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# Potentials of conservation agriculture in rainfed ecosystems

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## ABSTRACT

*Conservation agriculture (CA) is one of the key resource conservation technologies in agricultural production system which suggests minimum soil disturbance, leaving and managing the crop residues on soil surface and adopt spatial and temporal crop sequencing/crop rotation to derive potential resource use efficiency with minimal adverse environmental impacts. Conservation agriculture primarily aimed at curtailing production cost and GHGs emission, improving soil health, total factor productivity and coping with impacts of climate change. Rainfed ecosystems are exemplified by uneven and unpredictable rainfall, structurally unstable soils and variable productivity. Rainfed agriculture is at the cross roads with 82 percent of cropland area in the world and 60 percent in India. Therefore, it is essential to enhance, improve and sustain the productivity of rainfed eco-systems under associated problems of water stress and soil degradation. Conservation agriculture has great potentials for impressive and overturning the downward twisting of resource scarcity, receding factor productivity and retreating cultivation costs making rainfed agriculture more resource use-efficient, competitive and sustainable. Research and development efforts have contributed significantly to increase acceptance of conservation agriculture in wheat based cropping system but raised a number of questions related to institutional, technological and policy aspects focused on technology generation, adaptation and further improvement and need to be addressed for its accelerated adoption on a sustained basis.*

**Key words**: CA, rainfed system, crop diversification, residue management, soil health and TFP.

## INTRODUCTION

Conservation agriculture is a resource conservation technology which includes minimum disturbance in soil by adopting zero-tillage along with permanent soil cover of crop residues on surface and best possible crop diversification to harness potential remuneration from applied inputs and hold back the adverse environmental impacts. Introduction of zero-tillage system provided a better option in recent years to minimize the cost of production, crop diversification and improve resource use efficiency. But without crop residues retention on the soil surface zero/reduced tillage system have no particular advantage since most of the rain water is lost as runoff which transport soil and plant nutrients. It would therefore emerge that no-tillage alone in the absence of soil surface cover is improbable to become a favored practice. However, overall productivity and residue availability being low in light of its higher demand for livestock feed poses a major limitation for residue use as soil cover in the rainfed ecosystems. It would appear that there is need to identify situations where availability of even moderate amount of residues can be combined with zero-tillage to enhance soil quality and efficient use of rainwater. There is no hesitation to put on record that managing zero-tillage system necessitates a higher level of management as compared to conventional crop production systems so the benefits of conservation agriculture primarily consist of reversing the process of degradation and that its advantage in terms of crop productivity may accrue only gradually.

Rainfed ecosystems set apart by irregular and erratic rainfall, structurally unstable soils and inconsistent productivity. It account nearly 57 % (80 M ha) from 141 M ha of net sown area in the country contributing to 40.0 per cent of food grain production and supporting more than 66.0 per cent of the livestock population. Despite considerable progress in irrigation development, 85.0 per cent of coarse cereals, 83.0 per cent of pulses, 42.0 per cent of rice, 70.0 per cent of oilseeds and 65.0 per cent of cotton are still cultivated under rainfed ecosystems (CRIDA, 2007). Though, remarkable gains were noted in some of the crops under rainfed ecosystem in recent times, the gap between

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attainable and farmers' yields still remain high which is a major cause of concern. Small and marginal farmers who are the backbone of rainfed systems are resource poor and risk averse. Moreover the need to design and implement alternative production systems with increased resource use efficiency, profitability and productivity, and reduced adverse environmental impact, has are urgently required (Gangwar *et al.*2010).

With several resource management problems recently emerging in irrigated regions, rainfed agriculture offers scope to contribute to the growing food needs of future particularly of pulses and edible oils. According to FAO (2011) the resource efficient or resource effective agriculture can play a major role in improving productivity in rainfed areas. Larger gap between attainable yields realized at research farms using improved technologies and those actually realized by majority of the farmers in any given region offer scope for enhancing overall productivity of crops in rainfed ecosystems anywhere between 50 to 70% in the short term with the adoption of the available resource conservation technologies, provided resource and institutional constraints in delivering the technology and inputs are addressed timely and adequately. Conservation agriculture has tremendous potentials for enhancing the total factor productivity and diminishing the cultivation costs to make rainfed agriculture more resource use-efficient, competitive and sustainable. With this view point present article has been framed to present an over view on conservation agriculture potentials in rainfed agriculture.

