural problem in many developing countries. This is also one of the obvious reasons for the yield decline in the rice-wheat system.

Farmers commonly remove wheat straw for feeding the animals. However, rice straw due to high lignin and silica and low protein content demerits for this purpose. Its management remains a key issue as it interferes with tillage and seeding operations. Burning is a common farming practice to dispose crop residues/stubbles in R-W system. Wheat plantation after paddy harvest is energy and time consuming process and is also becoming expensive due to sky rocketing fuel prices. Preparation of field vacated by rice involves removal or utilization of rice stubbles/straw. Disposal and utilization of these in the short time is difficult, compelling farmer to burn the residues to have a clean field. Nonetheless, burning helps clear soil surface and control soil borne pest and pathogens, it otherwise contributes to air pollution, killing of beneficial soil insects, microorganisms and massive loss of nutrients that can be recycled into the system.

Burning caused almost complete loss of N, the most limiting nutrient in crop production. Burning of crop residues has been identified as the potent source of emission of greenhouse gases. Burning of one tone straw can produce as much as 3 kg particulate matter, 60 kg $Co_2$, 1460 kg Co, 199 kg ash and 2 kg $So_2$. Such emissions bring modifications in atmospheric chemistry of regional environments that has linkages with global climate change scenario. Long term burning could have a negative impact on microbial population as well as their diversity which may take 5 years or longer to recover. Bacterial population involved in nitrification is particularly vulnerable to burning. Contrarily, residue retention and incorporation is believed to increase the same.

Management of rice residues offers a great challenge to agriculturists for enhancing sequestration of carbon and maintaining the sustainability of production. Crop residue is a valuable natural resource and needs to be managed as an important component of the system for improving soil health, managing weeds and sustaining the natural ecosystem, as well as enhancing productivity. Several management options like incorporation, surface retention, mulching and direct seeding in zero tillage can be opted as alternatives to current detrimental practice of residue burning. Every option has its own merits and demerits and needs to be evaluated for specificity of location, soil and situation. Assessing the impact of different residue management practices on soil characteristics can serve as an important tool in developing fertilizer recommendation practices.

Among a wide range of soil management practices aiming at restoring soil fertility, use of organic amendments particularly the use of crop residues seems striking one as it is abundantly and readily available. Incorporation of plant residues, coupled with appropriate tillage, can increase soil organic carbon, or if used as mulch, the residue can modify soil temperature, conserve moisture and help control weeds by smothering and allopathic effects.

**Laser land leveling**

It is a process of smoothing the land surface (± 2 cm) from its average elevation by using laser-equipped drag buckets, soil movers which are equipped with global positioning systems (GPS) and/or laser-guided instrumentation. To level the land, soil can be moved either by cutting or filling to create the desired slope/level. This technology gives uniform soil moisture distribution, better water application and distribution, good germination, enhanced input use efficiency, reduces weed, pest, and disease problems, reduced consumption of seeds, fertilizers, chemicals and fuel and improved yields. It may have cost and expertise constraints.

### Direct seeding of Rice

It is a cost effective technology for the seeding of rice crop. The dry seed is drilled into the non-puddled soils with proper land leveling and weed control measures. Sowing of seeds at a depth of 2-3 cm is done with zero till, minimum till machine or broadcasting it after ploughing and leveling the field at @ 30-37kg/ha (please make ha for uniformity) , fine and Basmati varieties will need 25-30 kg/ha. The seed is then covered with the thin layer of soil to aid in proper germination and to avoid the birds' damage. Soil moisture in soil should be sufficient for better germination. The sowing of crop starts from end of May to start of June. The problem of weeds is tackled by application of pre-emergence herbicides or by stale seedbed method. Next weeding can be done manually. This technology saves water by 10-30%, avoids soil degradation and plow-pan formation, saves labor, energy, fuel, seeds, and gives 10% higher yields with 10-15 days' early maturation of crop.

### Zero tillage

Zero tillage is one of a set of strategies aimed to enhance and sustain farm production by conserving and improving soil, water and biological resources. Essentially, it maintains a permanent or semi-permanent organic soil cover (e.g. a growing crop or dead mulch) that protects the soil from sun, rain and wind and allows soil micro-organisms and fauna to take on the task of "tilling" and soil nutrient balancing – natural processes disturbed by mechanical tillage systems. For example, there was a lot of problem of rice stubbles for the sowing of wheat, farmers were burning the residues destroying soil or managing it by disc plough or rotavator increasing cost of production. To address this issue; new technology of Turbo seeder has been introduced. It cuts and churns the stubbles and places it between the rows of seed drilled into the soil by inverted 'T' shaped openers. There is no problem of operation or germination as observed in Zone disk tiller and Happy Seeder. It decreases cost of production; improves soil health, saves water, labor and energy.

### Drip irrigation

Widespread appreciation of the "global water crisis" recognizes that scarcity of clean water is affecting food production and conservation of ecosystems. By 2025, it is predicted that most developing countries will face either physical or economic water scarcity. So we have to go for efficient irrigation methods. Drip irrigation is one of them. It irrigates the plants drop by drop on the soil surface or directly into the root zone with the help of network of pump, valves, pipes, tubing, and emitters. It reduces evaporation, controls weeds, increase water and fertilizer use efficiency, saves water and fertilizer and increase yields.

**Sprinkler irrigation systems**: maximize efficiency and minimize the labor and capital requirement and, at the same time, maintain a favorable growing environment for the crop. Hence they are recommended for varying soils, topography and crops. Flexibility and efficient water control have permitted a wide range of soils to be irrigated that have surface water applications, thereby allowing more land to be irrigated. Beginning has already been made in Pakistan to provide supplemental irrigation to *rainfed* lands and irrigated areas outside the Indus basin where water is at premium.

Sprinklers often have multiple uses. The same equipment can be used for irrigation, crop cooling, frost control and application of pesticides, herbicides and fertilizers. Many farmers in barani areas, which annually receive more than enough precipitation to satisfy crop requirements, are installing supplemental irrigation systems. This is due to the fact that usually there is no rain at right time in the required quantity. Timely irrigation at a critical crop growth stage can offer more than double yield by applying only a few centimeters of water. In areas where labor and water costs are high, sprinklers can be the most economical way to apply water. Sprinklers can also be used to increase the quantity and quality of fresh vegetables and fruits for markets, where color and quality are given importance.

### Solar water pumps

With the current energy crisis scenario all over the world, and especially for Pakistan it is need of the day to utilize renewable energy sources for power generation to use for different purposes. Solar water pumps get solar energy from the sun and convert it into electricity by which water pumps can run for pumping of water for irrigation purposes. It is economic and environmental friendly technology. In comparison with the Diesel pump system, following are the benefits of solar pump system;

- Simple installation
- No moving part.
- Noise less operation
- No emission of carbon dioxide and Sulphur dioxide
- 20 years' life
- Zero Operation and maintenance cost
- No fuel required.
- Real energy independence.
- Un-manned operation (automatic start and stop)

**Biogas Plants**

Biogas is a flammable gas produced from renewable resources that can be used in many applications as an alternative to fossil fuel-based natural gas. A biogas plant is an anaerobic digester of organic material for the purposes of treating waste and concurrently generating biogas fuel. The feedstock of this plant is the animal dung, plant material, grease food wastes etc. Biogas converts this farm waste to biogas which can be used for home cooking purpose, lightning and for pumping water for irrigation. The slurry is being used to enhance soil fertility and soil health.

- **Extension** (advisory, inputs etc)

**Extension of Direct Seeding of Rice Technology**

- Modified wheat drill for rice seed drilling-reduced seed breakage from 5.1% to 1.7%
- Established 243 DSR plots which resulted in yield increment 12-20% and average benefit of Rs. 3,000-6,000 per acre.

Demonstration of Alternate Wetting and Drying (AWD) • Farmers saved 2-4 irrigations with AWD and water saving of worth Rs. 2000-3000/acre and 3-5% high yield.

**Dissemination of Conservation Agriculture Technologies**

Partnership developed with 10 national partners (Agriculture research, extension and private sector)

- On – Farm CA technologies demonstration: Zero tillage wheat after rice, mung and maize; Ridge planting of wheat, Bed planting and better agronomy on 300 sites in 20 districts
- Training: 144 include 127 men and 17 women • Field Days: 700 farmers participated; it resulted in better yield, saving of irrigation water and saving in cost of cultivation.

**Pilot testing of New Conservation Agriculture Planters**

Provision of CA planters to partners (Agriculture Research, Extension and private)

- Multi crop bed planter for maize, cotton and wheat
- Plant various crops with one planter with inclined plate seeding system
- Planted maize, cotton, and wheat on 50 sites across the country
- Zero tillage Happy Seeder in rice-wheat area
- Timely wheat planting on 25 sites under heavy residue without burning of rice residue

**Policy Intervention, Research and Extension on Conservation Agriculture Management**

Under agricultural resources, generally soil and water is considered. Some authors may like to include farm labour also in the above list. From the point of view of CA, however, it is soil and water which would merit our attention most. Soil erosion and water-logging have been described as ‘creeping death’ and ‘cancer of soil’ respectively by some authors. They constitute a real threat to our agricultural and hence to our economy in general. It goes without saying that the conservation and judicious utilization of these resources is not only important for the coming generations but also and probably more so for the present generation. The long-run policy for the conservation of agricultural resources should aim at maximum community participation in conservation practices. The state participation, however, would be required to a large degree in the short-run because the problems of water-logging, alkalinity and soil erosion are serious national problems which can’t be coped with effectively by individuals or even communities, in their present state. They need government action immediately. Once, however, the problem has been reduced in magnitude, and the communities have been trained and indoctrinated in the use of conservation practices, governments, role may be gradually reduced.

**Best practices of conservation agriculture (by crop/by farming systems)**

**Zero tillage technology for wheat**

In Pakistan, under rice-wheat cropping system, farmers grow rice in Kharif season followed by Wheat in Rabi season. The total area under rice in Pakistan is about 2.4 million hectares, out of which 62 percent of rice area is in Punjab alone. Out of total rice area in the country, 50 percent is under fine rice varieties.

Farmers in the Indo-Gangetic Plains are rapidly adopting zero-tillage for sowing wheat after rice. Because of the benefits from zero tillage i.e. more yield, cost effectiveness, significant saving in water, soil quality and inputs, the zero tillage area surpassed 200,000 hectare in the year 2001 in the Indo-Gangetic Plains and its adoption is expected to exceed one million in the next few years because local manufacturers are trying hard to fulfil the equipment demand. In India and Pakistan on an average, there is a net benefit of US$150 per ha, through higher yields and less land preparation cost (Gupta, 2002). The zero-tillage technology is widely maintained as an integrated approach that can tackle the problem of wheat yield stagnation in the rice-wheat zone by improving planting time, reducing weed infestation, and enhancing fertiliser and water use efficiency [Malik and Singh (1995); Malik (1996); Hobbs, et al. (1997, 2002)]. It is observed that zero-tillage technology helps in reducing the Phalaris minor weed infestation and also enables timely seeding of the wheat crop [Hobbs, et al. (1997)]. With comprehensive efforts being done by OFWM, the new technology has entered now in the critical phase of mass-scale development and promotion. During the past two years substantial wheat acreage was sown with zero-tillage drill. It stood at about 30 thousand hectares during rabi 2000-01, which increased to almost 80 thousand hectares during rabi 2001-02. The experts attribute this acceleration in the adoption of the technology to its benefits like: reduction in sowing cost, increased fertiliser and water use efficiency, ease in operation at hard and low lying fields, and considerable improvements in wheat yields through timely planting and better crop stands established.

**Direct seeded Rice**

Direct Seeded Rice (DSR) in place of the traditional transplanted rice is a way to reduce labor charges for nursery raising, puddling and transplanting. DSR is sown directly into the moist soil like wheat, corn or cotton and does not need continuous submergence so it reduces overall water requirement also. Precision levelling is desirable, it increases water efficiency, improves crop stand and optimize input use.

**Advantages of DSR:** DSR saves labour up to 75 % and water saving up to 30 %. The crop matures early as compared to conventional rice transplanting. After rice crop, following wheat crop can be sown timely due to wider time window as compared to transplanted rice. In case of DSR, puddling of soil before rice plantation is not done which saves lot of machinery operation saving lot of energy in term of fuel consumption by machinery. Moreover, DSR avoids soil compaction since puddling is not done.

### Bed and Furrow planting for cotton wheat maize and rice

Bed and furrow planting technology permits growing of crops on bed with less water. This technique has been tested for various crops and proved quite successful for cotton, maize, wheat, rice etc. Cotton was grown on 1.22 million hectares by adopting this practice. Wheat during 2003-04 has expanded to 2000 hectares. The following advantages have been observed widely in the country.

I. Efficiency of irrigation water is improved.
   a. Bed planting facilitates irrigation before seeding and thus provides an opportunity for weed control prior to planting.

II. Plant stand is better due to bed plantation

III. There is considerable saving in seed due bed planting.

### LASER Land Levelling Technology

Effective land leveling is meant to optimize water-use efficiency, improve crop establishment, reduce the irrigation time and effort required to manage crop. Laser technology can ensure very accurate and precision land leveling to extent of +2 cm. Laser land leveling adopted in Pakistan has shown encouraging results under zero tillage technique wheat is sown using residual moisture with no or minimum tillage without irrigating the fields with the aim to sow wheat in time after rice, conservation of water, and reduced cultivation cost (Akhtar, 2006). Precision land leveling is being promoted since inception of OFWM Program. Use of LASER technology in the precision land leveling is the latest development, which was introduced in the Punjab during 1985. The LASER controlled land leveling system consists of a LASER transmitter, a signal receiver, an electrical control panel, and a solenoid hydraulic control valve. The LASER transmitter transmits a LASER beam, which is intercepted by the signal receiver mounted on a leveling blade attached to the tractor. The control panel mounted on the tractor interprets the signal from the receiver and opens or closes the hydraulic control valve that raises or lowers the leveling blade. The same has proved to be highly beneficial because it minimizes the cost of operation, ensures better degree of accuracy in much lesser time, saves irrigation water, ascertains uniform seed germination, increases fertilizer use efficiency, and resultantly enhances crop yields. This technology is getting popular.

The World Bank assisted "Punjab Irrigated-Agriculture Productivity Improvement Project (PIPIP)" to install high irrigation system on 50,000 hectares, improvement of 5500 unimproved water courses, completion of lining on 1500 water courses, rehabilitation of 2000 irrigation schemes outside the canal commands and provision of 3000 Laser units to the Agricultural service provider since July 2012 in the entire province. It spans over a period of five years (2012-13 to 2016-17) with a total cost of Rs. 36,000 million (government share of Rs. 21,250 million, all IDA financing, and farmers' contribution of Rs. 14,750 million).

The key objective of the project is to maximize productivity of irrigation water. Government of the Punjab has launched ADP funded project entitled" Provision of Laser Land levellers to Farmers/ Service Providers on Subsidized Cost" at a total cost of Rs. 1,350 million for provision of 6,000 Laser land levellers to the farmers'/service providers during three years (2015-16 to 2017-18). It has been approved to provide one-time financial assistance of Rs. 450,000 per LASER unit, out of which half amount (Rs. 225,000) will be provided out of ADP funded "Provision of Laser Land Levellers to Farmers/ Service Providers on Subsidized Cost" and remaining Rs. 225,000 from the World Bank assisted PIPIP.

