

Conservation agriculture:

Challenges and prospects in rainfed cropping systems

G Pratibha*, I Srinivas, K V Rao, K Srinivas, J V N S Prasad, M Srinivasa Rao, Shivakumar Anna, K Sammi Reddy and V K Singh

ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, Telangana 500 059

Under growing challenges of climate change, land degradation may be exacerbated in the future, and sustainability of natural resources may become a major concern. Conventional agriculture (CA) with intense tillage, without residue and monocropping is responsible for land degradation, yield stagnation and environmental pollution. Hence, conservation agriculture with three principles of no tillage, residue retention and crop diversification is a potential strategy to reverse land degradation with enhanced crop yields, reduced production costs, higher resource (nutrient, water, energy) use efficiency and reduced soil and water erosion in rainfed agriculture. Integration of complimentary practices like in situ moisture conservation, nutrient and weed management were essential for success of CA in rainfed regions.

Keywords: Conservation agriculture, Rainfed areas, Residue management, Termites

INDIA has 48% of its cropped area as rainfed/dryland. It contributes 44% of food grains and supports 40% and 75% human and livestock population respectively. It is estimated that 70% of productive drylands are threatened by different forms of land degradation, per capita land holdings are decreasing, at an alarming rate due to intensive cultivation practices. Further the past strategies of crop production like intense tillage, high fertilizer use are ineffective now due to extensive problems of resource degradation. In this scenario, globally, conservation agriculture (CA), which has proved an environmentally friendly strategy has opened a new paradigm to achieve sustainable production and profitability in rainfed regions and addressed the issue

of land degradation by arresting and reversing the downward spiral of resource degradation and efficient use of natural resources through the key principles like adoption of reduced tillage, crop rotations, residue retention and controlled traffic.

The Food and Agriculture Organization (FAO) defined CA with the following quantifying parameters:

- Minimal soil disturbance: The disturbed area must be less than 15 cm wide or 25% of the cropped area (whichever is lower);
- Soil cover: Soil cover should be more than 30%. The aim of retention of sufficient residue on the soil surface is to protect the soil from water/wind erosion, evaporation to improve water productivity and enhance soil physical, chemical, and biological properties associated with long-term sustainable productivity;
- Crop rotation: The rotation should involve different crops in two rainy (*kharif*) seasons. The objective of diversified crop rotations is to moderate/mitigate possible weeds, disease and pest problems.

Challenges and strategies for better adoption of CA in rainfed agriculture

The adoption of CA is high under rainfed conditions across the globe. But in India, the adoption is very low in rainfed regions and is limited to irrigated regions of Indo-Gangetic plains (IGP) regions. This low adoption



Three principles of conservation agriculture



(a) (b) (c)
Strategies for residue generation in rainfed areas (a) Pigeonpea-30 cm harvesting height; (b) Maize-60 cm harvesting height; (c) Dhaincha as live mulch

and upscaling of CA by small farmers in rainfed agriculture is due to several challenges like technological barriers, social barriers (attitude, small farm sizes, lack of knowledge, expertise). The major challenges and the strategies are:

Crop diversification: The crop rotation preferably cereal-legume is important pillar of CA for reduction of pest and weeds build up. Lack of functional input and output, markets for various crops and machinery is a major impediment to the widespread adoption of crop rotation. However, to have crop rotation it requires a more holistic approach at the government level.

Availability of crop residues: Surface cover with crop residues is essential for success of CA, but the crop residues are highly priced in rainfed agriculture, since they have many competing uses. These uses further may be aggravated in rainfed regions of India, where the crop and livestock production are closely integrated in mixed smallholder farming systems. In addition, lower crop productivity and residue production due to moisture stress, uncontrolled grazing, monocropping in Alfisols, termite infestation, strong winds during off-season which blow away the residues are some of the factors which contribute to poor residue retention in rainfed regions.

Therefore, interventions are needed to produce enough fodder, while at the same time recycle the residues to the soil. The major strategies were crop rotation with crops which have low fodder value, growing of short duration legumes like horsegram as pre-monsoon or as post-monsoon if the rainfall is around 70 mm between October–December. Intercropping with grain legumes/green manures crops like Dhaincha as live mulch in between crop rows and the green manure crop is harvested at 30–45 days and applied on the soil as surface mulch. This live mulch besides addition of crop residue, soil moisture conservation adds additional nitrogen and reduces weed incidence. 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 bottom portion of the residue is fibrous and 30 cm height for crops like pigeonpea and castor. The advantage of anchored residues is that it is not blown by winds and has a low termite infestation. This method of residue application has better acceptability.

Termite attack: In rainfed Alfisols, the major constraint for surface residue retention is termite infestation. The residues disappear within 2–3 months after harvest of the crop due to termite infestation. The termites infestation differs with the residue quality used and their placement. Termite infestation was higher on the residues which come in contact with soil than the anchored ones. Termite control can be achieved by application of chlorpyrifos or application of fresh cow dung slurry @2.5 t/ha.