## Scenario of conservation agriculture

The global empirical evidence shows that farmer-led transformation of agricultural production systems based on Conservation Agriculture (CA) principles is already occurring and gathering momentum worldwide as a new paradigm for the 21$^{st}$ century. CA systems are now practiced globally on about 125 M ha in 2011 which was only 2.8 M ha in 1974 across different agro-ecosystems (Figure1). In India, efforts to adapt and promote resource conservation technologies have been underway for nearly two decade but it is only in the past 7 to 8 years that the technologies are finding rapid acceptance by farmers. Efforts to develop and spread conservation agriculture in India have been made through the combined efforts of several State Agricultural Universities, ICAR institutes and the International Research Organizations which resulted in spread of different forms of CA on an area of about 3.0 M ha mostly confined in the Indo-Gangetic Plains (Gupta & Sayre 2007 and Somasundaram *et al.* 2014). Unlike, in the rest of the world, in India spread of these technologies is taking place in the irrigated regions where rice-wheat cropping system dominates. Conservation agriculture systems have not been promoted in rainfed or the mountain agro-ecosystems which contribute key proportion in national food basket and have great potential for further increase in crop productivity and sustaining soil health and environmental quality on one hand and matching with available resources of majority of the farming communities.

## Potentials of conservation agriculture

Conservation agriculture is aimed to conserve, improve and make more efficient use of natural resources through integrated management of available soil water and biological resources combined with external input. It has been estimated that per hectare spreading of area under CA could save 34.5 liters of diesel in addition to saving of water, labour and protection of soil from degradative processes, primarily in rainfed production system (Somasundaram *et al.* 2014).

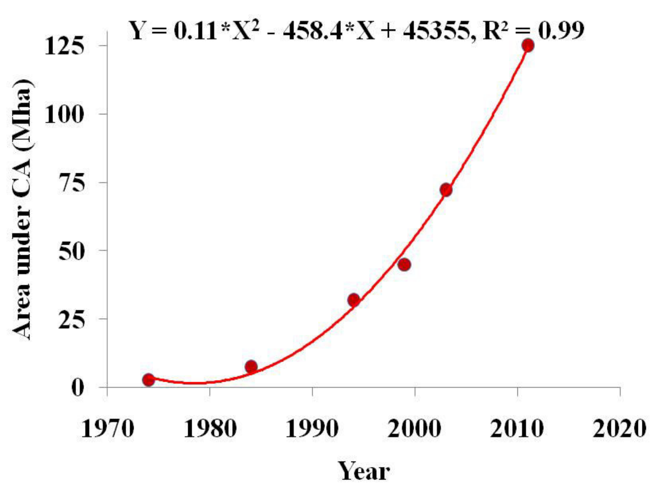


*Figure 1:* Global adaptation of conservation agriculture (FAO, 2011)

In coordination with other known good practices (quality seeds, integrated pest, nutrient, weed and water management, etc.) conservation agriculture is a base for intensified sustainable agricultural production. The yield levels of CA systems are comparable with and even higher than those under conventional intensive tillage systems, which means that CA does not lead to yield penalties and at the same time, it complies with the generally accepted ideas of sustainability. As a result of the increased system diversity and the stimulation of biological processes in the soil and above the surface as well as due to reduced erosion and leaching, the use of chemical fertilizer and pesticides, including herbicides, is reduced in the long term. Ground water resources are replenished through better water infiltration and reduced surface runoff. Water quality is improved due to decreasing reduced contamination levels from agro-chemicals and soil erosion (Laurent *et al.* 2011). It further helps in the sequestering of carbon in soil at a rate ranging from about 0.2 to 1.0 t $ha^{-1}yr^{-1}$ depending on the agro-ecological location and management practices (Corsi *et al.* 2012). Labor requirements are generally reduced by about 50 percent, which allows farmers to save on time, fuel and machinery costs (Baker *et al.* 2007; Crabtree 2010 and Lindwall & Sonntag 2011). Fuel savings under conservation agriculture has been reported by Sorrenson & Montoya (1991) to the tune of 65 percent in general. The accelerated adoption and spread of conservation agriculture technologies particularly conservation-tillage and residue retention on soil surface in rice and wheat based cropping system is attributed to assortment of potential benefits which includes.

**Improvement in soil health**

Rainfed agriculture is at the cross roads with 82 percent of cropland area in the world and 60 percent in India. Therefore, it is essential to enhance, improve and sustain the productivity of rainfed eco-systems under associated problems of soil degradation and desertification. The degradative processes can be reversed by enhancing the soil carbon pools and their mean residence time which necessitate adoption of sustainable land management practices. Important among these are conservation agriculture and integrated nutrient management (Lal 2010). The goal is to create positive soil carbon, water, and nutrients budgets in soils under rainfed eco-systems. There has been ample number of reports on the effect of various tillage and residue management practices in modifying the physical, chemical and microbiological environment of soil (Hobbs 2001, Malik *et al.* 2004 and Sidhu *et al.*2007). All of these are considerably diverse and contradictory owing to their dependence on regional soil and climatic variability and the duration of the experimental study. Study conducted by Singh *et al.* (2013) clearly showed that conservation tillage significantly reduce the bulk density and enhance the organic carbon and infiltration rate in rhizosphere (Table 1).