**Water course improvement**

Tertiary level irrigation system in the Punjab comprises of more than 58,500 watercourses. It has been established that a significant portion of irrigation water (40%) is lost in these century old community watercourses because of their poor maintenance and aging. The main sources of these losses are seepage, spillage, and side leakage from the watercourses, resulting from following factors:

i. Irregular profile and zigzag alignment of banks, with many points of weakness
ii. Variable cross section of water channels
iii. Silt deposition causing restrictions in flow and overtopping
iv. Trees, shrubs, and vegetation growing in watercourses
v. Damage caused by rodents and farm animals

vi. Frequent bank cutting and plugging for water abstraction

i. Drip Irrigation System

Drip irrigation is the most efficient method of irrigation. While efficiency of sprinkler system is around 75-85 percent, efficiency of drip irrigation system is 90 percent or higher. In drip irrigation much less water is wasted in irrigation. In the backdrop of growing shortage of water for irrigation, drip irrigation is an efficient technique to improve irrigation efficiency, saving water and protecting the land from becoming saline and water-logged as against flood irrigation, which has otherwise been causing salinity and water-logging. This system has great importance in arid and semi-arid regions of the country such as Balochistan, Cholistan and Thal in Punjab and Thar areas of Sindh. The government has already launched Rs.75 billion subsidized drip irrigation program for the next five years with a determination to improve irrigation efficiency. Pakistan has also sought for the help of Japanese government to double the efficiency in irrigation water use, with the help of drip irrigation technology to the extent of 90 percent. The government's endeavor is to ensure that at least 300,000 acres of land will be brought under drip irrigation this year for which federal and provincial governments would be providing 80 percent subsidy on drip irrigation equipment.

**Sprinkler Irrigation System**

Sprinkler irrigation systems are now being introduced in the country. They have been installed in several demonstration plots in the country. Furthermore, progressive farmers are also installing these systems in collaboration with Water Resources Institute (WRI), National Agricultural Research Centre (NARC), Islamabad. All the components are now locally manufactured in collaboration with the pump and plastic industry in Lahore.

CAEWRI-NARC, in collaboration with a local enterprise, has developed a range of sprinkler system using locally available materials and technology. The estimated cost of this sprinkler irrigation system is in the range of Rs10,000 -12,000 per acres for a system of at least five acres using diesel-operated pumps.

Major limitations for large-scale introduction of pressurized irrigation systems were availability of services to meet farmers need for design and installation of these systems, farmers' training and provision after such services, CAEWRI-NARC has established an Irrigation Service Support Programme (ISSP), for providing support to farmers in the installation of these systems and already extended these services to more than 25 farmers and a number of institutions. Farmers are bearing 100 per cent cost of these systems and the demand is so high that the WRI is not in a position to extend timely services to all the clientele.

The farmers from any part of Pakistan can contact WRI-NARC for designing of trickle or sprinkler system. They have to fill a form and return it to WRI-ISSP-NARC. After consultations with farmers, survey, mapping and designing of the system are conducted free of cost.

**Bio-gas Technology**

Pakistan, being an agricultural country, annually produces million tons of solid organic waste in the form of biomass such as corn cobs, cotton waste, rice husk, wheat straw, wheat stalk and other energy crop residues; this biomass has great potential for biogas production (Irfan et al., 2011). A single cow or buffalo may produce averagely fifteen-kilogram dung in a day. Almost 6 kg of dung can produce $1m^3$ biogas, so from this calculation a single cow or buffalo can produce almost $2.5m^3$ biogas in one day normally. Almost 2.5 KWh electrical powers can be generated from $1m^3$ of biogas (Waqar Uddin et al. 2016). In Pakistan, total 172.2 million livestock animals produce 652 million kg dung per day. This large amount of dung can be used for biogas production (Waqar Uddin et al. 2016). Biogas can also be produced from number of organic wastes like waste of banana stem, slaughterhouses wastage, waste of paper industry, poultry waste and street waste except animal dung (Zainol et al. 2008, Afzaeli et al., 2014). The present energy crisis of Pakistan can be overcome by utilizing this biogas as a renewable energy and alternative source. The total potential of biogas available in the country is 14.25 million meter$^3$ per day (Zainol et al. 2008)., Pakistan has installed its first biogas plant in Sindh in the year 1959 Pakistan Council for Appropriate Technology (PCAT) has installed 10 biogas plants installed in Azad Jammu & Kashmir in 1974. In the same year, Directorate General of New and Renewable Energy Resources planned to launch a project with the aim to set up 4000 biogas plants by 1986. Later on, Biogas Support Program (BSP) was launched to establish 1200 biogas plants in year 2000 and 10,000 biogas plants were projected to be established until 2006. Pakistan Dairy Development Company (PDDC) also took a part in biogas plant installation and 556 plants have been installed under this program by 2009 (Yadvika et al. 2004). There are 14,000 biogas plants with the cost of Rs. 356 million which have been installed by Rural Support Program Network (RSPN) starting from 2009 (GOP economic survey 2009-2010). Pakistan Council of Renewable Energy Technologies (PCRET) is installing various renewable technologies (RE) to overcome the present energy crisis. Since 2002, PCRET has installed 4016 biogas plants throughout the country. These biogas plants are producing 20, 545 $m^3$/ day biogas according to the government of Pakistan, Ministry of Science and Technology, 2014.

Biogas slurry is of high nutrient value and the economic benefits of biogas further increase if this is used/ sold as a fertilizer. The survey found that 81% of plant owners are in fact utilising biogas slurry in this way containing more in nutrients than other types of manure. This also reduces the use of chemical fertilizers. 15% of participants however, throw away the slurry believing this to be of less nutrient value than a normal fertilizer, it is therefore advised to provide further information on this to participants. 4% of participants are using slurry as fuel for cooking which they report it to be highly flammable.

**Solar Pumps**

Pakistan is an agriculture country. Due to recent load shedding and continuous increase in diesel & other fuel prices SRS is offering unique solar pump solutions. With our foreign partners we are helping the farmers to adopt technologies by which water can be conserved and to irrigate the land through alternative sources of energy. Water can be conserved by drip irrigation instead of flood irrigation. For drip irrigation we can utilize solar pumps which are now available in 1in, 2in & 2.5in dia. These pumps get power from solar energy through high quality PV panels. If the water table is up to 60ft then surface pump of low wattage is used, otherwise submersible pumps are used.

**Tunnel farming for vegetable production**

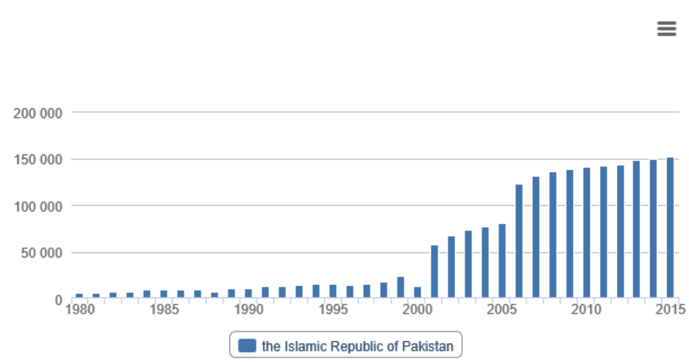
Fruit & Vegetable Development Project (FDVP) of the Punjab Agriculture department has installed 45 tunnels in six regions of the province. The regions selected for tunnel farming included Lahore, Rawalpindi, Multan, Sargodha, Toba Tek Singh and Rahim Yar Khan and the framers of 45 villages of these regions will be educated about cultivation of four vegetables, cucumber, tomato, green chili and capsicum, during off-season. The tunnels were set up over an area of 40 X 80 square feet for education purposes only while hybrid seeds would be used for cultivation as production of these seeds was more than normal seeds. On the other hand, the production of tunnel farming was 10 times more than normal farming, they added. Previously, tunnel framing was continued in only 600 hectares acre land of the province and now only in Okra and Sahiwal districts around 600 hectares land was being used for this farming only. So, vegetables tunnel farming has becoming a growing phenomenon in Pakistan. High demand for the produce followed by high returns and improved quality has motivated the farming community to enter into tunnel farming business. However, it is felt that there is a demand for technical know-how of this field in order for people to enter this business. The immense potential for advisory / consultancy business in tunnel farming cannot be ignored.

Fish Production

**Fish Production**

The graph below shows total aquaculture production in Pakistan according to FAO statistics:

Fish (000 tons)



### Challenges in Up Scaling Conservation Agriculture

Pakistan is an agricultural country, yet the agricultural sector is not able to produce the potential level of production from the existing resources. This is attributed to the lack of utilisation of modern technologies in agriculture, small landholding and high input costs. Lack of awareness is the first and foremost reason. The farmers who have knowledge about these technologies, the exact reasons for their reluctance in implementation of conservation agriculture in Pakistan include smaller farm size (< 1 ha), land tenure system, high-cost technology, unavailability of technology locally, heterogeneity of cropping systems or crop diversity and lack of technical expertise and knowledge. Perhaps the two major problems towards its implementation are small landholdings and high cost of this technology.

### Potential for Future Conservation Agriculture Research and Development

- Strong collaborative network is needed between scientists, extension workers and farmers to tailor conservation technologies as per local conditions.
- The necessary modification in machinery required may be done on priority to make technologies success by involving stake holders.
- The crop varieties may be bred keeping in view environmental changes involving breeding program.
- Training program for Farmers' awareness regarding conservation technologies must be on top priority.
- Since landholding is small, machinery may be designed/altered as per local needs to make conservation agriculture successful involving scientists, engineers, extension workers and farmers.
- The researcher and extension workers must work with farmers to popularize the technologies for mass scale adoption.

Since national agricultural research system (NARS) is poorly funded, ill equipped, weakly linked with international and national stakeholders, thinly staffed with mostly low capacity and unmotivated scientific manpower, lack autonomy, and generally mismanaged. The support to enhance the conservation agricultural in the country is needed from international donor. We are looking forward to be a part of any project on regional scale.

### Conclusions

There is a need to drive conservation agricultural technologies in Pakistan. It is suggested that despite small landholding and low income levels, conservation technologies can make a significant difference in the livelihoods of equipment operators and farmers. There is a good scope of many conservation technologies to be implemented in the country. In this perspective, farmers and government authorities should look forward to adopt new and sustainable technologies to increase the efficiency of available resources and reducing the inputs costs. Before a widespread implementation of conservation agriculture in the country, its effectiveness needs to be realised on experimental farms for different possible precision applications.

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# Best Practices of Conservation Agriculture in Sri Lanka

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## Introduction

Sri Lanka is a tropical island having a total land extent of 6.5 million hectare and a population of about 21 million people. Natural resource base with a great ecological diversity favors for growing wide range of crops. For example, 46 agro-ecological region (NRMC, 2003), 14 soils at great group level (Panabokke, 1996), topographic classes ranging from flat to mountainous (Dimantha, 1992) and 103 natural river basins with surface and sub surface water resources (NARESA, 1991) show the diversity of resource base. With this diversity, three major agricultural sectors namely plantation, export agriculture and food crops have been evolved and consequently many cropping systems have also been established in those sectors. Sri Lanka had almost all favorable factors in the past required for agriculture such as fertile soil and sufficient water resources with timely raining and favorable climatic conditions and labour resources familiarized with traditional systems. But it has been significantly affected by many factors; high demand for food due to population increase, economic policy changes, industry and commercial based monoculture, technology improvement for high productivity, climate changes and so on. Although conservation agriculture has not been prioritized in conventional agriculture, this paper discusses about the best practices still in operation which may strengthen conservation agriculture in Sri Lanka.

## Agricultural Scenario

### Land and land use

Total land area of Sri Lanka (6,552,500 ha) has been utilized for various purposes as indicated in the Table 1 and major topographic classes are given in Table 2.

Table 1. Land use categories and extent

| Land Use Category | Extent (ha) |
|---|---|
| 1. Agriculture (Tea, Rubber, Coconut, Paddy, & other crops) | 2,605,647 |
| 2. Urban Areas | 29,353 |

| | |
|---|---|
| 3. Forests, Wildlife, Reserves & Catchments areas | 2,000,000 |
| 4. Underutilized Lands | 728,800 |
| 5. Reservations (Reservoirs, Streams, & Irrigation Channels) | 585,300 |
| 6. Steeply sloping lands, unsuitable for Agriculture | 380,000 |
| 7. Barren Lands | 77,000 |
| 8. Highlands over 5000 feet (1600m) above mean sea level | 76,400 |
| 9. Mangroves & Marsh Lands | 70,000 |

Source: Department of Land Use Policy Planning, 2002

Table 2. Major topographic classes in Sri Lanka

| Topography class | Slope range (%) | Land extent ('000 ha) | Fraction of total land extent (%) |
|---|---|---|---|
| Flat to undulating | 0 – 8 | 4300 | 67 |
| Rolling | 8 – 30 | 730 | 11 |
| Hilly and mountainous | 30 – 60 | 1370 | 21 |
| Extremely steep | > 60 | 80 | 1 |

(Source: Adapted from Dimantha, 1992)

At the beginning of the twentieth century, the per capita extent of land in Sri Lanka was 10.53 hectares. With the increase in population up to 18.7 million by 2001 the per capita extent had decreased to 0.35 ha. At present, 21.2 million population has decreased it further (Annual Reports of Central Bank, 2001 and 2016). As the population continues to grow the per capita extent of land will further decline rapidly in the future. This trend has contributed not only the fragmentation of lands into small unproductive units but also to an acute shortage of arable land. According to the Census of Agriculture 2002, there were 139,465 agricultural operators engaged in agricultural activities but not owned any land (Censes of Agriculture 2002). This has led to encroachments on state lands and an increase in urban migration. On the other hand, extent of productive land is decreasing because of land degradation. However this demands for implementing proper land use policy, based on scientific approach.

## Climate and Climate Change

Geographical location of Sri Lanka is within tropics between 5° 55" to 9° 51" North latitude and between 79° 42"to 81° 53" East longitude and therefore, the climate of the country could be characterized as tropical.

Rainfall in the country has multiple origins. Monsoonal, convectional and expressional rains accounts for a major share of the annual rainfall. The mean annual rainfall varies from under 900 mm in the driest area to over 5,000 mm in the wettest area. The driest area fall in the Southeastern and Northwestern corners of the country while the wettest area fall in the western slopes of the central highlands. There is very unique temporal distribution of rainfall over the year which makes four unique climatic seasons in the country. Those are the first inter monsoon season (March to April), the Southwest monsoon season (May to September), the second inter monsoon season (October to November) and Northeast monsoon season (December to February).

Regional differences observed in air temperature over Sri Lanka are mainly governed by the altitude. The mean monthly temperatures differ slightly depending on the seasonal movement of the sun with some modified influence caused by rainfall. The mean annual temperature in Sri Lanka remains largely homogeneous in the low lands and rapidly decreases towards the highlands. In the low lands, up to an altitude of 100m to 150m, the mean annual temperature varies between 26.5$^{o}$C to 28.5$^{o}$C with an annual mean temperature of 27.5$^{o}$C. In the central highlands, the temperature falls quickly as the altitude increases. The mean annual temperature of Nuwara Eliya, a city located at an altitude of 1800 m, is 15.9$^{o}$C. The coldest month with respect to mean monthly temperature in the island is generally January, and the warmest months are April and August.

