MAINSTREAMING THE CONSERVATION AGRICULTURE IN NEPAL

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ABSTRACT

Conservation agriculture (CA) system involves minimum soil disturbance, permanent soil cover, and crop rotations. In Nepal, efforts to develop, refine and disseminate conservation-based agricultural technologies started since the rice-wheat consortium in Terai in the 1990s. There are more payoffs than tradeoffs for the adoption of CA. Nepal Agricultural Research Council (NARC) with CIMMYT and IRRI has been working on it under various ecologies. Studies revealed that it reduces the production cost, saves water and nutrients, increases yields, improves soil health, mitigates global warming and improves resource use efficiency. However, there are many bottlenecks for its promotion; like lack of appropriate CA machineries, trade-offs of using crop residue in crop-livestock systems, crop residue burnings, unavailability of skilled manpower and peoples' mindset. Therefore, there is an urgent need to develop strategies to mainstream the CA in Nepal. The paper highlights on strengths, weaknesses, opportunities, and threats of CA for promotion and the way forward.

Key Words: Productivity, conservation agriculture, constraints, mainstreaming, way-forward

INTRODUCTION

To meet the global food, feed, fiber, and bioenergy demand and to reduce hunger and poverty, there is no alternative to increase agricultural productivity. This can be achieved by increasing the efficiency of total and individual factor productivities. However, until now, agricultural intensification from intensive tillage-based production systems generally has had a negative effect on the quality of many of the essential natural resources such as soil, water, terrain, biodiversity, and the associated ecosystem services provided by nature. This degradation of the land resource base has caused crop yields and factor productivities to decline and has forced farmers, scientists and development stakeholders to search for an alternative paradigm that is ecologically sustainable as well as profitable. Another challenge for agriculture is its environmental footprint and climate change. Agriculture is responsible for about 30% of the total greenhouse gas emissions of CO_2, N_2O, and CH_4 while being directly affected by the consequences of a changing climate (IPCC, 2007).

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A set of soil-crop-nutrient-water-landscape system management practices known as Conservation Agriculture (CA) has the potential to deliver all of these goals. CA saves energy input and mineral nitrogen use in farming and thus reduces emissions; it enhances biological activity in soils, resulting in the long-term yield and factor productivity increases. While tilling the soil is not a necessity, but CA itself doesn't provide the optimum conditions for truly sustainable and productive agriculture, it has to be complemented with other techniques, such as integrated pest management, plant nutrient management, and weed and water management (FAO, 2012).

CA is the resource-saving agricultural production system that aims to achieve production intensification and high yields while enhancing the natural resource base through compliance with three interrelated principles, along with other good production practices of plant nutrition and pest management (Abrol and Sangar, 2006).

CONSERVATION AGRICULTURE

Conservation agriculture is a management system that maintains a soil cover through surface retention of crop residues with no/zero till and reduced tillage. CA is described by FAO (http://www.fao.org.ag/ca) as a concept for resource-saving agricultural crop production which is based on enhancing the natural and biological processes above and below the ground. As per Dumanski *et al.* (2006) conservation agriculture (CA) is not "business as usual", based on maximizing yields while exploiting the soil and agro-ecosystem resources, rather CA is based on optimizing yields and profits, to achieve a balance of agricultural, economic and environmental benefits. With CA, farming communities become providers of more healthy living environments for the wider community through reduced use of fossil fuels, pesticides, and other pollutants, and through conservation of environmental integrity and services. As per FAO definition CA is i) to achieve acceptable profits, ii) high and sustained production levels, and iii) conserve the environment. It aims at reversing the process of degradation intrinsic to conventional agricultural practices like intensive agriculture, burning, or removal of crop residues from the field.

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, hence can also be referred to as resource-efficient agriculture.

Conservation agriculture systems require a total paradigm shift from conventional agriculture with regard to management of crops, soil, water, nutrients, weeds, and farm machinery (Table 1).

Table 1. Some distinguishing features between conventional and conservation agriculture.

Particulars	Conventional agriculture	Conservation agriculture
Closeness to nature	Cultivating the land, using science and technology to exploit nature	Least interference with natural processes
Soil movement	Excessive mechanical tillage and soil erosion	No-till or drastically reduced tillage
Erosion	High wind and soil erosion	Low wind and soil erosion
Residue management	Residue burning or removal (bare surface)	Surface retention of residues (permanently covered)
Water infiltration	Low	High
Use of FYM/composts	*Ex-situ* management	*In-situ* management
Bio-manuring	Green manuring (incorporated)	Brown manuring/cover crops (surface retention)
Weed management	Kills established weeds but also stimulates more weed seeds to germinate	Weeds are a problem in the early stages of adoption, but residue retention reduces the weeds
Soil compaction	Free-wheeling of farm machinery, increased soil compaction	Controlled traffic, compaction in tramline, no compaction in crop area
Cropping system/pattern	Mono cropping/culture, less efficient rotations	Diversified and more efficient rotations
Field operations	Heavy reliance on manual labor, uncertainty of operations	Mechanized operations, ensure timeliness of operations
Productivity	Productivity gains in long-run are in declining	Productivity gains in long-run are in incremental order
Economic benefit	Less	Higher
Energy use	High	Low
Labor use	High	Low