Table 1: Effect of tillage practices on soil properties in pigeonpea-wheat rotation (pooled data of 2010-11 and 2011-12)

| Treatment | Bulk Density (Mg $m^{-3}$) | | Organic Carbon (g $kg^{-1}$) | Infiltration Rate (mm $hr^{-1}$) |
|---|---|---|---|---|
| | 0-15 cm | 15-30 cm | | |
| Conventional tillage | 1.56 | 1.60 | 3.24 | 5.36 |
| Minimum tillage | 1.50 | 1.61 | 3.25 | 5.36 |
| Zero-tillage | 1.49 | 1.59 | 3.30 | 6.60 |
| CD (*p=0.05*) | 0.01 | NS | 0.04 | 0.07 |

*(Source: Singh et al, 2013)*

**Reduce soil compaction**

No-tillage is usually reported to increase the soil bulk density in initial years and therefore, makes the soil more compact at surface but lesser in rhizospheric zone (Lopez-Fando *et al.* 2007). But in due course of time, significant increase in soil organic matter and protection of surface layer by cover residue mulch against the action of falling raindrops have usually contributed in improving the soil aggregation, saturated hydraulic conductivity and reduces the soil compaction (Figure 2) under no-tillage as compared to conventional methods (Osunbitan *et al.* 2005 and Alvaro-Fuentes *et al.* 2009).

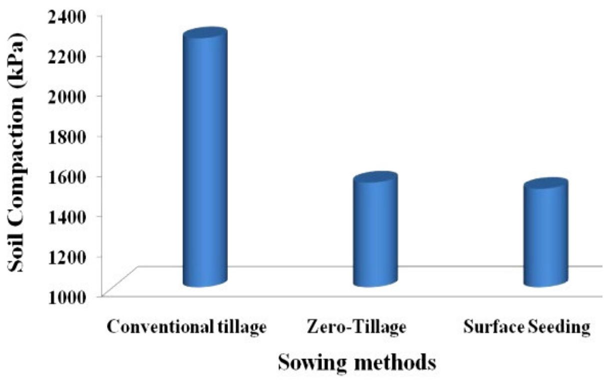


*Figure 2*: Effect of different tillage practices on soil compaction (Source: Alvaro-Fuentes *et al.* 2009)

**Improvement in biological activity and organic carbon and reduction in soil erosion**

Surface cover under CA reduces erosion and run-off losses and facilitates the biological activities (Figure 3) which results in poor crusting, higher aggregate stability and improved infiltration. Numerous evidences are available which reveals that conservation agriculture promotes the biological activities in soil and nourishes the soil health (Acharya *et al.*1998, Rodriguez *et al.* 2006 and Verhulst *et al.* 2010). Study of Schertz and Kemper (1994) revealed that soil erosion reduced with increasing the residue load on soil surface (Figure 4). Sorenson (1997) also reported a reduction in soil erosion from 3.4-8.0 t ha$^{-1}$ under conventional tillage to 0.4 t ha$^{-1}$ under zero-till, and water loss reduced from about 990 to 170 t ha$^{-1}$. However, a watershed study in Brazil showed 22 percent reduction in sediment load from 1994 to 1998 only because of zero-till adoption (Derpsch 2001). Similarly, Singh *et al.* (2006) also reported that zero-tillage along with crop residue as mulch conserved 11 percent more rain water as compared to conventional tillage at 4 percent slope. At the same time inside the fields the producer is taking attempts to lower the amount of fertilizer and pesticides used within the fields so that organisms and microbial activity have a chance to establish themselves in the soil and habitat as a whole (Green *et al.* 2005). Conservation agriculture provides an opportunity for carbon sequestration in soil and creating a nutrient-rich environment in plant rhizosphere. It has been reported that organic matter levels have increased from 1.9 to 6.2 percent after 19 years of continuous no-till experiment (Schertz and Kemper, 1994). In another study, Hargrove and Frye (1987) also found a buildup of organic carbon in soil under conservation tillage practice in (Figure 5).

**Reduction in cost of production**

The conventional practice of excessive tillage, involving 3–5 tillage operations, consumes a high proportion (25–30%) of total operational energy thus become expensive for crop production and is a key factor contributing to accelerated adoption of zero-till technology (Sidhu *et al.* 2004). Study shows that the cost of wheat production under conservation tillage is reduced by Rs.1400 to 2000 per hectare which is directly attributed to savings on account of fuel and labour costs (Somasundaram *et al.* 2014).