Depending on the total annual rainfall, the island has been divided into 3 major climatic zones namely Wet, Intermediate and Dry zones (Panabokke, 1996). The Wet zone is the area which receives mean annual rainfall of above 2,500 mm. The Intermediate zone receives mean annual rainfall of 1,750 to 2,500 mm. The mean annual rainfall of the Dry zone is below 1,750 mm. The temporal variation of the rainfall over the island is very prominent so that two distinct rainfall patterns are evident. In most parts of the country, the rainfall within the year shows a bimodal pattern while in the rest of the area uni-modal distribution pattern is evident. The bimodal distribution pattern shows two rainy periods and two dry periods within the year. One dry period falls during February to March while the other falls during July to September. Based on the three major climatic zones (to represent rainfall) discussed above and three elevations classes (to represent the temperature) namely, low country (< 300m), mid country (300 – 900m) and up country (> 900m), 7 agro climatic zones have been delineated in the country. They are Dry zone Low country (DL), Wet zone Low country (WL), Intermediate zone Low country (IL), Wet zone Mid country (WM), Wet zone Up country (WU), Intermediate zone Mid country (IM) and Intermediate zone Up country (IU). These 7 agro climatic zones have been further delineated into 46 agro-ecological regions (NRMC, 2003).

Recent climate changes can be described as increases in extreme events of rainfall, increases in temperature and increases in sea water levels. In most locations in Sri Lanka, annual rainfall has shown neither significant increasing nor decreasing trend in the face of recent climatic changes in the country. However, variability of annual and seasonal rainfall has increased during recent decades especially with respect to Northeast monsoon which is the source of water for the major cultivation season (Maha) in the country. It is also true for the first inter monsoon rains in the country, especially during April which is the major rain producing month of the minor cultivation season (Yala) in the dry and intermediate zones of the country. Increased occurrence of extremely rainfall events due to recent climatic changes has resulted frequent droughts and floods. Under such a situation, crop losses due to soil moisture stresses (decreased soil moisture) increased soil erosion and damages from storm water are some of adverse effects on farming systems. Increased temperature has been affected to yield of almost all crops grown in all farming systems. It also negatively affected plant protection due to increases in insect damages and infestation of various pathogens such as bacteria, virus and fungi. Increased temperature particularly in dry and intermediate zones of the country accelerates soil organic matter decomposition and thereby lowering soil health. As an island, Sri Lanka is highly vulnerable to increases in sea water level with varying degrees of sectoral impacts. Sea water intrusion to agricultural lands is vulnerable as a result of the changing climate which has lead to further reduction of land available for agriculture. Increased sea water level has also exacerbated coastal erosion in affecting coconut, and other low country crop cultivations.

**Crop Production**

Crops grown in farming systems has been the main source of foods in Sri Lanka. At present, about 106 food crops are grown in the country which include cereals (rice and maize mainly and millets), yams (mainly cassava, sweet potato and local yams), pulses (green gram, black gram, cowpea, soybean, groundnut), vegetable (mainly brinjal, capsicum, tomato, okra, snake gourd, ridge guard, bitter gourd, cucumber, sweet pumpkin, ash pumpkin, konl-khol, ash plantain, potato, cabbage, carrot, lettuce, bell paper, broccoli, beet, reddish, leak, beans, winged bean, vegetable cowpea, murunga, mushroom, jack and breadfruit), leafy vegetable (kathurumurunga, spinach, thampala, gotukola, mukunuwenna, kankun, and kohila), fruits (banana, pineapple, papaw, mango, passion fruit, sweet melon, cashew, grapes, orange, lime, strawberry, dragon fruit, star fruit, guava, avocado, sapodilla, anona, pomegranate, rambutan, mangosteen and durian), spices and condiments (cinnamon, pepper, cardamom, clove, nutmeg, vanilla, chilli, red onion, big onion, turmeric, ginger), beverages (tea and coffee), and other crops (coconut, sugarcane and sesame). In addition, considerable number of plants have been naturally grown in lands are also used as food. Furthermore, few crops which are not grown in the country are totally imported from other countries in order to meet consumer needs. Some of them are wheat, lentil, chick pea, pigeon pea, garlic, barley, oat, coriander, fennel, cumin seed, fenugreek and apple.

With the completion of the *Mahaweli* river diversion in 1980s, the largest water-energy-food nexus in the country, Sri Lanka achieved significant improvement in food security. However, some short duration shortages in food supply appear hardly due to spatial and temporal variations in food production and market. These issues have been addressing at present through making necessary improvements for food transport and storage. Need of enhancing production of major food crops in order to strengthen food and nutrient security and self sufficiency is always highlighted. At present, drought condition has badly affected to all crops especially to paddy production. Apart from that, significant fraction of crop produce of particularly fruits and vegetable is lost due to damages from wild animals (Kendaragama, 2015) and while transport. Although adoption of appropriate packing and transport technologies help minimize transport related crop losses, the damages from wild animals, mainly Elephant (*Elephas maximus*), Boar (*Sus scrofa*), Monkey (*Rhesus macaque*), Porcupine (*Hystrix indica*), Peacock (*Pavo cristatus*) and Squirrels are yet to be addressed.

**National Food Production Programme**

Sri Lanka spends around Rs. 200 billion annually to import main food items including livestock and fisheries products. However, there is a possibility of producing most of the imported food items domestically with high quality and it has been identified as a timely need in order to save the foreign exchange spent on food import. Considering the consumption pattern of Sri Lanka, nutritionists have recommended that a person should consume 200 grams of vegetables and fruits each per day. However, present day consumption level is 100 grams only. Current per capita consumption of sea food including fish is only 40 grams, although the recommended quantity is to be 60 grams per day. Further, a person in Sri Lanka consumes low level of dairy products despite the fact that 100 ml per day is required. This has been resulted in low level of nutrition among people in Sri Lanka. In considering the above facts, “National Food Production Programme” has been implementing for the period of three years from 2016 to 2018 to achieve self-sufficiency in quality food through strategies and activities, proposed by the relevant national and provincial line ministries, departments and institutions. Objectives of this programme are published as follows.

- Make the country self-sufficient in food which can be produced locally, utilizing the lands available in optimal manner thus saving foreign exchange on food imports.
- Produce sufficient quality food for people by adopting environmentally friendly cultivation methods and using chemicals for weeds and pests to the extent of minimum possible.
- Ensure food security through proper management of buffer stocks.
- Ensure balanced development in the country through introducing and implementing a food production programme based on agro-eco zones.
- Minimize production cost and maximize productivity through application of quality inputs and appropriate technological methods.
- Establish a proper coordination among all stakeholders who are involved in the domestic food production programme and make it part and parcel of daily life of people including school children, farmer organizations and civil organizations.

National Food Production Programme (NFPP) is the present agriculture drive in food crop sector implementing with the collaboration of all agriculture stakeholders; Presidential Secretariat, Ministry of National Policy and Economic Affairs, Ministry of Finance, Ministry of Agriculture, Ministry of Aquatic Resources, Ministry of Irrigation, Ministry of Plantation Industries, Department of Agriculture, Department of Agrarian Services, Irrigation Department, Department of Export Agriculture, Department of Animal Production, Mahaweli Authority of Sri Lanka, All Provincial Councils, All Provincial Ministries of Agriculture, Livestock, Fisheries and Irrigation, all District Secretaries and divisional Secretaries. Some of major crops commodities annual requirement and productions figures are given in the table 3.

Table 3. Annual food crop requirement and production

| Food crop | Total annual requirement (mt) | Average annual production (mt) | Total Production in 2016 (mt) |
|---|---|---|---|
| Rice | 2,400,000 | 2,800,000 | 2,900,000 |
| Maize | 320,000 | 250,000 | 243,960 |
| Groundnut | 30,000 | 26,000 | 24,200 |

| Food crop | Total annual requirement (mt) | Average annual production (mt) | Total Production in 2016 (mt) |
|---|---|---|---|
| Green gram | 24,500 | 14,000 | 14,546 |
| Soybean | 190,000 | 8,000 | 7,946 |
| Big Onion | 275,000 | 70,000 | 65,223 |
| Red Onion | 80,000 | 80,000 | 63,675 |
| Green Chili | - | 70,000 | 72,311 |
| Potato | 230,000 | 90,000 | 95,805 |

Source: Crop Forecasting Unit, Department of Agriculture, 2017

To achieve the targets of NFPP, specific projects were identified under main thrust areas; input management, empowerment of farmers, marketing, natural resource management and adaptation to climate changes, state-private sector partnership, youth and women participation, knowledge management, traditional knowledge and practices, research and technology development, consumer health and satisfaction, food security, legal regulation framework, development of irrigation infrastructure facilities and institutional coordination.

### Farming Systems

Farming systems are found in homogenous agro-ecological regions. Farming systems technology and art of living have been evolved together over a long period time for efficient and sustainable management of available resources within ecological setting of the region.

In Sri Lanka, farming systems can be grouped as per the use of water and soil resources. The major categories are irrigated farming, rainfed farming, organic farming and pastoral systems. In those systems, many differences can be identified in technology, social systems and customs too.

### Irrigated farming

Irrigated farming has evolved mainly in the dry zone of Sri Lanka and its long existence as a farming system shows the adaptability, strength and stability in the agro-ecological setting of Dry zone of Sri Lanka. There are three major farming systems identified within this category**.**

#### *Major irrigation systems*

Major irrigation system where larger reservoirs fed with perennial streams developed and maintained by the government organisations namely Department of Irrigation and Mahaveli Authority with a set of rules and regulation. Those systems were used exclusively for irrigation until recently. However, due to urbanisation of the dry zone those reservoirs have now been used for providing water in addition to irrigation.

***Minor irrigation systems***

Although this system was managed by famer organisations in village level in the past, at present it is administered by Agrarian Service department in collaboration with the farmer organizations. There are two systems in minor irrigation fed two different water sources; Minor tanks in Cascade Systems (cascade systems in dry and intermediate zone) and Anicut systems in mid country intermediate zones

***Minor tanks in Cascade Systems:*** The traditional cascade system has been developed as organization of small tanks into a cascading sequence within micro catchments and it allows greater efficiencies in water use (NARESA, 1991). This system has been confined to undulating terrain in the inland dry and intermediate zones of the country. In this nexus, rain-fed upland farming is practiced in tank catchment areas, runoff and subsurface flow is collected in to village tanks for community use, and excess water is used for paddy farming in the tank command area. Drainage of the paddy fields in the upper part of the cascade flowed into a downstream tank for reuse in paddy fields below (Dharmasena-2000).

***Anicut system in the central hills:*** This traditional anicut system has been emerged as an earliest attempt in irrigation and made through diversion canals from perennial rivers (Goonasekara and Gamage, 1999). The diversion canal runs along a contour and spills into a natural drainage canal. It has been confined to rolling hills and mountainous terrain in the wet and intermediate zones of the country.

***Lift Irrigation or well irrigation systems***

In the Northern and North central provinces shallow ground water has been used for agriculture at small scale farming and the system has been managed by individual farmers. This system is spreading though out the dry and intermediate zones of in locations where shallow ground water is available with the financial assistance of government. So the farmers have practiced on demand supplementary irrigation. Traditionally this system has been very popular in the Northern Province and manual methods (*Andiya*) had been used for lifting water and presently small water pumps are used. Basically high value condiments, chilli and onion are the major crops cultivated in this system.

**Rainfed Farming**

Rainfed farming, the most ancient method of agriculture is still practiced in Sri Lanka at large scale. In the dry and intermediate ecological regions, this system is a resource poor system and in the wetter parts, plantation crops are also cultivated in rainfed systems. Following farming systems can be identified in Sri Lanka under this category.

- Shifting Cultivation
- Upland sedentary farming
- Rainfed lowland paddy cultivation
- Perennial plantations (tea, rubber coconut, spices)
- Perennial Home gardens (Kandyan forest gardens, and dry zone home gardens)

**Organic Farming**

Sri Lanka is a country with a long history of more than 2500 years and rural farmers still having knowledge on sustainable traditional farming systems. Agriculture practices before 1960s were totally based on organic principles. But the increase of population and limitation of lands resulted to import food items. Therefore, successive governments of the country were forced to change national policies to increase food production especially in late 60's with the green revolution. As a result, country has become as self sufficient in rice as the staple food and also in vegetable, fruit and some other crops production. However, the country has been gradually converted to chemical based modern agriculture and mono crop based industrialized agriculture. Even though country has not been able to produce all food crops needed, some food crops such as chilli, potato, onion, sugar etc are still imported. Although the main stream agriculture was evolved with such strategies, nongovernmental organizations, farming groups and some individual farmers are practicing organic agriculture. The presidential secretariat has established a task force to implement programmes under 'toxin free country' strategy and it helps to strengthen organic agriculture movement of the country. Organic practices in agriculture vary from small scale home gardens to large scale farms and those organic products in large scale such as spices, tea, coffee, coconut, fruits, vegetables, rice etc. have targeted export markets and small scale farmers mostly target local markets. With the media and government support, general public in the country are becoming more health conscious and concern about healthy food. Sri Lanka is the first country in the world introduced organic certified tea to the world market and now has expanded to other products; oils, herbal preparations, desiccated coconut and other coconut based products, oil seeds, fruits and cashew.

Table 4. Organic land, share of total agricultural land, number of organic producers in 2015

| Country | Organic land (Ha) | Organic share (%) | Organic producers (No.) |
|---|---|---|---|
| Afghanistan | 81 | 0.0002 % | - |
| Bangladesh | 6,860 (2012) | 0.1 % | 9,335 (2011) |
| Bhutan | 6,950 | 1.3 % | 2680 |
| India | 1,180,000 | 0.7 % | 585,200 |
| Nepal (2013) | 9,361 | 0.2 % | 687 |
| Pakistan | 34,209 | 0.1 % | 111 |
| Sr Lanka | 96,318 | 3.5 % | 8695 |

Source: The world of Organic Agriculture, Statics and Emerging trends, 2017

**Pastoral Systems**

Pastoral farming systems are also practiced in all ecological condition in Sri Lanka. The distribution of these farming systems has a bearing on the occurrence and availability of grasses and fodder in different ecological regions.

*Ranching in the dry and intermediate zones:*

This is extensive livestock farming with cattle and goats in large herds and it has been practices in the past in association with minor tank systems and shifting cultivation systems. Due to expansion of irrigation agriculture and prohibition of shifting farming have threatened the existence of this farming system.

*Intensive live-stock faming with neat cattle (upcountry and mid country):*

In the upcountry wet and intermediate zones, intensive livestock farming is practising with small herds. Most of the farmers practice cut and feeding, as there is less grassland available in those highly populated areas.

**Predominant Cropping Systems**

**Rice-based Cropping System**

Rice based cropping systems mainly comes under both rain-fed farming systems and irrigated cropping systems. In the Wet zone, rice based cropping systems are mainly rain-fed and also in the eastern part and north western provinces of the country where rain fall in the major rainy season is over 1000 mm, rain-fed paddy farming has been practiced. The cropping systems have been evolved and prevailed for a long period of time and it can be considered as sustainable cropping systems. The rice based cropping system, where rice is the major crop cultivated and land development is made for retaining water within the plots. Hence the lands are terraced and leveled and bund to keep standing water.

***Rice-Rice Cropping System***

This is the most intensive rice cultivation system in Sri Lanka and it practices across wet intermediate and dry zone. Over 350,000 ha of irrigable lands have been used for this cropping system and in the Dry zone, the irrigation systems fed with perennial streams where irrigation water is available for cultivation rice in both major and minor rainy seasons. Water sources in low country intermediate zone are also the perennial streams and therefore, rice is cultivated in both seasons. Although, in wet zone rainwater is adequate to cultivate both season under rain-fed condition, anicut systems were developed to provide supplementary irrigation.