Weed management: One of the major challenges perceived for low adoption of CA by the farmers is weed infestation during crop season as well as off-season and shift in the weed flora from annual weed species (easily controllable) to perennial weeds (difficult to control), broad-leaved weeds to grasses. Herbicides use is a prerequisite for weed control in CA. But, the herbicide efficacy of pre-emergence and post-emergence herbicides largely depends on the soil moisture. Considering these challenges of weed control and herbicide resistance of weeds in CA integrated weed management options with cautious use of herbicides may be another component that is crucial for successful implementation of CA. Studies at Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad in Alfisols have shown that weed control with pre-emergence herbicide + post-emergence herbicide and removal of escaped weeds mechanically has reduced the weeds as well as increased the seed yield of maize and pigeonpea in maize-pigeonpea annual rotation. Similar results were also reported in central India in black soils. Growing a cover crop like dhaincha in between the widely spaced crops, also reduced the weed infestation in CA. The existing weeds before sowing of crops need to be managed by applying non-selective herbicides like glyphosate. After 4–6 crop cycles, weed intensity was reduced in many studies mainly due to build of crop residues on soil surface and reduction in soil weed seed bank.

Fourth principle required to define CA for higher yields and resource conservation

The major limitation for success of CA in rainfed regions is poor soil moisture, nutrients etc. Hence, CA with only three principles alone is not sufficient for its

success in rainfed regions. Therefore, CA practices need to be integrated with complementary practices like *in situ* moisture conservation, nutrient and weed management which helps in increasing the adoption of CA.

In situ soil moisture conservation practices: Integration of *in situ* moisture conservation practices as fourth principle in CA has potential to reduce the soil erosion substantially, as well as increase the farmers' income by increasing grain yields and reducing production costs. In rainfed regions, inclusion of fourth principle of *in situ* moisture conservation practices with CA practices can be achieved through permanent raised bed and conservation furrow, permanent conservation furrow or live mulch.

Permanent bed planting: In bed planting, 100 cm wide beds and furrows of 35 cm width and 15–20 cm depth are prepared with raised-bed planter. The planter can reshape the bed, sowing and fertilizer application can be done simultaneously. During the first year, beds are prepared and maintained, in subsequent years beds are reshaped at the time of sowing. Depending on the spacing, 2–3 rows of crops, can be sown. Permanent bed under rainfed conditions have several advantages such as they help in timely sowing, require low fuel and labour costs, improve soil health and quality, reduce erosion, conserve soil moisture with higher water-use efficiency (15–20%) and lead to yield enhancement (10–15% in maize and pigeonpea). In bed planting, the temporary waterlogging conditions can be avoided by draining out the excess water in furrows. Consequently, better infiltration and aeration can be created than under conventional tillage (CT). Permanent beds conserve moisture and also act as a drainage channel during high rainfall events and provide better microclimate for plant growth and root development. This method of planting can be adopted in crops like maize, soybean and pigeonpea. Ridges and furrows (35 cm ridge and 30 cm furrow) can be prepared with the implement.

Nutrient management: Nitrogen is the most limiting nutrient for cereals in rainfed regions. Hence, N application with other nutrients is prerequisite for higher productivity and residue generation. In general, cereal crop residues have higher C:N ratio resulting in immobilization of nitrogen for a short time, thus higher nitrogen requirement is required by the crops in CA in

the initial years. Appropriate nutrient application and additional dose of fertilizer is required to be defined in CA to enhance both crop productivity and produce.

Right machinery: Key to success of CA in rainfed regions

Sowing of a crop in the presence of the preceding crop residues is a major constraint in CA. The planter like zero-till seed-cum-fertilizer drill, Happy Seeder, Turbo Seeder and Rotary-disc drill developed for CA in irrigated areas are not suitable for rainfed areas. Happy seeders will not work in undulated topography and the coulters also do not work when the residues are low. Hence, energy and fuel efficient implements which can sow the seeds and place the fertilizers at desired depth by cutting the surface retained residue in no tilled fields for good germination are important to make CA an acceptable technology among the farmers.

CRIDA precision planter with herbicide and fertilizer applicator was designed and developed at CRIDA. In this planter, 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 it provides better seed-soil contact as compared to traditional disc openers, hence germination is better. Besides, this planter works very well under undulated topography, since it has individually operated hinge type shank mechanism. Apart from the CRIDA precision planter, raised-bed planter and CRIDA paired row planter were developed at CRIDA for integration of *in situ* soil moisture conservation with three principles of CA.

Potential benefits, prospects and impacts of CA in rainfed areas

CA is identified as an environment friendly technology. But the benefits of CA are realized only when all the principles of CA are adopted simultaneously. In rainfed regions, the yields and profitability of crops in CA were higher as compared to CT after 4–5 years. The increased crop yields are due to associated benefits like reduction in soil degradation, improvement in soil quality. The total system productivity of zero-tillage direct-seeded rice can be improved with CA-based rice-legume system. In pigeonpea-castor system, zero-tillage (ZT) with the anchored crop residues of 10 cm and 30 cm and growing a legume crop like dhaincha as live mulch



Implements for key to success of Conservation Agriculture practices (a) CRIDA raised bed planter with herbicide applicator; (b) CRIDA zero till planter with ridger; (c) CRIDA precision planter with herbicide applicator

recorded 36.7 and 13.1% higher yield in CA over CT in pigeonpea and castor, respectively.