PRINCIPLES OF CONSERVATION AGRICULTURE

Conservation agriculture (CA) practices are built on ecological principles making the sustainable use of land (Lal, 2013). Adoption of CA for enhancing resource use efficiency (RUE) and crop productivity is the need of the time as a dominant tool for the management of natural resources. CA consists of 3 interconnected principles:

Minimal mechanical soil disturbance

Minimum soil disturbance provides/maintains optimum proportions of aeration in the rooting zone; moderate the process of oxidation of organic matter, porosity for soil moisture movement, retention, and release and limits the weed seeds for germination (Kassam and Friedrich, 2009).

Soil cover/residue retention

A soil cover is important to save from the harmful effects of rain and sun, to nourish the micro and macro organisms in the soil and plant roots. In turn, it improves soil aggregation, soil biological activity and soil biodiversity and enhances carbon sequestration (Ghosh et al., 2015).

Crop rotations

The rotation of crops is not only necessary for feeding the soil microorganisms, but also for exploring different soil layers for recycling by the crops in rotation. It also enriches the diverse soil flora and fauna. Cropping rotations involving legumes help in minimal rates of a build-up of a population of pest species through life cycle disruption, biological nitrogen fixation, control of off-site pollution, and enhancing biodiversity (Friedrich and Kassam, 2009; Dumanski et. al., 2006).

Table 2. Strength, weakness, opportunity and threats of CA in Nepal

Strengths	Weaknesses
• Evidence-based scientific knowledge generated to solve the multiple complex problems • Availability of resource conservation technology (RCT) based farm machineries (laser land leveler, zero-till seed cum fertilizer drills, bailing machines, boom sprayers • Availability of herbicides and weeding tools • Weather forecasting systems • International collaborations (CG centers, R-W consortium, CASI-Platform, CSISA, SRFSI, CIMMYT	• CA systems are much more complex than conventional systems. (Derpsch, 2001). • Intensive tillage-based mindset among the farmers, agricultural technicians and policy makers, • No data on the actual area under various CA based practices and responsible agency to estimate it, • Knowledge gap among the stakeholders, • Inadequate scale-neutral types of equipment and machineries, • Inadequate knowledge-intensive CA

• Curriculum of RCT in academic institutions, Critical manpower in universities, NARC, and Nepal based Consultative Group for International Agriculture Research (CGIAR) centers	based Package of Practices (POPs), • Infestation of weeds and their management, • Changes in pest dynamics, • Government policies are not CA friendly, • Land use systems (a problem in land consolidation), • Poor marketing system, • Inadequate research thrusts on CA in research institutions, • Extensive areas under sloppy hill agriculture-poor accessibility, • No specific technologies under maize-based relay/intercropping systems (maize/millet) in the hills
Opportunities	Threats
• Nepal have now three levels of governments (Federal, Provincial and Local) and the federal government develops the policy, provincial monitor and local governments are to plan and execute as per their own needs, • People are accepting that residue burning and repeated tillage are harmful to the farm, community and regional level, • CA-based farm machineries are now being available in the Nepalese markets. • Academic courses on CA in graduate and postgraduate programs of Agriculture and Forestry University (AFU) and Tribhuvan University (TU), Nepal since 2012, • Nepal Agricultural Research Council (NARC) in close collaboration with CIMMYT and IRRI have generated convincing CA-based technologies under various cropping systems in the past and data on the impact of CA in soil, crop performance and economics have been generated. It has 61 different research stations across the country stretching	• Adopting CA may, in the short term, involve costs, and risks. • Crop might be failed to produce the yield at par with conventional agriculture in initial years/seasons, • Many non-conventional biotic factors might be emerging like soil-borne pathogens (grey leaf pot disease) in maize due to infected stubbles kept as crop residue. • Weather and climatic condition might not be favorable as expected like direct seeded rice (DSR) and heavy flooding after rainfall. • More dependency on herbicides in the initial years/seasons. • Discontinuation.

from East to West and South to North,
- FAO has been giving high priorities to scale out the CA across the globe,
- International communities have very positive learning from their long-term experimentation on CA especially in South and North America, Europe, and Middle East,
- International trusts and foundations like BMG are also focusing their development thrusts towards CA,
- The momentum has been taken place in neighboring countries like China, India, and Pakistan and Nepal shares similar agro-ecologies with them.