***Rice Fallow Systems***

There are minor tank irrigation systems in the dry zone which are fed only with rainfall or ephemeral streams. In this system, water is available only for the major cropping season *Maha* and those tanks rarely get filled in *Yala* season hence rice fallow system is practiced under those minor irrigation systems. In addition, under the larger reservoirs which are not filled by minor rainy season *Yala*, rice fallow system is practice.

***Rice-Other field crops systems***

In the dry and intermediate zone of the country, crop diversification has been practiced over several decades as a remedial measure to water scarcity in the dry season and also this has become profitable venture in the intermediate zone. As the vegetable and other field crops get good prices in the market, farmers used to practice it even when there is adequate water is available for paddy cultivation. Hence in different ecological regions, different rice vegetable cropping systems have evolved.

***Rice -vegetable cropping systems***

In the upcountry intermediate zone where the elevation is around 1300m and annual rainfall is around 1800 mm, rice vegetable and potato cropping system has evolved and has prevailed over few decades. Rice is grown when heavy rains are received and potato is cultivated when the ambient temperature is less and vegetables are cultivated with less rain. Those lands are provided with irrigation water from a large number of anicuts made across perennial streams flowing into the major rivers. In the low country intermediate zone rice- maize, rice sweet- potato farming has been evolved.

**Maize-based Cropping System**

In the dry zone, maize cultivation began expand within this decade. The farmers cultivate maize in rain-fed uplands in the major rainy season and as there is no adequate rainfall in minor season the farmers use to fallow the lands. However, at present farmers cultivate Sesame in the dry season and has reached 200% cropping intensity. However, this system is still emerging as a cropping system and it too early to identify as a cropping system.

**Fruit based Cropping Systems**

Fruits are mainly cultivated in home gardens and recently fruits cultivations have been promoted as mono crop at commercial scale. That has not yet emerged as a cropping system.

**Vegetable based Cropping Systems**

Vegetable cropping systems are found in the up country, mid country intermediate zone and in the up country wet zone of the country. In the mid country intermediate zone vegetable are cultivated in the rainy season and the land is fallowed in the dry season. The crops cultivated are tomato, bean and cabbage. In upcountry intermediated zone where longer wet season is found another cropping system can be identified. There two consecutive vegetable crops are cultivated and lands are fallowed in the dry season. The crops cultivated are bean, tomato and carrot. In the up county wet zone Vegetable-potato-vegetable cropping system is practiced, in this cropping system year-round cultivation is practiced with no fallow period.

In the upcountry intermediate zone Rice -potato -vegetable cropping system is practiced in the anicut irrigation systems. Paddy is cultivated in the wet season where the water logging condition prevails in the rainy season. Although, rice is one major crop, the vegetables and potato crops are given priority as vegetable and potato generate more income in relation to rice.

**Fisheries based and Pasture based cropping systems**

In Sri Lanka, both cropping systems are not significant.

**Perennials based cropping systems**

In the wet zone of the country, the major cropping systems are perennial cropping systems. The major perennial crops are tea, rubber, coconut and spice crops such as cinnamon, pepper etc.

### *Tea based cropping systems*

Tea (*Camellia sinensis*) has occupied a land extent of 189,800 ha as plantations and small holdings (LUPPD, 2007) and provides black tea for income from export and local consumption. This can be described as an agro-forestry system has been established in low, mid and up country wet and intermediate zones. Some shade trees such as *Grevillea robusta* (Silver Oak), *Albizia moluccana*, *Acacia decurrens* (Black wattle), *Erythrina lithosperma* (dadap), *Gliricidia maculata* are grown in this system to make shades to the plantation (Kathiravetpillai, 1990). The shade trees additionally provide green manure, soil moisture conservation, minimizing sun scorch in pruned branches of tea and also important as wind breaks, fire wood and timber.

Except those shade trees tea plantations are mainly mono crop cultivation at large plantations. However, small holdings have been developing as mix perennial systems with fruit and spice crops.

### *Rubber based cropping systems*

Rubber (*Hevea brasiliensis*) has occupied a land extent of 183,200 ha as plantations and small holdings (LUPPD, 2007). This can be also considered as an agro-forestry system in mid and low country wet and intermediate zones. Rubber has almost all attributes of a forestry species. In most cases, it is grown as a mono crop but in some older plantations, it is intercrop with some other tree crops such as cocoa. Space in between trees is occupied by an undergrowth or live mulch which is in most cases *Pueraria phaseoloides*, *Mucuna bracteata* or grasses. Rubber plantations provide a canopy which reduces the impact of sun as well as the atmospheric worming and remove less amount of soil water per unit land area as their roots are deeper (Samarappuli, 2010). Hence, commercially grown rubber plantations can be considered as an alternative to a forest system, which is sustainable, conveniently renewable and compatible with nature and that provide economic benefits.

### *Coconut Based cropping systems*

The total extent under coconut cultivation is around 3,130,700 ha (Agro stat, 2007). However, unlike tea and rubber 80% of the coconut is cultivated by small holders and farmers cultivated other crops under the coconut to generate more income from coconut lands. As coconut plants are cultivated around 8x8 m spacing there is ample space in between coconut trees to cultivate another crop. Therefore, shade loving crops such as pepper, cocoa, turmeric, ginger etc, have been cultivated under coconut since very long time and it can be recognized as a stable cropping system.

Coconut based agroforestry (inter cropping, mixed cropping, multiple cropping, alley cropping and mixed farming) research were undertaken for optimum utilization of resources, thereby increasing the productivity and returns from the land. Cocoa (*Theobroma cacao*), coffee (*Coffea canephora*), pepper (Piper nigrum), cinnamon (Cinnamomum verum), clove (Eugenia caryophyllus), nutmeg caryophyllus), nutmeg (*Myristica fragrans*), ranbutan (*Nephelium lappaceum*), mulberry (*Morus alba morus*), lemonine (*Citrus spp*) and vanila (*Vanilla planifolia*) performed better in the wet zone in the country and cashew (*Anacardium occidentale*), mango (*Mangifera indica*) and lime (*Citrus acida*) in the intermediate zone are grown as mix cropping (Gunathilake and Liyanage, 1995).

***Coconut -pepper cropping system***

Out of all coconut based cropping systems, coconut-pepper mix cropping is found to be highly sustainable system and this system is popular in the low country intermediate zone agro-ecological regions where the pepper cannot tolerate strong sunshine. *Grilicidia sepium* has been chosen as the supporting tree to pepper vine. Gliricidia and pepper are grown in rows between coconut rows. As gliricidia is a legume it fixes atmospheric $N_2$ and enriches the soil. In addition, farmers lop the gliricidia tree regularly and place the lopping at the base of the pepper vine as mulch. Gliricidia leaves add organic matter in to the soil regularly and other than providing nutrients it acts as mulch and conserve water. Consequently, both coconut and pepper have been mutually benefitted and yield of both crops has been increased in comparison to the mono crop.

***Coconut -fruit (Pineapple) cropping systems***

Coconut thrives well in the western and north-western provinces in low country wet and intermediate agro-climatic regions. The largest coconut plantations are found in those provinces. Pineapple is cultivated in rows under coconut. This mix cropping system also has been sustained over decades and yet the extent under this system is expanding into the drier parts of the country. Therefore, it can be also recognized as a sustainable cropping pattern.

***Cinnamon plantations***

Cinnamon (*Cinnamomum zeylanicum*) is of great economic and social importance as a spice crop. Sri Lanka is the world largest producer and exporter of ‘true cinnamon’ contributing more than 90% of the share to the world’s true cinnamon trade. This agro-forestry system has been confined to low country wet zone and it exits as plantations and small holdings in home gardens with other tree crops.

### *Mixed perennial croplands*

The mixed perennials have occupied a land extent of 164,325 ha (LUPPD, 2007) and provides spices and beverages for income from export and local consumption. This agro-forestry system has been confined to low and mid country wet and intermediate zones in the country. The main crops of mixed perennial croplands include pepper (*Piper nigrum*), coffee (*Coffea sp.*), cocoa (*Theobroma cacao*), clove (*Eugenia carophyllata*) and nutmeg (*Myristica fragrans*) and the space between trees is occupied by grasses as an undergrowth or live mulch. In addition, leaf litter will also serves as dead mulch.

### *Kandyan forest gardens*

The Kandyan forest gardens (KFGs) have been a dominant form of traditional agro-forestry system for centuries, particularly in mid country wet zone in the country. The homesteads in Sri Lanka have occupied a land extent of 1,028,600 (LUPPD, 2007) of which a major portion exists as KFGs. It provides spices, fruits, beverages, condiments, vegetable, flowers, medicinal herbs, fire wood, timber for food and income as well as cool and pleasant living environment for rural communities in the region. On an average, the KFGs are one-third of a hectare in size with over 250 individual woody perennials of about 30 species (NARESA, 1991). Studies related to hydrology (Gunawardena et al., 1994), soil fertility (Kendaragama and Jayasundara, 2012), cash crops (Jacob and Alies, 1987), household income (Kendaragama, 1983), shared gender leadership (Kendaragama and Pathirana, 2011) and alternatives for the system (Gunaratne, 2001) have highlighted some physical, biological, economic and social aspects of this agro-forestry system. Major tree species in this agro-forestry system include coconut (*Cocos nucifera*), king coconut (*Cocos sp.*), arecanut (*Areca catechu*), pepper (*Piper nigrum*), coffee (*Coffea sp.*), cocoa (*Theobroma cacao*), clove (*Eugenia carophyllata*), nutmeg (*Myristica fragrans*), jakfruit (*Artocarpus integrifolla*), breadfruit (*Artocarpus altilis*), banana (*Musa sapientum*), mango (*Mangifera indica*), durian, avocado (*Persea Americana*) and papaw (*Carica papaya*). The space between trees is occupied by grasses as an undergrowth or live mulch. In addition, the leaf litter serves as dead mulch.

## Conservation Agriculture for Sustainable Intensification of Agriculture

Rain-fed upland farming and irrigated farming are two major categories of farming systems in Sri Lanka. Irrigated farming which evolved over 2500 years ago has developed all irrigated lands into terraces and rice based cropping systems are practiced in those terraced lands. Hence the soil erosion has been controlled and physical soil conservation is assured. Although rain-fed upland farming has also adopted soil conservation measures, yet soil erosion is taking place at an alarming rate leading to severe land degradation, filling of reservoirs, eutrophication in water bodies. The plantation sector in the wet and intermediate zones of the country has adopted soil conservation measures to protect their soil. Some other upland farmers those who practice annual rainfed farming have adopted conservation measures. However a majority of them have not yet adopted conservation measures and lands continue to erode leading to severe land degradation.

**The processes of land degradation in Sri Lanka**

Misuse of and over use of land resource and over sue of inputs especially fertilizer and agro-chemicals have been identified as the major causes of soil degradation (Nayakakorala, 1998). It has enlisted 12 processors of land degradation in Sri Lanka: Soil erosion by water, erosion by wind, pollution, salinization, alkalization, desertification, eutrophication, soil compaction, sealing, crust formation and water logging (Kendraragama, 2012). In addition, continuous cultivation of same crop for long time, accumulation pathogenic microbes, and infestation of noxious weeds also leading processes of land degradation. These processes decline the physical chemical and biological fertility of the soil leading to drastic reduction in land productivity. Consequently, the cost of crop production has been drastically increased in rainfed uplands making agriculture uneconomical.

**Policy**

The policy of soil conservation is to bring down the soil erosion rates equivalent to soil erosion rates under forest cover otherwise to reduce accelerated soil erosion to the zero level in farming systems throughout the country. However, as the soil erosion rates in the hill areas, where the catchment areas of major rivers are lying, are alarmingly high, priority has been given to minimize soil degradation in hilly area of central highlands. Even though, soil conservation programs are currently implemented in the other parts of the country for as there is an urgent need to reduce rates of soil losses.

Department of agriculture is the Main institute in Sri Lanka that provides leadership for soil conservation. The head of the institute has delegated the authority to Natural Resources Management Centre (NRMC) to implement the soil conservation act. This department works in collaboration with other government organizations, non-government organizations, private sector organizations and community based farmer organizations for minimizing soil degradation. Soil conservation program includes research, demonstrations, training officials and farmers, awareness programs, providing incentives and using legal provisions in the soil conservation Act. In addition, a number of provisions have been included to the soil conservation Act in related enactments for controlling soil degradation. The most important Acts are listed below.

- Forest Ordinance (1907) and Subsequent Amendments
- Land development Ordinance (1907) and Subsequent Amendments
- Fauna and Flora Protection Ordinance (1937) and Subsequent Amendments
- State Land Ordinance (1947) and Subsequent Amendments
- Soil Conservation Act (1951) and Subsequent Amendments
- Rubber Control Act (1956)
- Tea Control Act (1957)
- Water Resources Board Act (1964)
- Land Grant Special Provisions Act (1979)
- State Land (Recovery of Possession) Act (1979)
- Agrarian Service Act (1979) and Subsequent Amendments
- Mahaveli Authority Act (1979) and Subsequent Amendments
- National Environment Act (1980)

**Technologies**

Technologies have been developed basically to reduce the soil erosion in the plantation crops in the hill areas. As the water and runoff are the major agents in soil erosion the runoff or storm water management measures have been chosen for soil conservation. Nineteen soil and water conservation measures have been recommended for Sri Lanka (Kendaragama, 2013) and those are given the table No 4. In the past it has been relied on physical measures for soil conservation. Subsequently, more emphasis was given on agronomic practices. In current research programs on soil conservation more emphasis is given biological and bio engineering measures for gully stabilization, identification of suitable plant species for Sloping Agriculture Land Technology (SALT) and also for storm water management.

Table 4. Recommended soil and moisture conservation measures

| Category | Type of measure |
|---|---|
| Mechanical measures | Soil bunds |
| | Stone bunds |
| | Lock and spill drains |
| | Terraces |
| | Common flat forms |
| | Individual flat forms |
| Biological measures | Tree hedgerows (Double) |
| | Tree hedgerow (Single) |
| | Shrub hedgerows |
| | Cover crops |
| Agronomic measures | Contour tillage |
| | Mulching |
| | Contour planting |
| | Selective weeding |
| | Application of organic manure |
| | Agro-forestry |
| Off farm measures | Leader drains |
| | Drop structures |
| | Check dams |

Source: NRMC, Department of Agriculture, 2016

**Extension Services**

Agriculture Extension for food crop sector is a decentralized system. Provincial Departments of Agriculture responsible for provincial areas and central Government Department of Agriculture under the Ministry of Agriculture is responsible for interprovincial areas which are under major irrigation schemes. Department of Agrarian Services also assists extension activities under the Ministry of Agriculture. Mahaweli Authority under the Ministry of Mahaweli Development and Environment also conducts extension activities in Mahaweli project areas which cover most productive agricultural lands in the major irrigation systems of Mahaweli River.

Apart from that, separate crop based state institutions are operating their extension activities to achieve specific production targets; Tea Research Institute (TRI), Tea Small Holding Development Authority (TSHDA), Coconut Cultivation Board (CCB) and Rubber Research Institute (RRI) are under Ministry of Plantation. Department of Export Agriculture is under the Ministry of Primary Industries and Department of Animal Production and Health is under Ministry of Rural Economic Affairs.