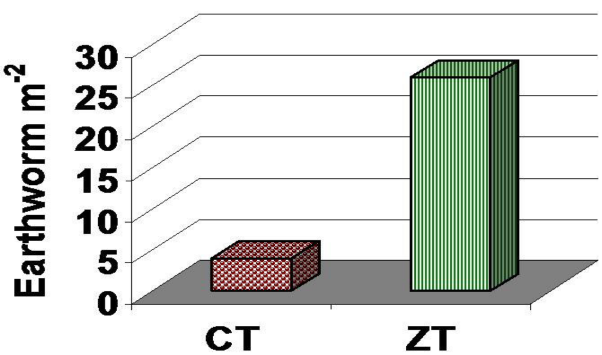


Fig.3: Effect tillage on earthworm

Table 2: Economics of wheat sowing under conventional and conservation systems

| Particulars | Sowing Techniques | | | |
|---|---|---|---|---|
| | Conventional | Conservation | | |
| | | Zero-till | Roto-till | Strip-till |
| Time (h) | 10.80 | 3.23 (70.1) | 3.4 (68.1) | 4.17 (61.3) |
| Fuel used (l ha$^{-1}$) | 34.60 | 11.50 (66.8) | 13.80 (60.1) | 17.50 (49.4) |
| Operational energy (MJ ha$^{-1}$) | 1976.11 | 648.96 (67.2) | 783.60 (60.3) | 1001.76 (49.3) |
| Cost of operation (Rs ha$^{-1}$) | 3400 | 1400 (58.8) | 1800 (47.1) | 2000 (41.2) |
| Saving (Rs ha$^{-1}$) | - | 2000 | 1600 | 1400 |

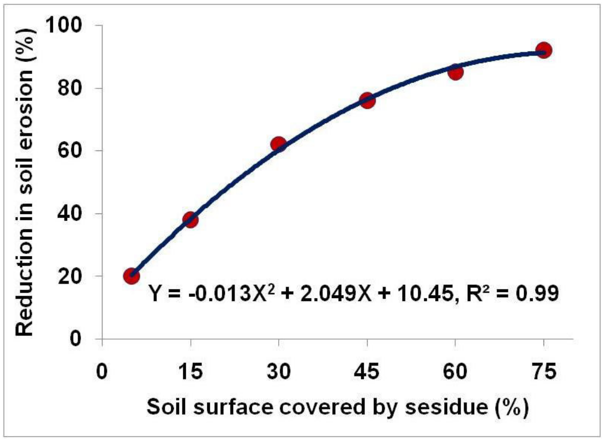


*Figure 4*: Effect of surface residue load on soil erosion

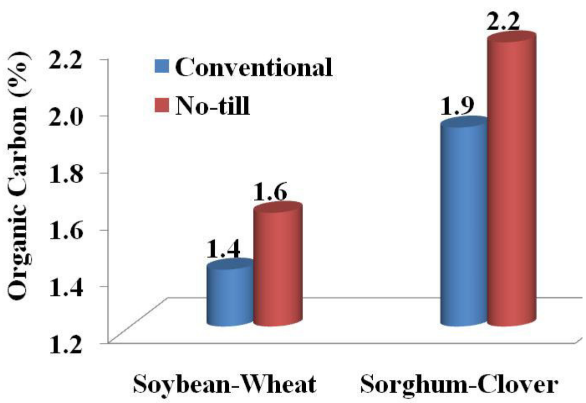


*Figure 5*: Effect of tillage practice and cropping systems on Soil OC

## Decreases the weed incidence

In general, it is assumed that conservation agriculture promotes the weed infestation but it was noted that problem of weed flora reduced within 3-4 years of CA adoption mainly because weed seeds present in lower soil depth could not germinate. The results of field experiment conducted at Ranchi under AICRP on Forage crops (Annual Report 2013) showed that infestations of narrow leave weeds were lowest (65.75) in conservation tillage followed by conventional (70.50) and significantly higher (81.41) narrow leave weeds were obtained in minimum tillage practice (Table 3). Another study conducted in Brazil (Ruedell 1990) under soybean-wheat rotation also showed a noticeable reduction in weed population in conservation agriculture as compared to conventional system (Table 4).

Table 3: Effect of tillage practice on weed population under rice-oat cropping system

| Tillage Practice | Weed population $m^{-2}$ | |
|---|---|---|
| | Narrow leaves | Broad leaves |
| Zero –tillage | 65.75 | 10.25 |
| Minimum tillage | 81.41 | 22.16 |
| Conventional tillage | 70.50 | 14.83 |
| Sem $\pm$ | 1.86 | 0.47 |
| CD (*p=0.05*) | 7.28 | 1.84 |

*Source: Annual Report of AICRP on Forage Crops (2013)*

Table 4: Effect of tillage practices on population of weeds

| Occurrence of weeds | Weed population (No. $m^{-2}$) in two agricultural systems | | | |
|---|---|---|---|---|
| | Without rotation | | With rotation | |
| | Conservation | Conventional | Conservation | Conventional |
| Broad leave weeds in wheat | 36 | 44 | 102 | 167 |
| Narrow leave weeds in wheat | 17 | 30 | 41 | 44 |
| Broad leave weeds in soybean | 4 | 20 | 15 | 71 |