Potential benefits of CA

(1) Reduction in cost of production

Table 3. The economics of various studies carried out by various authors in Nepal.

References	Economic analysis (benefit cost ratio)		Remarks
	Conventional tillage without residue	No tillage with residue	
Karki *et al.*, (2014)	1.7	2.5	Hills (maize-wheat/tori)
Paudel *et al.*, (2014)	2.3	2.5	Terai (maize + soybean-wheat)
Khatri and Karki (2015)	2.42	2.53	Terai: (maize + soybean-wheat)
Karki *et al.*, (2015a)	2.43	3.3	Terai (maize - maize)
Karki *et al.*, (2015b)	1.18	1.36	Hill (maize - wheat/tori)

(2) Enhancement of soil quality (Gathala *et al.*, 2011b). In rice-wheat cropping system of Nepal, 22% higher carbon content of soil in zero tilled residue retained plot was recorded over conventionally tilled plots (Paudel *et al.*, 2014).

(3) Enhancement, in the long-term C sequestration and build-up in soil organic matter to mitigate Green House Gas emissions and impart greater resilience to production systems to climate change related aberrations (Saharawat *et al.*, 2012).

(4) Reduction of the incidence of weeds, such as Phalaris minor in wheat (Malik *et al.,* 2005)

(5) No-tillage system along with site-specific approaches for nutrient management can increase yield, nutrient use efficiency and profitability while decreasing greenhouse gas (GHG) from wheat production in NW India (Sapkota *et al.,* 2014).

(6) Enhancement of production and productivity (Pariyar *et al.*, 2019).

(7) Reduces seeding time by about 6 days on small farms to over 17 days on large farms (CSISA, 2018).

(8) Reduction in greenhouse gas emission and improved environmental sustainability (Marasini *et al.*, 2018).

(9) Avoiding crop residue burning reduces loss of nutrients, and environmental pollution, which reduces a serious health hazard (Sidhu *et al.,* 2007).

(10) Providing opportunities for crop diversification and intensification-for example in sugarcane-based systems, mustard, chickpea, pigeonpea etc. (Jat *et al.,* 2005).

(11) Improvement of resource use efficiency through residue decomposition, soil structural improvement, increased recycling and availability of plant nutrients (Jat *et al.,* 2009).

(12) Surface residues as mulch to control weeds, moderate soil temperature, reduce evaporation, and improve biological activity (Gathala *et al.,* 2011b).

(13) Energy saving: Savings of energy in conservation-tillage treatments were attributed to reduced energy use in land preparation (69–100%) and irrigation (23–27%), which consumed a large amount of fuel energy (Nandan *et al.,* 2021).

(14) Conservation agriculture conserves the moisture ensuring timely sowing and emergence of crops (Acharya *et al.*, 2017).

(15) Low risk (Laborde, 2018).

KEY CA TECHNOLOGIES IN NEPAL

(1) Direct-Seeded Rice (DSR)

DSR is an alternative rice establishment method in which rice seeds are broadcast or directly seeded in the dry tillage or wet tillage (puddled) field instead of transplanting the seedlings in the puddled field. The common DSR technologies in Nepal are:

(i) Wet direct-seeded rice (WDSR): This method is common in Jhapa and Morang and high rainfall areas of other Terai districts. In this method, rice seeds soaked for 24-72-hours and sprouted are broadcast or sown in lines using drum seeder under wet tillage and puddled soil (Bedari *et al.,* 2020).

(ii) Dry direct-seeded rice (DSR): This is an ancient method of rice establishment in the hill districts of Nepal, especially in the western mid-hill districts: Gorkha, Lamjung, Tanahun, Parbat, Syangja, Palpa. It is known as Ghaiya Dhan, grown mostly in rainfed upland unbunded terraces with seeding in March-April. Terai receives adequate rainfall (>1300 mm) during rice season, even under rainfed condition and without supplementary irrigation, performance of DSR can be good and this technology seems promisig in high rainfall areas (Devkota *et al.,* 2019).

(2) Zero tillage (ZT) in maize

An on-station replicated experiment conducted by Karki *et al.,* (2014) in maize-wheat system during 2011-2013 in Rampur, Chitwan found that ZT sole maize without residue retention in field was counter-productive to the farmers, where ZT maize with retained residue had 6% higher yield than CT maize without residue retention, indicating ZT can replace CT in maize, which saves labor and the production costs related to field preparation and crop establishment.