All the above institutions have their own extension staff to work with farmers/farm organizations and information unit to implement or coordinate media activities. Conservation agriculture principles can be applied to all sectors and therefore, particular crop based extension systems could be utilized to strengthen conservation agriculture practices in Sri Lanka. However, field level needs should be identified and implemented appropriate extension programmes.

**Usage of Farm Machinery**

Sri Lanka is experiencing dramatic climatic changes and also labour shortage for farming activities and therefore, land preparation and crop establishment at the beginning of rains is really challenged. Strengthening of appropriate farm mechanization has been identified as an appropriate solution.

Although most of land preparation is now mechanized by two wheel or four wheel tractors, usage of machinery for plant establishment is still not at satisfactory level. However, several projects have distributed more than 500 paddy transplanters and one transplanter can cover up to 50 acres per season. Farmers of Southern part of the island prefer to use box seeder introduced by Farm Machinery Research Centre (FMRC) of the Department of Agriculture. Dry sowing is practiced in northern part of the island and farmers request dry sowing seeders. Seeders imported from India have been tested successfully and yet to be introduced.

Most of lands are not properly leveled and therefore, laser leveling has been proposed for land leveling. In addition, bund forming machines have to be introduced as it is neglected or poorly done due to labour shortage and high cost of labour. To minimize tillage, FMRC has introduced Injector Planter for Maize and Dry Sowing Seeder for paddy. The injector planter is designed to couple with both two and four wheel tractors. Through extension programs these machines have been popularizing and now several hundred is in the field especially in Uva province. These machines are locally fabricated by small scale manufacturers registered at FMRC. Multi chopper for compost making was introduced by FMRC in 1990's. Although several local manufacturers have fabricated that machine locally, now there are cheaper imported machines available in the market.

**Policy intervention, Research and Extension on Conservation Agriculture Management**

The policy adopted in early stages was implementation of soil and water conservation programs aiming at individual farmer plots. Consequently, adoption of off farm technologies was neglected the lands and properties and infrastructure were affected. Therefore, the watershed approach was introduced covering all the private lands as well as public sector properties and infrastructure in few decades back. There have been 18 foreign funded projects involved in soil erosion control since 1975 in the country (Jayakody et. al., 2007). It shows a satisfactory progress in watershed approach in soil conservation. Therefore, it was possible to provide equal emphasis for both on farm as well as off farm soil and water conservation work.

There after another approach was added to the soil conservation. That was implementation of watershed approach through community based farmer organization. The public institutions involved in soil and water conservation related activities and implementation of regulatory work.

In 2002, a National Action Plan for combating land degradation in Sri Lanka was prepared by the Ministry of Environment and Natural Resources. Subsequently, in 2004, a National Watershed Management Policy was also prepared by the same ministry. At presently, 14 major governmental and non governmental institutions are involved in soil conservation and watershed management in central highlands.

- Natural Resources Management Center of the Department of Agriculture
- Provincial Departments of Agriculture in the Central, Uva and Sabaragamuwa provinces
- Forest Department
- Department of Export Agriculture
- Department of Agrarian Development
- Irrigation Department
- Department of Animal Production and Health
- Tea Research Institute
- Rubber Research Institute
- Tea Small Holder Authority
- Hadabima Authority of Sri Lanka
- Several Non Government Organizations and few private sector organizations

Few years ago, a soil conservation master plan was prepared by the Ministry of Agriculture Development and Agrarian Development, in collaboration with the above organizations. The major objective of the master plan was to network above organizations for a common soil conservation program for the country.

### Best practices of conservation agriculture

### Rice-based Cropping Systems

The rice based cropping system where rice is the major crop cultivated and land development is made for retaining water within the plots. Hence the lands are terraced and levelled and bunded to keep standing water.

### Rice-Rice Cropping System

The rice-rice copping system has been evolved over two thousand year ago. Yet the paddy lands are very fertile and farmers obtain rice yields over 8 metric tons per ha per season. The management practices they use for obtaining higher yields continuously are as follows.

***Deep ploughing:*** Farmers' plough their lands using disk plough or tine tiller at least 20 cm and permit hard pans to develop below that. This practice helps the rice plants to develop deep rooting system and maintain a large root volume.

***Incorporation of crop residues, organic matter, and charred paddy husk:*** It is recommended to the Farmers to add the crop residues that are paddy straw, compost or dried cow dung and farmers adopt these recommendations and maintain soil organic matter content over 3%. Also, it has helped to maintain the micronutrient at a favourable level. This increases the fertilizer use efficiency. In addition, farmers add charred paddy husk at the rate of 500 kg/ha. This reduces the soil salinity and maintains it at a favourable level or below 2 m mhos/cm. Also, it adds more silica into the soils which helps to resistance pest and diseases.

***Soil test based fertilizer Recommendation****:* There are larger differences in major rice soils in retaining plant nutrients. Hence fertilizer recommendation was made in basis of major agro-ecological regions. Subsequently, a program was launched for soil test based fertilizer recommendations in order to avoid excess use or to avoid deficiencies. This program has been activated by strengthening the regional laboratories for testing a large number of soil samples and a soil samples were tested at a subsidized rate. This system is now in operation and a large number farmer has adopted it. Therefore, accumulation of nutrients exceeding toxic levels has been avoided in major rice growing regions of the country.

### Rice- Other field crops systems

*Land selection:* Land selection is one of the most vital activities in Rice - other field cropping systems to avoid crop losses due to water logging and soil sanity. Farmers advised to use well drained soils and imperfectly drained soils with precautions for other field crop cultivation in dry season. Farmers with training and experience select well drained soils for other field crop cultivation and use poorly drained lands for paddy cultivation even in the dry season.

***On farm water management to avoid soil erosion****:* On farm water management is very import for avoiding soil erosion in irrigable farm lands. The Reddish Brown Earth Soils (Rhodustalfs) is the major soil group in the Dry Zone of Sri Lanka. This soil is hard when dry and sticky and erodible when moist. While irrigation water is conveyed above 7 lt / second flow rates the irrigation canals tend to erode. By training and experience farmers are knowledgeable to make canals along the contours with non erodible flow rates to avoid soil particles being washed away with water.

### Adoption of Sloping Agricultural Lands Technology (SALT)

For averting soil degradation in rainfed vegetable cropping systems in the mid country and up country intermediate zones gliricidia has been planted in double row system along contours with 5 m intervals between rows. The gliricidia row spacing has been determined according to the cautionary slope where row spacing decreases as the land slope increases. The vegetable crops are planted in between the gliricidia rows planting. When the gliricidia plants are well established the trees are lopped and the sticks are placed between the glicidia rows as a barrier to runoff. The gliricidia leaves and twigs are used as a mulch to cover the land. In addition to reducing soil erosion, this system help maintain the soil organic matter content a favourable levels.

### Soil erosion control measures in Perennial Cropping Systems

***Adoption of physical Soil Conservation measures in Tea cultivations****:* Tea is cultivated in 189,800 ha in large plantations as well as small holdings. Also this can be identified as an agro-forestry system and this cropping system is confined to low country, mid country and upcountry wet zones where annual rainfall is over 2500 mm. To minimize soil erosion in those lands a subsidy scheme has been launched to encourage soil conservation. All the farmers large and small develop lands before planting tea with recommended soil conservations measures. Contour rock bunds, lock and spill drains along contours, lead drains paved with rocks have constructed as per recommendation consequently, soil erosion is minimized in the tea plantations.

***Adoption Soil test based fertilizer recommendations for tea:*** The tea research Institutes has offered subsidy rates for testing soil samples in tea lands. Hence, tea growers have used to apply fertilizer following the test based fertilizer recommendation. This practice have led to correct the soil chemical properties such as soil pH which intern enhance nutrient availability to the plants and thereby increases fertilizer use efficiency. In addition this situation minimized pollution of water bodies with nutrients washed away from tea lands.

***Mulching:*** Mulching has been practiced across many farming systems and cropping systems as the best method of moisture conservation. In annual cropping system where seasonal crops are cultivated dead mulches such as crop residues, paddy straw, lopping from the live fences and artificial mulches such as reflective polythene has been used. The organic mulched has found to maintain soil temperature at favourable level and avoid baking soil surface in strong sunshine. It makes the soil and mulch interface a favourable environment for microbes. Increased microbial activities decompose the mulch and add organic matter and plant nutrients improving the soil structure (Karunathilaka, 1993). Artificial mulches such as reflective polythene used for vegetable cultivation act as a repellent of insects, reduce soil erosion, conserve water, control weeds consequently increase yield as an overall effect.

***Soil Conservation with live mulch in Rubber plantations****:* Rubber (*Hevea brasiliensis*) has been cultivated in large plantations as well as in small holdings. Rubber is mainly cultivated as a monocrop. Rubber cultivation which is similar to a forest grows taller and protects the soil from heavy sun. The major soil control measure recommended is cultivation of *pueraria phasioloids*. Almost all the growers have adopted the recommended soil conservation method and have minimized the soil erosion and have ensured the sustainability.

## Rubber based Cropping Systems

Rubber (*Hevea brasiliensis*) has occupied a land extent of 183,200 ha as plantations and small holdings (LUPPD, 2007). This can be also considered as an agro-forestry system in mid and low country wet and intermediate zones. Rubber has almost all attributes of a forestry species. In most cases, it is grown as a mono crop but in some older plantations, it is intercrop with some other tree crops such as cocoa. Rubber plantations provide a canopy which reduces the impact of sun as well as the atmospheric worming and remove less amount of soil water per unit land area as their roots are deeper (Samarappuli, 2010). Hence, commercially grown rubber plantations can be considered as an alternative to a forest system, which is sustainable, conveniently renewable and compatible with nature and that provide economic benefits.

## Coconut based Cropping Systems

The total extent under coconut cultivation is around 3130700ha (Agro-stat, 2007). However, unlike tea and rubber 80% of the coconut is cultivated by small holders and farmers cultivated other crops under the coconut to generate more income from coconut lands. As coconut plants are cultivated around 8x8 m spacing there is ample space in between coconut trees to cultivate another crop. Therefore, shade loving crops such as pepper, coca, turmeric, ginger etc, have been cultivated under coconut since very long time and it can be recognized as a stable cropping system.

***Coconut -pepper cropping system****:* Out of all coconut based cropping systems, coconut-pepper mix cropping is found to be highly sustainable system and this system is popular in the low country intermediate zone agro-ecological regions where the pepper cannot tolerate strong sunshine. *Grilicidia sepium* has been chosen as the supporting tree to pepper vine. Gliricidia and pepper are grown in rows between coconut rows. As gliricidia is a legume it fixes atmospheric $N_2$ and enriches the soil. In addition, farmers lop the gliricidia tree regularly and place the lopping at the base of the pepper vine as mulch. Gliricidia leaves add organic matter in to the soil regularly and other than providing nutrients it acts as mulch and conserve water. Consequently, both coconut and pepper have been mutually benefitted and yield of both crops has been increased in comparison to the monocrop.

***Coconut- fruit (Pineapple) cropping systems***: Coconut thrives well in the western and north-western provinces in low country wet and intermediate agro-climatic regions. The largest coconut plantations are found in those provinces. Pineapple is cultivated in rows under coconut. This mix cropping system also has been sustained over decades and yet the extent under this system is expanding into the drier parts of the country. Therefore, it can be also recognized as a sustainable cropping pattern.

## Rain Water Harvesting

There are two crop growing seasons in Sri Lanka and The food crops are mainly grown in the Dry and intermediate climatic regions of the country. The Rainfall in *Maha* major rainy season is adequate for an economical crop yield in seasonal crops. However the rainfall in *Yala* is inadequate to realize an economical yield even from a drought resistant crop. Therefore, water harvesting in rainfed agriculture in the Dry and in the Intermediate Zone can be identified as a best practice to mitigate the situation.

Although the Maha rainfall is adequate for an economical crop growth crop losses are often reported due to moisture stress triggered short dry spells occurred during sensitive growing periods of seasonal crops. Although irrigation is the best option for moisture stress as there are irrigation sources available for a large extent of rainfed lands, it has to continue to rely on rainwater for further increase in agriculture production. There are two water harvesting systems are presently practiced by upland rainfed farmers; Rainwater harvesting for Rainfed farming and Rainwater harvesting for supplementary Irrigation.

***Rainwater harvesting for Rainfed farming****:* This system is practiced where the seasonal rainfall is less than 750 mm per season. For rainwater harvesting for rainfed farming, people terrace the land and let the rain water to infiltrate into the soil uniformly within the terrace. Also the infiltrated soil moisture is deposited in the soil profile and available to the plants growing subsequently. As the rainwater is effectively stored in the profile the crops grow with less moisture stress and result in economic yields.

***Rainwater harvesting for supplementary irrigation****:* This system is practiced in the areas where the rainfall is higher at least 750 mm per season. Lands are terraced as in the earlier system farm ponds are made in suitable places to collect excess rainwater coming as runoff. The farm ponds are paved to prevent the seepage and percolation losses. The water impounded in the ponds are used judicially to prevent moisture in sensitive growth stages such as flowering and pod filling. Water efficient irrigation systems such as low pressure drip systems can be utilized for supplementary irrigation. Farmers in Mid country inter mediate zone have minimized the crop losses and have secured substantial income from vegetable farming.

**Challenges in Up Scaling Conservation Agriculture**

Land conservation in Sri Lanka is taking place at low rate. It will take a long time for conserving all the lands those are susceptible to soil degradation at present rate. Up scaling the conservation agriculture is essential to expedite to conserve all the lands at a shorter time to avoid further degradation of the arable lands. Due to the population pressure the uplands in the urban area in the wet zone has devoted more for settlements rather for agriculture. Only the low lands in the wet zone especially in the urban and coastal have been underutilized.

On the other hand the arable lands in the dry and inter mediate zone has vested less priority and in relation to the lands in the central high lands. Rather than the technical issues the socio economic and legal issues have affected effective utilisation and adoption of the conservation farming practices for those lands.

### Ownership of the land

Ownership of the land has become of the major problem that hinders the land conservation. Majority of the lands belongs to the Government of Sri Lanka. Only around 15% of the lands are given to the people legally. However most of the lands used for upland rainfed farming belong to the Government, Hence farmers are not interested in developing who do not have sense of possessive to the land.

The lands which are owned by several people (siblings) do not work to conserve their lands as they cannot make unanimous decision for land conservation. When the owners sought to legal solution for clearing ownership issues and it takes long time to get court decision. Because of the lengthy legal processes, owners abandon the lands without bringing about any development.

### Acts that prevent changing traditional land use

The agrarian development act is a strong act that does not permit the farmers to change land use of the wetlands. Hence most of the lands in the coastal areas which are traditionally used for paddy farming are not conserved and have abandoned.

- Rainfed farmers are the most resource poor farmers in the country. Also these farmers cannot generate good income from the already degraded lands to invest to conserve their farm. The subsidy schemes that are not adequate to develop total extent of lands that need restoration of soil fertility.
- The paddy cultivation in the wet-zone has become uneconomical due to the low productivity of those lands. However with the new rice varieties developed and technologies generated for those lands could raise the productivity to economical scales. The demonstrations and pilot scale cultivation have displayed the potential increasing. However, most of the people who possess the lands in urban areas are not interested in paddy farming. In addition, there are lot of opportunities for them to earn more money from non agriculture means.
- As the wet lands in the wet zone has been abandoned for a long period of the infrastructure specially the farm roads, anicuts and the drainage canals are in dilapidated condition due to aging and poor maintenance. Hence, a strong effort has to make to improve the system and also of funds has to be allocated.
- Also the natural hazards play a major role in discouraging paddy cultivation. The floods that occurs wash away the crops make heavy losses to the farmers.