*Source: Ruedell 1990*

## Savings in water and nutrients

Conservation agriculture requires significantly less water use due to increased infiltration and enhanced water holding capacity from crop residues left on the soil surface. Mulches also protect the soil surface from extreme temperatures and greatly reduce surface evaporation, which is particularly important in tropical and sub-tropical climates. In rainfed regions, the benefits of conservation agriculture are most salient during drought years, when the risk of total crop failure is significantly reduced due to enhanced water use efficiency. Limited experimental results and farmers experience indicate that considerable saving in water (20-30 %) and nutrients are achieved with conservation agriculture (Singh *et al.* 2010). Similarly, Jat *et al.* (2011) also reported that major benefits of conservation agriculture includes reduced cost on fuel and lobour, timely sowing of crops with higher productivity, reduced weed intensity and saving of irrigation water up to 15-20 per cent.

Soil nutrient supplies and cycling are enhanced by the biochemical decomposition of organic crop residues at the soil surface. While much of the nitrogen needs of primary food crops can be achieved by planting nitrogen-fixing legume species, other plant essential nutrients often must be supplemented by additional chemical and/or organic fertilizer inputs. In general, soil fertility is built up over time under conservation agriculture, and fewer fertilizer amendments are required to achieve optimal yields.

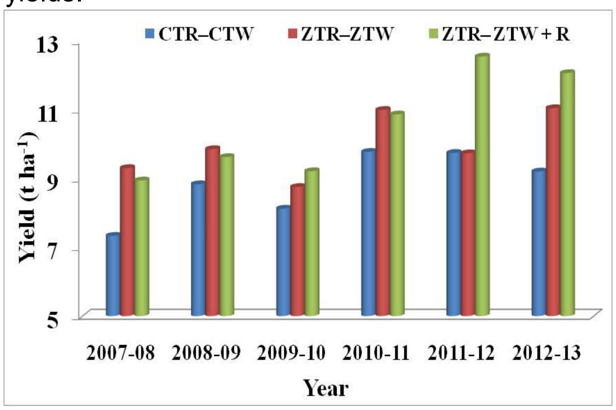


*Figure* 6: Effect of tillage practices on productivity of rice-wheat system

## Potential for higher yield

Wheat yields in properly managed zero-till planting were invariably higher by 4 to 6 per cent compared to conventionally prepared fields for comparable planting date (Jat *et al.* 2005). Field experiments conducted under diverse agro-environment revealed that rice seeded with zero-till technology yielded 19.0, 2.4, 5.0 and 1.4 percent more as compared to those in conventional tillage system at Ranchi, Bhubaneswar, Jabalpur and Raipur (Table 5).

Table 5: Effect of tillage practice on rice yields under different eco-systems

| Tillage Practice | Rice Yield (q ha$^{-1}$) | | | |
|---|---|---|---|---|
| | Ranchi | Bhubaneswar | Jabalpur | Raipur |
| Zero –tillage | 29.89 | 38.23 | 52.14 | 52.34 |
| Minimum tillage | 27.04 | 38.20 | 50.02 | 50.49 |
| Conventional tillage | 25.11 | 37.34 | 49.68 | 51.64 |
| SEm $\pm$ | 0.91 | 0.53 | 1.63 | 1.67 |
| CD (*p=0.05*) | 3.57 | NS | NS | NS |

*Source: Annual Report of AICRP on Forage Crops (2013)*


*Figure 7*: Practice of on-farm residue burning

The results of six years study conducted at farmer's field in Bihar (Jat *et al.* 2014) clearly showed differential benefits of conservation agriculture based management practices (zero tillage and residue retention) on crop yield of rice-wheat system. Productivity of rice-wheat system under conservation agriculture (ZTR–ZTW and ZTR–ZTW + Residue on surface) was higher and sustainable as compare to conventional system (Figure 6).

## Environmental benefits

Conservation agriculture involving zero-till and surface managed crop residue systems is an excellent opportunity to eliminate burning of crop residues (Figure 7) which contribute to large amount of green house gases and particulate matter. Burning of crop residues, also contributes 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. The resource conservation technologies with innovations in residue management avoid straw burning, improve soil organic carbon, input efficiency and have the potential to reduce green house gasses emissions (Pathak *et al.* 2011).

## Opportunities for crop diversification

Adopting conservation agriculture system offers opportunities for crop diversification enhance the cropping intensity, contributes to system resilience, reduces the vulnerability to yield and minimizing pest problems. Limited studies indicate that a variety of crops like mustard, chickpea, pigeonpea, sugarcane, etc., could be well adapted to the new systems with advantage. Area under pigeonpea in central India is shrinking in recent years mainly because of long duration (220 to 250 days to maturity), severe frost and diseases (wilt and sterility mosaic) which force to growing of only a single crop in a year and restrict the net returns per unit area. Opportunity for sequential cropping has emerged with the introduction of short-duration cultivars and expansion of irrigation facilities (Ahlawat *et al.* 2005). Problem of delayed sowing mainly because of tillage to seed bed preparation for subsequent wheat crop in pigeonpea-wheat rotation was observed which resulted in crucial as yield reductions to the tune of 1 – 1.5 % per day delay after the optimum sowing date (Hobbs & Morris 1996, Rai *et al.* 2003). To overcome above problems, conservation tillage and management of pre-sowing irrigation in pigeonpea–wheat cropping sequence has been evaluated at Morena (Singh *et al.* 2013). The result of the study was encouraging as the wheat yield and net return were significantly improved with least energy inputs due to adoption of conservation agriculture (Table 6).