In sorghum-blackgram system, sorghum and blackgram yield were 33.4 and 28% higher in minimum tillage than CT. While retention of sorghum residue by manipulation of harvesting height at 60 cm height, and at 35 cm height recorded 32.8 and 14.8% higher grain yield than no residue retention (control). Also, 100% and 50% of blackgram residue retention recorded 33% and 16% higher sorghum grain yield respectively, than control.

Potential of CA to adaptation and mitigation of climate change

CA has a strong potential to provide adaptation and mitigation strategies to manage extreme climatic events. Adaptive strategies include improved ability to cope with drought and soil temperature variability. It helps in timely sowing or advancement of sowing due to saving of time spent on tillage, which is very important in rainfed agriculture. The mitigation strategies include enhanced soil carbon sequestration and reduced greenhouse gases (GHGs) emissions. CA provides an opportunity to avoid residue burning, which contributes to large amounts of greenhouse gases like CO₂, CH₄ and N₂O. Besides reduction in GHG emissions, it also contributes to reduction in considerable loss of plant nutrients, which can be recycled when properly managed. While in the CT, there is a gradual decline in soil organic matter due to accelerated oxidation.

Resource-use efficiency and environment

ICAR-CRIDA studies indicate that CA (ZT + 30 cm anchored crop residue + sesbania intercrop) recorded 14.3% higher water losses, whereas the sediment and nutrient loss were 22 and 30% lower than CT and RT respectively. In maize-pigeonpea cropping system, *in situ* moisture conservation through conservation furrow and raised bed reduced the water loss by 80%. This protects the environment by reduction in contamination of water bodies. CA with residue have a substantial energy saving of 58%, due to reduced fuel consumption, higher energy-use efficiency, lower GHG emissions over CT.

Impact of CA on soil health

In rainfed regions, soil physical constraints are the key constraints. CA brings desirable changes in many soil physical properties. Studies in Alfisols at CRIDA in pigeonpea-castor and sorghum-blackgram cropping systems recorded slightly higher bulk density (BD) as compared to CT. However, the BD values did not cross the critical limit which can cause restrictions to root proliferation. Whereas, in Alfisols in maize-pigeonpea cropping system where nitrogen management was

included as complementary practice recorded 2.9, 8.5 and 13.3% lower BD in CT, reduced tillage (RT) and CA, respectively and 4.8, 14.9 and 21.9% increase in porosity in CT, RT and NT, respectively. RT with residue increased rate of infiltration by 53.5% in pigeonpea-castor system. In sorghum-blackgram system RT with 100% and 50% residue retention recorded 56% and 51% higher infiltration rate over CT without residue respectively. The aggregate stability, water-stable aggregation, aggregate associate C and different carbon pools increased in Alfisols. In ZT and CT, a decrease in water stable aggregates, aggregate stability C was observed over pigeonpea-castor system.

In Alfisols of CRIDA, after 10 crop cycles of pigeonpea-castor system, organic carbon (OC) was significantly higher in CA as compared to CT and RT. Increase in residue levels increased the OC content. After 6 crop cycles in maize-pigeonpea cropping system, integration of *insitu* moisture conservation through permanent conservation furrow recorded significantly higher OC content (0.47, 0.53 and 0.42%) and this was followed by permanent raised bed and furrow method (0.41, 0.43 and 0.39%) and CA with residues (0.32, 0.41 and 0.33).

SUMMARY

CA is one of the technologies which fit into sustainable intensification of agricultural practices as it helps the farmers in resource conservation, enhancing productivity and mitigating adverse impact of climate change. Hence, outscaling of CA for reversing resource degradation is essential. There is a need for policy initiatives and reorientation of research into multilocal and participatory mode on CA and livestock interactions to rationalize the residue needs for CA *vis-à-vis* livestock fodder in rainfed production systems. The impact of CA could be realized the long term and also when all the principles are adopted. Integration of complementary practices like *in situ* moisture conservation, nutrient and weed management are essential. Besides, long term studies on the influence of CA on a resource/input use efficiency, soil health, pest dynamics, carbon sequestration, greenhouse gas emissions and environmental benefits including ecosystem services in different production systems and rainfall are also needed for large scale adoption and popularization of conservation technologies for sustainable agriculture. Further, convergence or integration of CA into relevant programs is required. Local, national and regional policy and decision makers could spearhead and support the formulation and development of strategies for scaling up CA technology.

*Corresponding author's e-mail: pratibhaagro65@gmail.com

Authors !

Upload your article for *Indian Farming* and visit <https://epubs.icar.org.in>