- Poor coordination among the governmental institutes and low priorities given for the development of agricultural lands and not paying for the environmental damages also has discouraged the paddy farming.

Transforming to Conservation agriculture as it does not provide fast economic benefits. Hence, farmers do not like to invest on the land development activities.

**Potential for Future Conservation Agriculture Research and Development**

The technology used for soil conservation is more physical processes and agronomic practices. As the problem of soil degradation was well understood in the past, mostly the soil erosion was addressed with mechanical means of soil conservation. As the knowledge on soil degradation was widened agronomic measures were adopted in addition to the mechanical methods. At present the biological measures have been invented for soil conservation as the knowledge on soil degradation has further widened.

However, even in the lands which are preserved with mechanical and agronomic measures, deterioration of soil physical, chemical and biological conditions are still observed. Hence, further research studies have to be carried out to understand the soil degradation process in depth and also to develop measures and recommendations for future practice.

In addition, impact of global warming on soil fertility has not been well understood also the performance of the soil microbes that involved in biological cycles has not fully studied. Hence there is a necessity to study further on soil degradation with intensification of agriculture as well as about the impact of global warming on soil fertility.

Therefore, streamlining relevant research and development activities of all related agriculture stakeholders is a need today and it definitely benefit Sri Lanka to strengthen the future of conservation agriculture. At the regional level, separate institution for sustainable agriculture in SAARC region would be established for research and development on the related issues and it may benefits all member countries to share knowledge and experience effectively and efficiently on Conservation Agriculture.

**Conclusion**

a) Soil degradation has been taking place at alarming rates reducing soil productivity and increasing the cost of production. And it has further increased with intensification of agriculture and global warming.

b) Sufficient enactment and legal provision have been approved for conserving agricultural as well as other lands in the country. Although, there are sufficient legal provisions to avoid soil degradation the rules and regulations have not been adequately implemented for averting soil degradation.

c) Although lands under few farming systems are conserved, majority of the arable lands are not conserved with suitable conservation measures.

d) As mainly the physical and agronomic practices are adopted for soil conservation, there is a large potential to research and development to generate new technology to conserve soil through biological means.

e) Farm mechanization through appropriate machineries and technologies is essential to practice conservation agriculture sustainably.

f) Other than the financial difficulties there are many social and legal issues that hinders the adoption of land conservation practices by the farmers

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# Scaling up Conservation Agriculture through Market Mechanism: Practical Action Initiatives in Nepal

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## Background

In Nepal, the overall agriculture sector is subsistence in nature with 31% % share in national Gross Domestic Product (GDP). Only 15 % of the farmers are involved in commercial agriculture. Only 17 % of the total land is arable that accounts for daily livelihood of around 66 % of Nepal's overall population (CBS, 2011). Though the country witnessed a remarkable progress on poverty reduction from 42 % (1995) to 25 % (2013), there is a huge imbalance in progress across different ecological and regional belt. Poverty is still very high in rural areas where agriculture is the main source of livelihood. In the hilly and mountain areas, 42 % of the farmers are still below the poverty line which is almost double compared to the poverty incidence at the national level (ADB, 2017).

Widespread poverty especially in the rural areas is mainly attributed to low income in agriculture. Low level of productivity and lack of vibrant market system to connect rural production to domestic and international market are the key factors behind poor benefits in agriculture. In this context, Government of Nepal (GoN) has taken agriculture commercialisation as a key strategy to reduce poverty in rural areas. The government has given a high priority to the use of chemical fertilisers, improved technology and market linkage. Thus, more intensive farming with high use of chemical fertiliser and intensive mono-cropping are on increasing trend particularly in *Terai* areas. The demand for chemical fertilisers is found to be increasing by 15 % per annum (MoAD, 2016). Similarly, due to food deficiency, farmers are involved in intensifying land use by cropping two or more crops per year in the same land which has increased the frequency of tillage. The intensity under the conventional land management practice is increasing the rate of soil degradation due to frequent and massive land ploughing. Recently, the use of portable tractor is quite trending mainly owing to shortage of human labour as male labour migration to urban areas and foreign lands is high. This has certainly increased labour efficiency but has also intensified the problem of soil erosion and degradation. Various negative consequences have already been realised such as depletion of soil nutrient, low level of organic matters, and soil erosion. The negative consequence is further worsened by climate change effects. Due to all these factors, organic matter content in soil is decreased to 1 % against the minimum requirement of 5 % for healthy soil (*ADS, 2015*). To deal with these issues, conservation agriculture could be an option. This paper highlights the issues to scale up conservation agriculture technology and practices in Nepal.

## Conservation Agriculture

Many farmers in Nepal are experiencing reduction in yield due to declining soil fertility. Rising food demand and shortage of land has forced farmers to go for intensive tilling and hoeing every year which has resulted hardpan in soil that restricts root growth, causes low infiltration of water in soil and high run-off triggering soil erosion. To get higher yield, farmers use high dose of chemical fertilisers which in the long run results various negative impacts on soil such as low microbial activity. Conservation agriculture (CA) enables the reverse of this trend. Conservation agriculture is an approach to manage agro-ecosystem to improve production and productivity while maintaining natural resource base (Karki and Shrestha, 2014). It is an alternative agricultural production system that minimises soil disturbances and conserves the composition and natural biodiversity. It prevents hardpan formation, protects soil, increases soil moisture and restores soil fertility to stabilise yields and improves production. Conservation agriculture helps cut cost in farming while increasing their yields. Conservation agriculture consists of three core principles– maintenance of permanent or semi-permanent soil cover, minimum soil disturbance through tillage, and regular crop rotations. To gain a full benefit, all principles have to be applied at the same time. But in practice, it may depend on farmers' specific socioeconomic context (FAO, 2017).

## Issues Related to Sustainable Soil Management in Nepal

Three main issues are quite alarming in Nepalese agriculture- low organic matter (OM) content in soil (1% OM), labour shortage, water scarcity and ultimately lower productivity making agriculture a less competitive option. Sustainable intensification in crop yield cannot be accomplished without addressing these issues. Among various reasons of soil degradation, cultivation in sloppy terrain, high rate of soil erosion, unsustainable intensification, and lack of soil management practices are important ones. Due to limited arable land (18% arable land), farmers in Nepal have involved in planting two or more crops per year in the same agricultural land which has exaggerated the tillage practices. In conventional system, farmers plough the land by hoe or bullock drawn ploughs at least once after the harvest of post monsoon season crop and one to two times for land preparation and sowing of spring/summer crop. In between March to June, farmers leave the ploughed field fallow to expose to sun. This type of tillage and land management destroys soil aggregates, causes loss of soil particles and exposes it to erosive forces such as rainfall and wind ultimately making soil vulnerable to erosion. Therefore, repeated tillage, removal and burning of crop residues and absence of crop rotations are fundamental causes of unsustainable agriculture system in Nepal. In this context, the conservation agriculture practice has high significance in Nepalese agriculture. Conservation agriculture practices are beneficial technology on sloppy lands prone to degradation and erosion and rain-fed farming systems with low inputs (Shrestha et al., 2004). Conservation agriculture promotes reverse degradation processes, improves resource quality, reduces production costs and helps achieve sustained high productivity. Therefore, CA based crop management practices across various agro-ecologies need to be identified and promoted in Nepal.

**Issues in Promotion and Scaling Up of Conservation Agriculture Practices in Nepal**

a) Poor access to knowledge and technology in rural areas. Many government and research works are limited to technology demonstration with little focus on increasing access to technology and knowledge at farm level.

b) Poor roads to transport heavy machines/equipment; farmers' ability to afford machines is limited; and there is high dependence on rain-fed agriculture that may limit the promotion of CA based technologies.

c) Limited incorporation of crop-residue to build soil OM

d) Poor Extension services -agriculture extension system should focus on increasing awareness among farmers. However, formal extension system caters extension services only to 15 % farmers while rest 85 %depends on informal system mainly on agro-vets, traders and friends.

e) Weak linkage between research and extension system.

**Pilot project to scale up conservation agriculture practices in Nepal**

Pilot Programme for Climate Resilience (PPCR) project is implemented by Practical Action Consulting (PAC) with financial support from International Finance Corporation (IFC). The project aims to develop and demonstrate climate adaptive methods, practices and technologies focusing on three crops: Rice, Sugarcane and Maize. The main objective of the project is to increase farmers' adoption of proven adaptive practices and long term improvements in resilience and productivity. Four *Terai* Districts are selected to implement the project: Bara, Parsa, Morang and Sunsari. These locations were selected by three 'lead firms' – private companies (Probiotech, Nutri food and Eastern Terai Sugar Mill) who are collaborating and co-investing in the project. These lead firms focus on three crops: Pro-biotech Industries Pvt. Ltd. focuses on maize, Nutri food Pvt. Ltd. on rice, and Eastern Terai Sugar Mill on sugarcane. The following results are anticipated by the end of the project year 2018.

- Climate Smart Demonstration plots (one for each crop) established in the fields of lead firms and of sixty lead farmers (20 each per crop).
- Climate smart agronomic package of practices for rice, maize and sugarcane developed and used for farmers' training.
- Capacity developed of 15 extension officers (five per crop) through Training of Trainers (ToT).
- 15,000 farmers, of whom 50 % are women, trained on climate adaptive cultivation practices (5,000 per crop).
- On-farm productivity increased by 20 % against the baseline.
- Farm based revenue of 9,000 farmers increased by 20 per cent.

**Project Implementation Approach**

The project modality is based on leveraging lead firms' business relationship with smallholder farmers to promote climate adaptive practices. Most of the smallholder farmers in the selected districts are engaged in commercial farming and supply raw materials to the near-by factory. In the given context, the project approach is to utilise lead firm for technology demonstration and extension to reach out to all the smallholder farmers who supply raw materials to the factory. The project has supported lead firms to develop a package of practices on climate adaptive technologies and practices in the selected crops. It facilitated lead firms to identify leader farmers and deliver training and demonstrations through leader farmers. Finally, leader farmers are developed as local business service providers as they own mechanical technology such as seed drillers/planters and rent out to local farmers.

**Project Interventions:**

| Rice | Maize | Sugarcane |
|---|---|---|
| Varietal selection (based on climate scenario and other variables)<br>Laser land levelling (Nimbus)<br>Optimum need based water usage<br>Requirement based fertiliser usage<br>Incorporation of crop residue (sugarcane and maize)<br>Adjustment of planting and major operation time | | |
| Direct Seeded Rice (DSR) | Raised bed | Trench method planting |
| Minimum till in rice wheat system | Zero/minimum till | Tree planting in bunds |
| Alternate wetting and drying (AWD) | Furrow and gated pipe plus trash mulching | |
| | Soy promotion | Intercropping |

**A Case on Promotion of Zero/Minimum Tillage Technology Service through Lead Farmers in Maize**

| Market intervention areas | What/why | How is it being done? |
|---|---|---|
| Step 1: Developing the supply side | Some of the LF have shown their interest to purchase customised machineries tested by Agricultural Machinery Engineering Division (AMED) of NARC and PPCR in joint demo plots | • Identification of farmers who intend to purchase set of machineries.<br>• Assembling the demand and identify supplier.<br>• Conducting participatory meeting with AMED, purchasing farmers and supplier to validate the demand and design.<br>• Orientation to supplier on design aspects taking assistance from AMED. Continuous monitoring and supervision from AMED required. |

| | | |
|---|---|---|
| Step 2:<br>Ensuring availability of machines through Leader Farmers (LF) | LF uses the machines in their demo plots and make it available for use by fellow farmers | • Identification of LF with entrepreneurship zeal.<br>• Facilitate them in developing business plan for purchase and lease of machineries and equipment – create groups or use existing groups.<br>• Facilitation support to LF for linkage with banking and financial institutions for access to loan.<br>• Facilitation for availability of machineries and equipment on time to farmer. |

**Result of Promoting Zero/Minimum Tillage in Maize**

| Before intervention | After intervention | Impact |
|---|---|---|
| Used to plough the field about six times before planting. | Ploughing for 1/2 time following raised bed. | Reduction in the cost of production by up to 60 per cent. |
| More use of fertilisers. | Reduction in the use of fertilisers by 50 per cent. | |
| Used to irrigate five times. | Have to irrigate two to three times only. | |
| Used to spray herbicide four times. | Need to spray herbicide twice only. | |

**Overall Results (Preliminary Results) by Crops**

### Sugarcane

- 6,000 farmers trained on climate adaptive practices.
- Average productivity increased from 50 Mt/ha to 96.1 Mt/ha.
- Benefit/cost ratio increased from 1.4 to 1.8 for main crop and from 1.9 to 3.4 for ratoon crop.
- 90 %adoption rate of climate adaptive practices.
- Sugar recovery increased from 8.4 to 9.6 per cent.
- 1400 NRs/ha cost saved due to better irrigation practices.
- 7hrs/ha time saved.
- Local service providers developed.
- Replication of technology and practices to sister mill.

**Maize**

- 5,000 farmers trained on climate adaptive technology and practices by leader farmers.
- Average net return increased from baseline figure 65,321 NPRs/ha to 78,480 NPR/ha.
- 60 %adoption rate maintained.
- Procurement from local farmers increased by 20 per cent.
- Average benefit cost ratio increased from 1.4 to 1.7.

**Rice**

- 5,000 farmers trained on climate adaptive technology and practices.
- 60 % adoption rate maintained.
- Average benefit cost ratio increased from 1.3 to 1.8

**Learning**

- The benefit of CA is difficult to generalise as yield is affected by various other factors and local condition. Thus, it needs to be customised in local context based on given socioeconomic constraints.
- Unlike input intensive technologies such as new varieties, fertilisers and pesticides, CA is more knowledge intensive technology and practices which requires collaborative learning, evaluation and adoption. In Nepal, previous studies also indicate that farmers to farmer technology transfer is very successful in promoting conservation technologies.
- Increasing access to technology among rural farmers through a mechanism that is compatible to the existing socioeconomic context is very critical.
- Working through value chain actors to demonstrate and promote technology and knowledge system provides ground for sustainable impact and commercial solution of the problems.

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## Proceedings of the SAARC Regional Consultation Meeting on Conservation Agriculture

**held during 28th to 30th August 2017 in Paro, Bhutan**

### Background

Conservation agriculture encompasses three management objectives: eliminating or significantly reducing tillage to minimize soil disturbance; retaining crop residues on the soil surface and encouraging economically viable crop rotations that best complement reduced tillage and crop residue retention. It is important to note that conservation agriculture is not a fixed management system but rather a set of principles that have demonstrated value across a wide range of agro-ecological regions. The precise ways that conservation agriculture-based management strategies are implemented as well as the advantages derived from these management innovations are contingent on regional and site-specific cropping system characteristics.

Benefits of conservation agriculture based crop management often include as reduced production costs and labour and energy requirements; timely field operations and avoidance of terminal heat stress; improved soil quality and reduced erosion; enhanced rainfall infiltration and reduced evaporative losses; higher crop water productivity (kg of grain/ $m^3$ of water); more stable and higher crop yields under rain-fed and lack of assured irrigation conditions; and many other environmental benefits. Conservation agriculture-based crop management can provide a buffering mechanism against many of the abiotic stresses that limit productivity in rain-fed conditions, especially with respect to conserving and maximizing the productive use of water.