Table 6: Yield and economics of wheat as affected by time of pre-irrigation and tillage practices (pooled data of 2010-11 and 2011-12)

| Treatment | Seed Yield (q ha$^{-1}$) | Straw Yield (q ha$^{-1}$) | Cost of production (Rs ha$^{-1}$) | Net return (Rs ha$^{-1}$) | B:C Ratio | Energy input ($\times 10^3$ MJ ha$^{-1}$) |
|---|---|---|---|---|---|---|
| Time of pre-irrigation | | | | | | |
| Before harvesting of pigeonpea | 44.5 | 53.6 | 24013 | 47861 | 3.01 | 16.06 |
| After harvesting of pigeonpea | 40.6 | 48.7 | 23757 | 41636 | 2.76 | 16.03 |
| CD (*p=0.05*) | 1.12 | 1.20 | NS | 1594 | 0.05 | 0.02 |
| Tillage practices | | | | | | |
| Conventional tillage | 41.9 | 50.3 | 25635 | 42312 | 2.66 | 16.88 |
| Minimum tillage | 41.6 | 59.8 | 24145 | 42720 | 2.77 | 16.01 |
| Zero-tillage | 44.1 | 53.3 | 21875 | 49214 | 3.24 | 15.24 |
| CD (*p=0.05*) | 0.69 | 1.15 | 399 | 569 | 0.09 | 0.02 |

## Potential for in-situ crop residue management

It is estimated that during the year 2011-12 India has produced 93.9 million tons (Mt) of wheat, 104.6 Mt of rice, 21.6 Mt of maize, 20.7 Mt of millets, 357.7 Mt of sugarcane, 8.1 Mt of fibre crops, 17.2 Mt of pulses and 30.0 Mt of oilseeds crops (MoA 2012) resulting in the production of a huge volume of crop residues both on-farm and off-farm. It is also estimated that approximately 500-550 Mt of crop residues are produced per year in the country (MNRE 2009) and the share of different crops in total residue production are depicted in Figure 7. However, a large portion of it is remain unused (Figure 8) and burnt on-farm primarily to clean the field for sowing of the succeeding crop. The problem of on-farm burning of crop residues is intensifying in recent years due to shortage of human labour, high cost of removing the crop residues by conventional methods and use of combines for harvesting of crops. The residues of cereals, pulses, oilseeds, fiber crops and sugarcane are typically burnt on-farm across different states of the country. Conservation agriculture provides the opportunity for

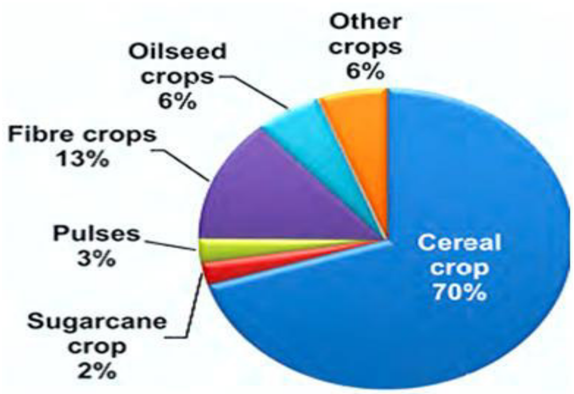


*Figure 7*: Share of crop residue produced in India

management of crop residues and offers an optimal ground cover through planting into loose and anchored residues (full residue retention) using Combo Happy Seeder (A) or Turbo seeder (B). Farmers participatory trials (154) conducted during three consecutive years (2007-08 to 2009-10) clearly indicated that sowing of wheat by Happy Seeder produces higher yield as compare to the conventional system and also facilitate the residue management without burning (Table 7).