(3) Surface seeding in wheat

No land preparation is needed in his method and the sprouted wheat seeds are broadcast onto the saturated soil either in standing rice crop before its harvest (relay surface seeding) or after harvest (Hobbs 2001). In Nepal, surface seeding of wheat, lentil, and lathyrus is mostly used in the areas where long-duration rice varieties are cultivated and difficult to timely drain out water from the field to allow timely field preparation and seeding. This system offers advantageous in terms of timely sowing, reduced risk of bird attacks, and low production cost. Tripathi (2010) reported that benefits of surface seeding of wheat are even more pronounced in terms of cost savings and returns compared to when it is sown under ZT or RT after draining the saturated soil. The saving in cultivation cost with surface seeding in wheat was more than 150% compared to CT wheat.

(4) Zero tillage in wheat (ZTW)

Pandey et al, (2020) in an experiment at Bhairahawa, Nepal find out that ZTW out-yielded (3.44 tha^{-1}) the conventionally tilled (CT) wheat (3.22 tha^{-1}). They reported the benefit: cost ratio of 2.38 in ZT compared to 1.81 in CT and wheat seeding can be done at least 15 days earlier than CT.

(5) Brown manuring using Dhaincha in DSR field

Brown manuring is a technique of growing green manuring crops viz., *Sesbania* sp. or *Crotolaria* juncea @20-30 kg/ha together as an inter or mixed crop when DSR is sown and killing them at 30 days after rice seeding through the application of selective post-emergence herbicides for manuring. Co-cultured *Sesbania or Crotolaria* crop is knocked down and dried by spraying 2,4-D ethyl ester @ 0.5 kg a.i. ha^{-1} as revealed by Gaire *et al.,* (2019).

(6) No-till garlic production

The garlic seeds are planted directly into untilled soil having the rice residues anchored on the surface immediately after the harvest of rice. It is being practiced in the terai districts of mid to far western Nepal. It has multiples advantages of reduced cost of production, timely sowing and yields at par with conventional practice of land preparation (ICIMOD, 2013).

SCALING-UP OF CONSERVATION AGRICULTURE

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:

(1) Research and development: Greater support from stakeholders including policy and decision makers at the local, national and regional levels will facilitate research and development on expansion of CA. On-station research should be backed by farmers' participatory on-farm research. Adaptive research on selection of crop species and their package of practices (sowing to post harvest operations), selection of cover crop and rotations, maintenance of soil cover and CA equipment need to be carried-out in the field.

(2) Diversification: CA offers opportunities for diversified cropping systems in different agro-ecological regions. The government policies affect crop diversification are pricing policy, tax and tariff policies, trade policies and policies on public expenditure and agrarian reforms (Behera *et al.,* 2007).

(3) Strengthening farmer's capacity: Training on CA to farmers, service providers and field technicians should be at all levels. In the long term, CA should be included in curricula from primary school to university levels.

(4) Institutionalization: Institutionalizing CA into local, provincial, national and regional policy and decision makers could spearhead and support the formulation and development of strategies and mechanisms for scaling up the technology.

(5) Agricultural mechanization: The new machineries, viz. happy seeder, turbo seeder, laser land leveler etc. found useful for CA are more suitable for plain areas and medium to large farm. Hill farmers

having small to marginal farms need smaller versions of the machines at the local level. Up-scaling of mechanized CA can be achieved through custom hiring centers, private entrepreneurs, and cooperatives and farmer's organizations, especially for small and marginal farmers.

(6) Champions: Identify the champion farmers, capacitate and reward them which have a great impact on the quality of life for all.

(7) Building partnership: A system perspective where scientists, farmers, extension agents, policy makers and other stakeholders' partnership are needed in developing and promoting technologies. Instead of using a top-down approach, a more participatory system is required to experiment and find out the solutions.

(8) Soft loans and no custom duties: Soft loans to buy the equipment, machinery, and inputs through banks and credit agencies at lower interest rates and provide no custom duties for the introduction of such equipment from abroad. Chinese government in recent years 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). Currently in Shanxi, Shandong and Henan provinces over 80% area under maize cultivation depends on no till seeder.

CONCLUSION

A paradigm shift has become a necessity in present context of widespread problems of resource degradation and declining factors productivity. Improving productivity, conservation of scarce resources along with soil quality, protecting environment and improvement of livelihood are the key concerns. Developing and promoting CA systems can be an option to address the issues and will call for CA friendly policies and greatly enhance the capacity of scientists working with farming communities, policy makers, extension personnel, academicians, service providers and other key stakeholders in a system perspective. Similarly, the success stories of CA across the globe can also be taken into consideration. A task force consisting of all stakeholders need to be formed in order to formulate the CA friendly agricultural policies. Thus, short, medium and long-term strategies for research and development on CA can be formulated and implemented in Nepal.

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