For resource-poor farmers, there must be short-term payoffs from investments in climate risk management since the cost of adaptation can erode the asset bases of vulnerable groups and increase insecurity. In many circumstance, CA can be profitably adopted by farmers with little or no disadvantage because CA not only reduces production costs, but it also stabilizes and enhances crop yields, particularly against current climate risks as it builds resilience against climate changes and variability. This should significantly reduce production risks posed by climate factors and labour shortages, thereby enabling a higher level of investments in inputs and management intensity that, in turn, would lead to sustained increases in yields and more secure livelihoods for resource-limited farmers.

There are other pathways to improve water availability and productivity among smallholders, e.g., capturing and storing excess flows, adjusting the cropping calendar, and making use of weather forecast and other environmental information. The value of these pathways as complementary or independent approaches for building resilience to climate risks will also be evaluated in the targeted dry land areas. To be certain that farming systems as a whole benefits from any new interventions, innovations like conservation agriculture-based crop management are most usefully viewed from an enterprise perspective. This perspective facilitates the identification of optimal allocation strategies for competing uses for resources (e.g., crop residues for livestock versus soil quality), thereby minimizing tradeoffs and building synergies across the entire farming system. Also, sound agronomic management is required for all factors of production and not simply those directly changed by conservation agriculture.

Among farmers in Central Asia, researchers have identified several constraints to the adoption of conservation tillage among smallholders including: (i) weed control; (ii) competing uses for crop residues and uncontrolled grazing of residues left in the field; (iii) lack of dedicated forage and fodder crops and (iv) absence of machinery for crop establishment without tillage. Similar problems could be anticipated in the smallholder rain-fed systems of South Asia Region.

In South Asia 42% of the 4.13 million $km^2$ total area is estimated to be affected by various kinds of degradation (Sarkar et al., 2011). Especially in India and Pakistan, 63 million ha of rain-fed land and 16 million ha of irrigated land have been lost to desertification. This lost land accounts to 7% of regional agricultural gross domestic product. The trend of land productivity in other SAARC Countries is in decline. Further, with mounting pressure on land from other uses (urban infrastructure/ industrial expansion) and degradation of natural resources, agricultural land is shrinking rapidly, thus limiting the food production. As the arable land becomes limited, the conventional agriculture that capitalizes on manipulation of soil (or tillage) excessively coupled with mono-cropping (specialized farming) may further deteriorate the productive capacity of the land.

One technology that has prospects to conserve and facilitate improved and efficient use of natural resources through integrated management of available soil, water and biological resources combined with external inputs is Conservation Agriculture. Emanating from three broad principles of (i) minimum soil disturbance, (ii) permanent organic soil cover, and (iii) diversified crop rotations, conservation agriculture is often referred to as a resource- efficient or resource- effective agriculture (FAO) that contributes to environmental conservation as well as to enhancement and sustenance of agricultural production. Conservation agriculture is founded on the principle of no-tillage or minimum tillage as a way of sustenance. It is gaining popularity among farmers throughout the world. Although it is difficult to get an accurate estimate of the total area covered, Derpsch and Benites (2003) calculated that CA is practiced in 72 million ha globally. One of the main reasons for this no-tillage revolution has been the greater profitability of CA over conventional systems as a result of lower input costs (less fossil-fuel use and more efficient input use) coupled in most cases with an increase in yield.

However, the limitation of conservation agriculture is a site specific, community- based and agro-ecological specific which may not have a blue-print for replication. The success or failure of conservation agriculture depends greatly on the flexibility and creativity of the practitioners and extension and research services of a region. Considering these consequences SAARC Agriculture Centre, Dhaka had been organized jointly SAARC Consultative Meeting on Conservation Agriculture during 28th to 30th August 2017 in Paro, Bhutan with College of Natural Resources, Royal University of Bhutan and Department of Agricultuture Bhutan with following objectives and outcomes.

**Objectives**

1. To incorporate best practices of conservation agriculture and disseminate information to all stakeholders.
2. To organize action research modality on selected CA sites in member countries and make comparative studies.
3. To promote policies, knowledge and information sharing practices.
4. To plan strategies for sustainable food production systems and resilient agricultural practices.

**Methodology**

The focal points were identified by respective SAARC Member States with the help of GB members who conducted research (trial set – focus on social, ecological and economic benefits of CA).

**Outputs of the meeting**

The Regional Experts Consultative Meeting on Conservation Agriculture in SAARC Member Countries conducted in Paro, Bhutan from 28 to 30 August 2017 was jointly organized by SAARC Agriculture Centre (SAC), Dhaka, Bangladesh, College of Natural Resources, Royal University of Bhutan, Lobesa, and Department of Agriculture, Ministry of Agriculture and Forests, Thimphu, Bhutan. The Program coordinated by Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh and Dr. Sonam Tashi, (Dean, Academic Affairs and Assoc. Professor, Dept. of Agriculture), College of Natural Resources, Royal University of Bhutan.

### Inagural Ceremony

Honourable Secretary Dasho Rinzin Dorji, Ministry of Agriculture and Forests was the chief guest of the opening ceremony and Mr. Ganesh Bahadur Chettri, Agriculture Specialist and Advisor of Department of Agriculture(DoA) chaired the opening session. There were 18 participants from the SAARC Member States, civil society and local participants. Dr. Sonam Tashi, Dean, Academic Affairs and Associate Professor, College of Natural Resources, Bhutan welcomed to all participants and Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre, highlighted about the concept, purpose and objectives of the meeting. He mentioned three principles of Conservation Agriculture as; (i) minimum soil disturbance, (ii) permanent organic soil cover, and (iii) diversified crop rotations in conservation agriculture system. As a chair of the chief guest, Honourable Secretary, Ministry of Agriculture and Forests Dasho Rinzin Dorji addressed the meeting with the past practices and current scenario of conservation agriculture practices in Bhutan. He expressed the reality on behalf of Farmers in South Asia. He express his dissatisfaction over the time, there is changed the term of “Agriculture Development”, e.g. “sustainable agriculture”, “Conservation agriculture” and “commercial agriculture”, in South Asia and the world, it becoming confusion to the farmers society. At the end Mr. Ganesh Bahadur Chettri concluded the opening session with highlighted the existing practices of Conservation Agriculture in Bhutan and South Asia. Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh expressed his gratitude and vote of thanks to distinguished guests and participants. Ms. Tshering Choden, Office of the Vice Chancellor, Royal University of Bhutan conducted the program.

### Technical Sessions

There were three technical session during the meeting. Two technical sessions were mainly allocated for the country paper presentation from Focal Points of SAARC Member States. Most of the focal points highlighted about the existing conservation practices in their own country. In addition to the Country presentations, Dr. PP Biswas presented the “Conservation Agriculture Practices and Successful Technologies in South Asia: Strategies for achieving SDGs”, he listed out the existing conservation technologies as well as areas of interventions on research, development and policy in South Asia. Likewise, Dr. Sujan Piya from Practical Action, South Asia Regional Office, Kathmandu, Nepal presented the up scaling conservation agriculture technologies and practices through civil society/non-government sector in South Asia.

In the brainstorming session, participants were discussed about the way forward steps of Conservation Agriculture in South Asia. Participants of the meeting mainly focused on implementation of CA through cluster approach like organic farming in farmers', participatory mode adopting at least one village/20 ha cluster and identify major cropping systems/crop rotations which could be readily taken up for conservation agriculture in different eco-systems namely irrigated, rainfed, dryland, arid, hill and coastal production zones. Likewise, System of Rice Intensification (SRI) with zero till single rice transplanter may be promoted. For more awareness activities in CA, involvement of NGOs in PPP model may be explored. In addition of these above developmental activities, research activities for developing suitable crop varieties for CA and developing gender friendly multi task machinery, which is suitable for low horsepower tractor capable of harvesting of crop, recovery of grains, chopping, windrowing, spreading of straw for uniform distribution of crop residues are important with innovative package of practices for conservation agriculture. Therefore, it is better to develop CA based Integrated Farming System models.

Regarding the Policy, there should be considered CA as one of the components of national Mission on sustainable agriculture and launching of dedicated scheme on CA converging all the related components of various schemes being run by different Ministries/Departments. On the other hand, supplying machineries for conservation agriculture on subsidized rates, promoting custom hiring systems and providing soft loans for purchase of implements also felt necessary. It is suggested to declaring tax holidays for manufacturing machineries to be used for conservation agriculture and creating human resources development and capacity building through training and teaching of graduate and post-graduate students of agricultural university. In addition of these policy interventions, introducing and providing carbon-credit to the farmers practicing conservation agriculture for carbon sequestration and greenhouse gas mitigation and encourage PPP (Public-Private Partnership) would be the milestone for promotion of Conservation Agriculture.

The details of the session discussions are as follows:

Technical Session- I: Country Presentations (Set A) started by Dr. PP Biswas's presentation title on: Conservation Agriculture Practices and Successful Technologies in South Asia: Strategies for achieving SDGs. Mr. Ganesh Bahadur Chetri, DoA and Dr. Tayan Raj Gurung, SPS (NRM), SAC played the role as a moderator of the session. He highlighted the following issues during his presentation.

- Conservation agriculture is now is called Cocktail agriculture, there should be identified the areas and major cropping sstems/crop rotations for effective CA.
- South Asia holding only 5 million ha under conservation agriculture, USA is the leading country among the world. There is lack of machinery suitable to small land holdings in South Asia.
- CA should be implemented through cluster approach in farmers's participatory mode like farming adopting atleast one village/20 ha cluseter.
- DSR/soybean/arhar/cotton/Bajra/maize/cotton-wheat cropping systems is common in South Asia and without good quality machine conservation agriculture couldn't sustained
- CA is low carbon agriculture and goal is to attain carbon Neutral Agriculture.

Dr. Md Ilias Hossain, Principle Scientific Officer, Bangladesh Agriculture Research Institute, Bangladesh presented on best practices of CA in Bangladesh highlighted the future aspects of CA practice in Bangladesh by outlining various types of challenges, such as:

- Long term challenges are foreseen in Bangladesh due to a steady rise in temperature in the country, gradual decrease in rainfall over the years, and decrease in ground water table, all of which hamper crop production. Studies also prove that the soil in order to recover its health take as long as thirteen years.
- The main constraint in the practice of CA being to change the mindset of the people and the farmers.
- Another challenge and a paradoxical issue was the use of machinery to fertilize the fields in the CA practice.
- The presentation on CA lists both the benefits and constraints from its practice and therefore communicates a confusing message to the farmers.
- The practice of CA without conserving resources cannot go hand in hand.

- The real challenge of bringing together all the organizations to work towards an integrated approach to CA.
- The SAARC nations spread from the hills to the plains, and therefore transferring tropical solutions as solutions to the hills may be a challenge.
- 30% productivity increased through conservation agriculture.

Mr. Pema Chofil , Program Director, Agriculture Research & Development Centre, Bajo, Bhutan and Dr. Sonam Tashi, Assoc. Professor, Dept. of Agriculture, College of Natural Resources, Royal University of Bhutan presented on best practices on CA in Bhutan. The presenter highlighted the challenges associated with CA in Bhutan, which included:

- Lack of political will and initial investment cost is high in Bhutan.
- Quality monitoring and assurance of policy in Bhutan around the SAARC region is the main problem.
- Education and continued support to the farmers for community consensus
- The practices related to CA implementation were shared the practice of mixed cropping in Bhutan.
- The use of farm machinery on the farms in Bhutan and the huge scope of CA in Bhutan that is committed to being a carbon neutral country.
- Promote green and sustainable agriculture and bio digester.
- Facebook group also help to create disseminating the conservation agriculture technology.
- Trenching, water harvesting, tank water storage, counter farming, mulching with straw, mulching with rice husks, hedgerow planting with napier, napier planning to stabilize slopes, pond water harvesting (silpaulin lined), bio-slurry collection for manuring, zero tillage chilli planting, no till chili planting, etc.

Dr. G. Pratibha Principal Scientist (Agronomy) ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, Telangana, India presented the status of CA in India. Dr. Tayan Raj Gurung, SPS (NRM) SAC played a role as a moderator in this session. She highlighted the main points as following:

- 74% rain fed agriculture in India and zero tillage saves 2-3 weeks times for crop production.

- Conservation system in agro-forestry system is effective in India.
- Zero tillage+ surface cover + crop rotation = conservation agriculture is popular in India.
- CA is the carbon positive system (maize-gram and soybean-wheat cropping system is effective.
- CA mitigates the use of steep tillage and weed and its associated problems in India.

Dr. Illais Hussain raised the questions about the success stories of conservation agriculture in India. Dr. Pratibha explains about the transplanted rice has no more weeds in India and explained about the success stories in India. Dr. Sonam Tashi asked about the land productivity about the cropping systems and seasons of residues decomposition. Dr. Pratibha explains that about 80% of residues are helpful to the conservation agriculture.

Mr. Prakash Acharya, Senior Crop Development Officer, Crop Development Directorate, Department of Agriculture, Harihar bhawan, Lalitpur, Nepal presented on best practices of CA in Nepal. The presenter reported that CA is gaining momentum in Nepal, but is challenged by due to 60.4% population engaged in Agriculutre, erratic rainfall, flood/drought and limited studies on benefits of CA in Nepal. Besides this, following points were highlighted:

- Maize soybean intercropping is the best practices in Nepal.
- Coriander +maize and spinach+maize intercropping is successful in Plain region in Nepal
- Reduced tillage in wheat, surface seeding in wheat and Direct seeded rice (DSR) has been becoming effective practices.
- Finally, he concluded as it was found that CA technology applied to the farms on the plains is different from those that were applied to the farms on the hills and mountains.

Dr. Arshad Ali, Director (LRRI), National Agriculture Research Centre, Pakistan presented the CA practices in Pakistan. He said there is no experimental data and the country is in its adoption stage to identify the most suitable technology associated with CA practices. The presenter shared the use of popular machinery on the farms in the country and he discussed mainly following points:

- The Pakistan seeder machine which has multiple benefits can only be used in the farms on the plains.
- Drip irrigation is used where water is short and productivity is much higher.

- Solar irrigation system is also gaining popularity.

Mr. W.A. G. Sisira Kumara, Additional Director General of Agriculture (Development), Department of Agriculture, Peradeniya, Sri Lanka presented on best practices of CA in Sri Lanka. The main challenge with CA practice in Sri Lanka is that different organizations think and work independently of the other. Another hindrance in the CA practice is due to the change in research policies and its direction due to the change in government.

- Rice and vegetable based are the predominant cropping systems and perennial cropping systems in Sri Lanka.
- Sloping Agricultural Land Technology (SALT) is popular in Sri Lanka.
- Soil control mechanism, mulching, bamboo structure, rain water harvesting and Integrated Plant Nutrient Management System (IPNMS) are widely practiced in Sri Lanka.
- CA is essential for upland farming to avoid further degradation of arable lands in Sri Lanka.
- Sri Lanka is popularly known in the agricultural world for their home gardens (KHK- Kandhya), a system of gardening that is practiced through generations and is now further modified to make it more organic and suitable to the present context. The KHK now extends and expands to include more types of farming, including vegetables and fruits and also cash crops such as coconut cultivation.