Table 7: Effect of seeding methods on wheat yield

| Year | Grain yield (t /ha) | |
|---|---|---|
| | Conservation tillage (Happy seeder) | Conventional till (CT) |
| 2007-08 | 4.59 | 4.50 |
| 2008-09 | 4.54 | 4.34 |
| 2009-10 | 4.42 | 4.30 |
| Mean | 4.56 | 4.42 |

(Anonymous 2012)

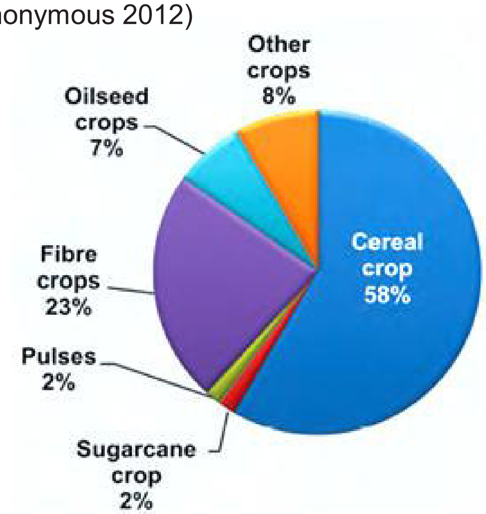


*Figure 8*: Share of unused crop residue in India

Results of a long-term experiment (10 years) conducted under rice-wheat in vertisols at JNKVV, Jabalpur indicated that adoption of zero-tillage in both the crops had a slight advantage in terms yield but deep tillage did not benefit either of the crop yields as compared to conventional tillage. Zero-tillage, thus, not only resulted in similar or slightly improved yields, it also involved lower cost of production on account of saving in fuel cost. Similarly, straw mulch application at the rate of 5.0 t ha-1 was found highly effective in further improving yield. With the adoption of conservation agriculture, the beneficial effects are likely to increase over time due to improvement in soil quality (Tomar 2008).

**Potentials for introduction of pulses in rainfed rice-fallow area**

In light of stagnation or declining productivity of crops challenge of meeting food demand of present and future can be cope up with utilization of fallow land particularly in vertisols of rainfed ecosystems. After rains, tillage operations are not possible in these areas and resulting in kharif fellow which can be avoided through direct dry seeding under conservation agriculture that also facilitate to overcomes the problems of crusting/compaction and poor emergence and plant population. It has been estimated that about 2.0 M ha area remains fallow during kharif season in Madhya Pradesh alone (Figure 9) which could be brought under cultivation through adoption of conservation agriculture. Subbarao *et al.* (2001) further estimated that out of 40.18 M ha rainfed rice grown in India about 11.65 M ha area is remain fallow during rabi season (Table 8) mainly because of scarcity of soil moisture.

Table 8: State wise distribution of rabi fallow of rainfed rice area in India

| State | Rainfed rice area (M ha) | Rabi fallow (M ha) |
|---|---|---|
| MP + Chhattisgarh | 5.6 | 4.38 |
| Bihar + Jharkhand | 5.97 | 2.2 |
| West Bengal | 4.62 | 1.72 |
| Orissa | 3.88 | 1.22 |
| Maharashtra | 1.76 | 0.63 |
| Assam | 2.23 | 0.54 |
| UP | 6.26 | 0.35 |
| AP | 2.66 | 0.31 |
| Others | 7.2 | 0.3 |
| Total | 40.18 | 11.65 |

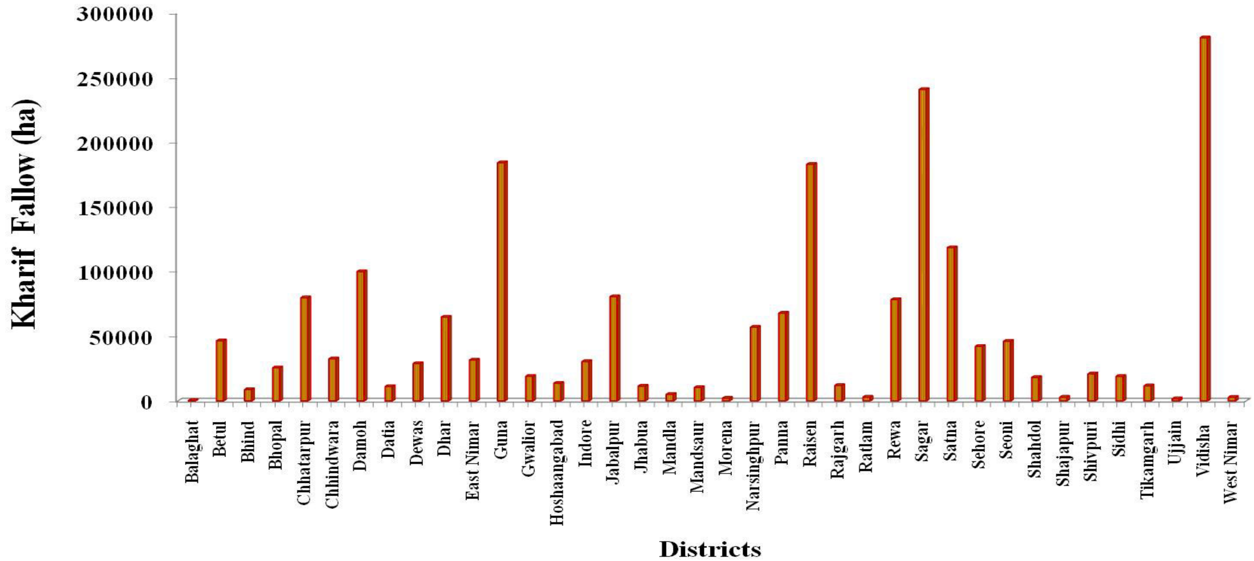


*Figure 9*: District wise distribution of kharif fallow area in Madhya Pradesh (Source: Subbarao *et al.* 2001)

Conservation agriculture has greater potentials to convert these mono-cropped areas in to double cropping by introducing less water requiring pulse crops. Chickpea is one of the major cool season grain legumes widely grown in India, and is suitable for rainfed rice-fallow areas of many states. Currently it is not a major crop in rice-based production systems in peninsular India, but has potential for expansion especially in the rainfed rice-fallow areas of Andhra Pradesh, Karnataka, Orissa, Madhya Pradesh, Chhattisgarh, Bihar and Jharkhand. *Utera* cropping is practiced with chickpea in some states and have great potential for its expansion for pulses production in the states of Uttar Pradesh (0.055 M ha), Madhya Pradesh (0.02 M ha), Jharkhand (0.02 M ha), Bihar, West Bengal and Assam (0.005 M ha each). Through adoption of CA coupled with short duration and high yielding rice varieties and heat resistant varieties of chickpea (JG11 and JG 14 of JNKVV, Jabalpur and others), the traditional rainfed rice-fallow cropping can be converted into rice-chickpea system. In central Madhya Pradesh, soybean-chickpea rotation is coming up in large areas, and this system has also been found economical to cotton in Guntur and Prakasham districts of Andhra Pradesh.

Relay cropping of small seeded lentil especially in medium deep soils could convert these mono-cropped areas into double-cropped areas and thus, increase legume production and sustain productivity of the rainfed rice-fallow areas. Expansion of this system requires development of genotypes especially suited for relay cropping and matching agro-technology, which has not received adequate attention so far.

Lathyrus is a robust legume commonly grown after rice in eastern India. It is suitable for rainfed rice-fallow areas under CA in Uttar Pradesh, Madhya Pradesh, Bihar, Chhattisgarh West Bengal, and Assam. Lathyrus has wide adaptability to grow in paddy soils and it suffers much less as compared to other pulses in adverse conditions of soil moisture. It thrives best on low-lying water retentive heavy soils. Most of the lathyrus is grown as a relay crop, where the seed is broadcast into the standing rice crop before its harvest (about 3 to 4 weeks). At the time of rice harvest, it is already established; and thus has an early advantage in establishing crop cover quickly.

## Challenges in adaptation of conservation agriculture

Conservation agriculture poses a challenge both for the scientific community and the farmers to overcome the past mindset and explore the opportunities that conservation agriculture offers for natural resources improvement. Conservation agriculture is now considered a route to sustainable agriculture. Spread of conservation agriculture, therefore, will call for a greatly strengthened research and linked development efforts.

- ❖ Although considerable and victorious efforts have been made in developing and promoting the machinery for seeding in no-till system, successful adoption of conservation agriculture systems will call for significantly accelerated effort in developing, standardizing and promoting quality machinery aimed at a range of crop and cropping sequences, permanent bed and furrow planting systems, harvesting operations to manage crop residues, etc.
- ❖ Conservation agriculture systems symbolize a major departure from the past ways of doing things. This implies that the whole range of practices including planting and harvesting, water and nutrient management, diseases and pest control etc. need to be evolved, evaluated and matched in the context of new systems.
- ❖ Managing conservation agriculture systems will be extremely challenging in terms of 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.

## Conclusion

Available information and our experience clearly reveals that implementation of conservation agriculture in rainfed ecosystem is need to be accelerated as it has great potential to improve the soil health, reduce the time required to harvesting and sowing of next crop, conserve water and nutrients, reverse the on-farm residue burning practice, save the fuel use and GHGs emission, breaking the yield barriers without surrendering the productivity potential.

Sowing of crops in presence of residue of preceding crop was the biggest problem in adoption of CA but introduction of new variant of zero-till machines (Happy Seeder and Turbo Seeder) has solved the problem. There is great opportunity for accelerated promotion of conservation agriculture in rainfed eco-system spread over 25 M ha area representing rice-fallow (12 M ha), cotton based system (3.2 M ha), soybean-wheat (2.23 M ha), soybean-chickpea (0.15 M ha), maize-wheat (1.8 M ha) and pearlmillet/sorghum/cluster bean-wheat (5.7 M ha) systems.

The conservation agriculture has great potential to improve yield and cropping intensity even in rainfed areas. Sustained research efforts, considering climate, soil and crops will go a long way in developing local area specific practices/machines for greater adaptation of conservation agriculture.

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