Dr. Sujan Piya, Practical Action, South Asia Regional Office, Kathmandu, Nepal presented regarding the Up-scaling conservation agriculture technology and practices through Private sector in South Asia. The presenter showcased CA through the lenses of a value chain model and shared the experience in Nepal relating to an agri-business and how it capitalizes and promote itself. He highlighted that due to CA 50% saving in labor cost in direct seeded rice and packages of practices was found in his research site in Nepal.

**Brain Stroming Session**

The Brain stroming session was moderated by Dr. Tayan Raj Gurung, SPS, SAC, Dhaka, Bangaldesh. The main Issues of dicussion and way forward in Brainstorming Session were as follows:

**Policy interventions**

- The role of the agrovets in the public private partnership model should be enhanced.

- Inclusion of CA as one of the components of sustainable agriculture campaign.
- Implementation of CA through a dedicated scheme with components like technology demonstration, capacity building, awareness and supply of inputs.
- Developing SAARC network consortium on CA for mutual benefit and creating awareness on CA among all the stakeholders.
- Incentivize CA by providing subsidy/soft loans.
- Declaring tax holidays for CA machinery manufacturing units and establishment of custom hiring centers.
- Extending financial assistance during early two-three years (transition phase) for adoption of CA to compensate yield loss.
- Create legislation to prevent crop residues burning.
- Waiving of custom duty on CA machineries to facilitate import.
- Encourage PPP (Public-Private Partnership) for promotion of CA.

**Developmental issues**

- CA should be implemented through cluster approach in farmers' participatory mode adopting at least one village/10- 20 ha cluster.
- Involvement of village self-help groups/ farmer's schools/groups, local agriculture service provider, farmer's cooperatives should be ensured. A revolving fund should be created to take up various operations under CA.
- Identify areas and major cropping systems with crop rotations within season.
- Permanent bed and furrow method/strip till system should be preferred due to multiple benefits.
- Cultivation of greengram/ blackgram/cowpea (fodder) /Greenmanuring/ sesame in summer needs to be explored and promotion of live mulch/ green leaf and brown manuring.

**Research Gaps**

- Develop suitable crop cultivars for effective CA practices and CA based Integrated Farming System models.
- Develop farmer, gender friendly multi-tasking machines operated manually/animal drawn/low horsepower tractors for various farm operations.

- Development of zero till variable depth and multi seed cum fertilizer drill, zero till multi crop transplanter, zero till single seedling rice transplanter, bed formers-cum- zero till planters suitable for different eco regions.
- Developing innovative package of practices for major cropping systems of different agro eco-systems and make provision of residue management under rainfed conditions.
- Assessing benefit: cost and environmental impacts including ecosystem services under CA vis-à-vis conventional practices to formulate future policies.

**Field Visit of CA Farming Area**

At the final day of meeting, on 30th August participants were visited Punakha and Wangdue Dzongkhags and gained knowledge on CA farming. Dean of College of Natural Resources explained the college's activities on agriculture development and Good Practices in agriculture. Agriculture Research Development Centre Bajo had been applying CA on horticulture.

**Conclusions and Recommendation**

The regional experts and participants were commended on their presentations and the meeting ended with the following conclusions:

a) Almost all SAARC Member States use a variety of technology and CA measures, and are equipped with appropriate technology to deal with challenges within their context. However, there is need for coordination with neighboring countries to learn best practices and this is also the reason why the experts from the region were pulled together.

b) One of the serious and important challenges has been the lack of awareness of our farmers and youth and also lack of awareness related to policies. Therefore, the need to collaborate with academic institutions like the Royal University of Bhutan is foreseen as useful and beneficial in Bhutan. By working directly with the College of Natural Resources (CNR), such awareness can be relayed and relevant people educated appropriately in this set up.

c) While cost-benefit ratio is studied and there are reported to prove its positive effects in Pakistan, India and Bangladesh, we are still unsure of how up-scaling can affect the yield and production level in the long run.

d) CA is enjoyed for the social benefits it accrues to the people and its users.

e) CA is composed of a series of challenges and opportunities, and that such a meeting will help us study and use the opportunities as future plans.

f) The lack of awareness of policy and how to explain it across all levels of the society is also a stumbling block when implementing CA.

**Future Strategies and Implements on CA**

**Key Policy intervention of Conservation Agriculture in South Asia**

- Strengthen R&D on user and gender friendly tools, equipments
- Introduction subsidy and incentive to CA practitioneners/farmers
- Policy should be needed skill development of farmers, LSP and operators
- Plan agriculture activity in our system with financial support.
- Pilot/demonstration farms in farmers' field with production based incentive system and cost sharing mechanism.
- SAARC Member States should review present subsidies and incentive schemes and analyze how it helps to CA.
- Provision of inputs (seed, fertilizer, chemical, and training) and machinery through Agricultural Service Providers (ASPs) since land holding is small and farmers cannot afford to buy machinery.
- Establishment of SAARC information unit in each country to validate, exchange CA based technology among the member countries.
- Policy on collaboration between research institute and private business (entrepreneurs) to innovate on mechanical technology.
- Policy on promote agribusiness for pro-farmers to generate revenue, improve their traditional agriculture practices and livelihood improvement through PPP, that is best policy for CA and sustainable agriculture.
- Review present acts and regulations on soil and water conservation and land ownership and land use to find gaps and laps related to CA.
- Networking all related stakeholders to improvement integrated approach.
- Include CA into the National Agricultural Policy focused on integrated sustainable conservation policy with inclusive endogenous technology

- Awareness of conservation agriculture technology, capacity development and exposure visit
- Localizing the CA technology, improving the existing planning systems through value chain in local condition
- Networking the proven scientific technology to the global partners (joint research)
- Public-private (NGO, INGO and Civil society) partnership (As UN declared SDG and we have to fulfilled these goals 1,2, 15 and 17)

## Meeting Agenda

**28 August 2017 (Monday)**

**Inaugural Session: Hotel Conference Hall, Hotel Drukchen, Paro**

Chair: Mr. Ganesh Chhetri, Specialist, Ministry of Agriculture and Forests

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|---|---|---|
| 09:00 | Registration & guests take their seats | |
| 09:20 | Arrival of Chief Guest | Hon'ble Secretary Dasho Rinzin Dorji, Ministry of Agriculture and Forests |
| 09:30 | Welcome Remarks | Dr. Sonam Tashi, Dean, Academic Affairs and Assoc. Professor, College of Natural Resources , Bhutan |
| 09:40 | Remarks: Concept, purpose and objectives of the meeting | Dr. Tayan Raj Gurung, Senior Program Specialist (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh |
| 09.50 | Keynote Address by Chief Guest | Hon'ble Secretary, Ministry of Agriculture and Forests |
| 10:10 | Remarks by Chairperson | Mr. Ganesh Bahadur Chhetri, MoAF |
| 10:.20 | Vote of Thanks | Dr. Pradyumna Raj Pandey, Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh |
| 10:30 | Photo Session and Tea break | |

**28 August 2017 (Monday)**

**Technical Session- I: Country Presentations (Set A)**

Moderator : Dr. Ganesh Bahadur Chhetri, Senior Agriculture Speicalist, MoAF

Rapporteur:

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|---|---|---|
| 11:00 | Key note paper: Conservation Agriculture Practices and Successful Technologies in South Asia: Strategies for achieving SDGs | Dr. PP Biswas<br>Principal Scientist (Soil)<br>Indian Council of Agriculture Research<br>New Delhi, India |
| 11:50 | Country presentation<br>(Bangladesh) | Dr. Md Ilias Hossain<br>Principle Scientific Officer<br>Bangladesh Agriculture Research Institute<br>Bangladesh |
| 12:10 | Country presentation<br>(Bhutan) | Mr. Pema Chofil<br>Program Director<br>Agriculture Research & Development Centre,<br>Bajo, Bhutan |

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|---|---|---|
| | | Dr. Sonam Tashi<br>Assoc. Professor, Dept. of Agriculture, College of Natural Resources, Royal University of Bhutan |
| 12:35 | Country presentation (India) | Dr. G. Pratibha<br>Principal Scientist (Agronomy)<br>ICAR- Central Research Institute for Dryland Agriculture, Hyderabad, Telangana, India |
| 12:55 | Open Discussion | |
| 13:10 | Closing remarks | |
| 13:15 | Lunch break | |

**Technical Session-II: Country Presentations (Set B)**

Moderator: Dr. Tayan Raj Gurung, SPS (NRM), SAC

Rapporteur: DoA Officials

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|---|---|---|
| 14:15 | Country presentation (Nepal) | Mr. Prakash Acharya<br>Senior Crop Development Officer<br>Crop Development Directorate<br>Department of Agriculture,<br>Hariharbhawan, Lalitpur, Nepal |
| 14:35 | Country presentation (Pakistan) | Dr. Arshad Ali<br>Director (LRRI)<br>National Agriculture Research Centre<br>Pakistan |
| 14:55 | Country presentation (Sri Lanka) | Mr. W.A. G. Sisira Kumara<br>Additional Director General of Agriculture (Development)<br>Department of Agriculture, Peradeniya<br>Sri Lanka |
| 15:15 | Discussion | |
| 15:35 | Tea break | |
| 15:35 | Using market- based approach for up- scaling conservation agriculture technology and practices in South Asia | Dr. Sujan Piya<br>Practical Action, South Asia Regional Office, Kathmandu, Nepal |
| 16.55 | Open discussion | |
| 16.20 | Closing remarks | |
| 18.00 | Reception dinner | |

29 August 2017 (Tuesday)

Technical Session-III: Brainstorming Session (Group work) and Way Forward

Facilitators: Dr. Tayan Raj Gurung, SPS (NRM) and Dr. P. P. Biswas, ICAR, India

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| Rapporteurs: | Dr. Sujan Piya and Dr. Pradyumna Raj Pandey | |
| 09.30 | Objectives and guideline of the group work | Dr. Tayan Raj Gurung, SPS (NRM) |
| 10.00- 12.00 (Group I) | Key Policy intervention issues of Conservation Agriculture in South Asia | Facilitator: Dr. Tayan Raj Gurung, SPS (NRM) |
| 11.00 | Tea break and refreshment (during the Group work) | |
| 10.00- 12.00 (Group II) | Key Program/ activity intervention, modality and way forward of Conservation Agriculture in South Asia | Facilitator: Dr. P P Biswas |
| 12.00 | Open Discussion | Facilitators: Dr. P P Biswas and Dr. Tayan Raj Gurung |
| 12.30 | Lunch | |

**Closing Session**

Chief Guest: President, College of Natural Resources, Royal University of Bhutan

Moderator:

| | | |
|---|---|---|
| 13.30 | Group presentations | Representatives of each group (3) |
| 14:30 | Key findings and Group work recommendations:<br>How conservation Agriculture can be utilized for the benefit of the South Asian farmers? | Dr. Sujan Piya, Practical Action and Dr. Pradyumna Raj Pandey, SAC |
| 14:45 | Remarks by 2 participants | Focal Point<br>Local participant |
| 15:00 | Remarks by Chief Guest | Dr. Phub Dorji, President, CNR, Bhutan |
| 15:20 | Certificate awarding | Chief guest |
| 15:35 | Vote of Thanks | Dr. Pradyumna Raj Pandey, SPS (Crops) |
| 15:35 | High Tea/ Social Networking and sideline meetings | |

**Day 3 (30 August 2017) Wednesday**

07:00-18:00 hrs: Field Visit to conservation agriculture sites in Bhutan

Field visit was in Punakha and Wangdue Dzongkhags (for this route permits for foreign delegates had to be obtained well in advanced; route permits can be obtained from the Immigration Office, Ministry of Foreign Affairs, Thimphu; all required documents have to be filled in for obtaining route-permits; Punakha and Wangdue districts are some 115 km [one way] east of Paro.

## Participant Lists

**Participants (National Focal Point Experts)**

| | | |
|---|---|---|
| 1. | Dr. P.P. Biswas | Principal Scientist (Soil), Indian Council of Agriculture Research<br>New Delhi, India |
| 2. | Mr. Abdul Ghafar Nazary | Expert of Renovation of Plant,Ministry of Agriculture, Irrigation and Livestock, Afghanistan |
| 3. | Dr. Md Ilias Hossain | Principle Scientific Officer, Bangladesh Agriculture Research Institute, Bangladesh |
| 4. | Mr. Pema Chofil | Program Director, Agriculture Research & Development Centre,<br>Bajo, Bhutan |
| 5. | Dr. Sonam Tashi | Assoc. Professor, Dept. of Agriculture, College of Natural Resources, Royal University of Bhutan |
| 6. | Dr. G. Pratibha | Principal Scientist (Agronomy), ICAR- Central Research Institute for Dryland Agriculture,Hyderabad, Telangana, India |
| 7. | Mr. Prakash Acharya | Senior Crop Development Officer, Crop Development Directorate<br>Department of Agriculture, Hariharbhawan, Lalitpur, Nepal |
| 8. | Dr. Arshad Ali | Director (LRRI), National Agriculture Research Centre<br>Pakistan |
| 9. | Mr. W.A. G. Sisira Kumara | Additional Director General of Agriculture (Development)<br>Department of Agriculture, Peradeniya<br>Sri Lanka |

**Partner Institution Participant**

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|---|---|---|
| 10. | Dr. Sujan Piya | Practical Action, South Asia Regional Office, Kathmandu, Nepal |

**SAC Participants**

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|---|---|---|---|
| 11. | Dr. Pradyumna Raj Pandey | SPS (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh | (Coordinator ) |
| 12. | Dr. Tayan Raj Gurung | SPS (NRM), SAARC Agriculture Centre, Dhaka, Bangladesh | |

**Other Participants**

| | | |
|---|---|---|
| 13. | Ganesh Bdr. Chhetri | Senior Specialist, MoAF, Thimphu |
| 14. | Kinley Tshering | Director, DoA, MoAF |
| 15. | Wangdila | Asst. District Agriculture Officer, MoAF, Paro |
| 16. | Sonam | Program Director, National Seed Centre, Paro |
| 17. | Tshering Choden | International Relations Officer, RUB, Thimphu |
| 18. | Drupchu Zangmo | Asst. Administrator, CNR, RUB |

## Coordinators


1. **Dr. Pradyumna Raj Pandey**, Senior Program Specialist (Crops), SAARC Agriculture Centre, Dhaka, Bangladesh, Cell: +880-1763708514, E-mail:pandeypr4@gmail.com
2. **Dr. Sonam Tashi,** (Dean, Academic Affairs and Assoc. Professor, Dept. of Agriculture), College of Natural Resources, Royal University of Bhutan, Lobesa: Punakha, Bhutan, Phone: 02 376251/02 376249, email: stashi.cnr@rub.edu.bt

# Photo Gallery

Welocme to the chief guest of the program Dasho Rinzin Dorji, Secretary Ministry of Agriculture and Forests, Bhutan

Inaguration Speech by the Chief Guest of the meeting Dasho Rinzin Dorji, Secretary Ministry of Agriculture and Forests, Bhutan

Opening ceremony of the Meeting

Mr. Ganesh Bahadur Cheetri, Senior Specialist, DoA, Bhutan
delivering his views

Dr. Pradyumna Raj Pandey, SPS, SAC delivering his vote of thanks

Closing Ceremony of the Meeting under the Chairmanship of Dr. Phub Dorji, President, CNR, Bhutan

Participants awarding certificate from Chief Guest of the closing ceremony

Field visit in Conservation Agriculutre Sites in Bhutan


Field visit in Conservation Agriculutre Sites in Bhutan