Conservation Agriculture in Maize Production Systems

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PREFACE

The burden of feeding the people of the country on the Agronomists and Indian farming community is increasing day by day as the population of the country is increasing at an alarming rate; starting from about 370 million (m) in 1947-48, it has already reached above 1 billion and is still on the rise. Feeding such a large population with restricted resources is not an easy task. The demand for cereals, which are the staple food in India, is estimated at 262 m tonnes (t) by 2020-21as against an estimated production of 218 m t in 2008-09.

As regards water, it is estimated that by 2050 about 22% of the geographical area and 17% of the population would be under absolute water scarcity (<500 m^3/ capita/year) and about 70% of the area and 76% of the population will be on the verge of scarcity and health risk with water availability less than 1,000 m^3/capita/year (Planning Commission, 2002). Soil as a natural resource in the country is under great stress. Crop responses to applied fertilizer has declined over years due to imbalanced use of NPK and deficiencies of secondary nutrient S and micronutrients Zn, Fe, Mn and B are emerging in several areas. As regards energy, it is the most important input in agriculture. It is required in almost every operation, such as, tilling and seeding of the land, pumping of water, harvesting of crops and their processing, transport to the market and in the manufacture of fertilizers and other farm chemicals. Talking just about the production of crops, the energy requirement increased 4.5 times between 1970 and 2005 as the productivity almost doubled from 837 to 1,583 kg/ha.

Fertilizer, water, energy (fuel) and other agro-chemicals including herbicides are the essential inputs in any intensive cropping systems for increasing productivity. Indiscriminate and injudicious use of these monetary inputs for achieving potential yield of crops has not only enhanced the cost of cropping but also threatened the environment. Major research and development efforts in the era of green revolution have focused on enhancing productivity of selected food grains and a few other crops. In the post- green revolution era, the issues of resource conservation have assumed greater importance in view of stagnating productivity, increasing production cost, and widespread resource degradation problems such as deteriorating soil health, declining water table and increasing environmental pollution. Of late, resource conservation system have drawn the attention of agronomist and other crop production scientist to device modified tillage and crop establishment techniques for higher productivity and improving input use efficiency. Innovative approaches are also being worked out to supplement nutrient needs and provide other benefit like moisture conservation, weed control, erosion control etc. Conservation agricultural (CA) are therefore the need of the time.

Recent researches on conservation agriculture and resource conserving techniques have provided exciting opportunities for improving input-use-efficiency, productivity and sustainability. These techniques/ practices include: conservation tillage, residue management, suitable cropping system, zero tillage, minimum tillage, rotary tillage, bed plating, surface seeding, laser land leveling, pressurized irrigation systems, system of rice intensification, aerobic rice, soil solarization, site-specific nutrient management, crop diversification, precision farming etc. adoption of these practices and techniques is the need of the hour as a method of 'low-input agriculture' to reduce cost and achieve sustainability in Indian agriculture.

This bulletin broadly covered status of CA in the world and its need in Indian agriculture, CA practices answer for climate change, development of machinery for CA, nutrient and weed management practices under CA, resource conservation techniques, crop diversification, benefits of these practices alongwith the success story of CA in maize based cropping system in India and other related areas.

It is hoped that this information will be useful to all those associated with conservation agriculture with special reference to maize based cropping system in the country.

March 2011 **Authors**

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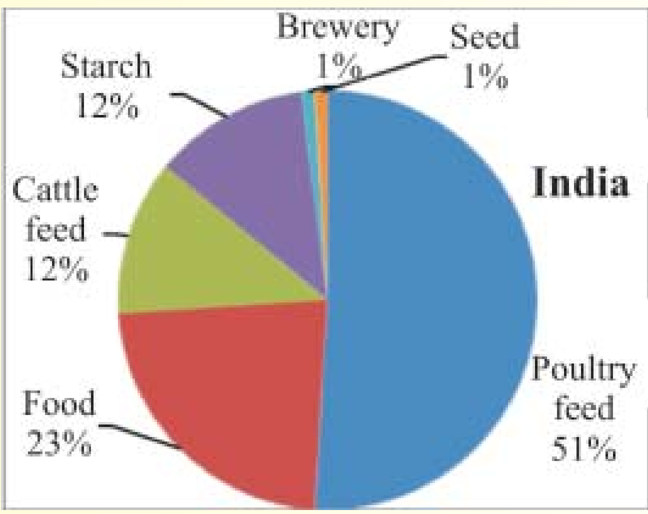
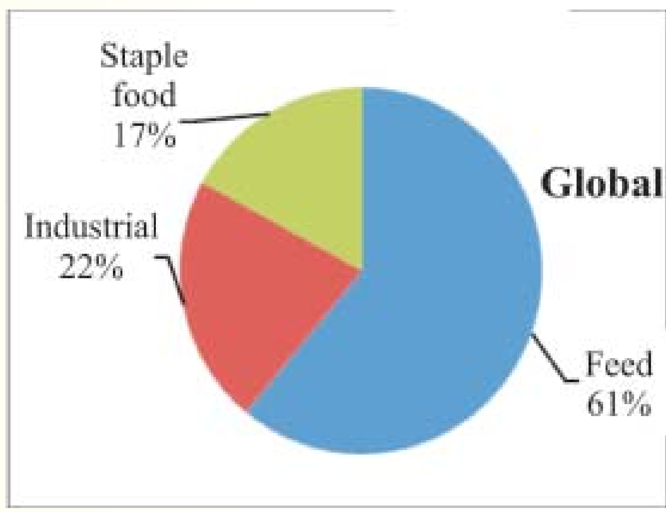
Conservation Agriculture in Maize Production Systems

1. Introduction

Maize (*Zea mays* L.) is one of the important cereal crop in India having wide adaptability to soil and diverse agro-climatic conditions and under different cropping sequences. It has emerged an important crop for food, nutritional security and farm economy in India and occupies 8.17 million hectares area with an average productivity of about 2.4 t/ ha, and contributing 8.5 % to national food basket. Presently, in India, maize is mainly used for preparation of poultry feed and extraction of starch and also provides food, animal feed, fodder and basic raw material for the various industries *viz*. bio-fuel, food sweeteners, cosmetics and alcoholic beverages etc .These diversified uses of maize also prompted higher production across the country.





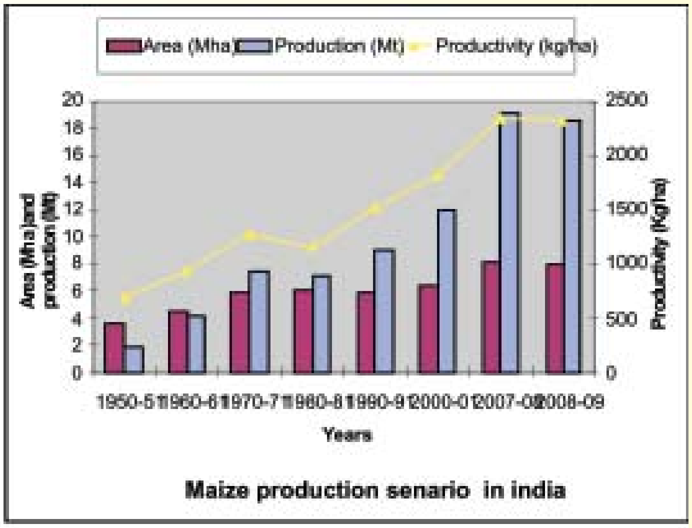
Current maize utilization pattern

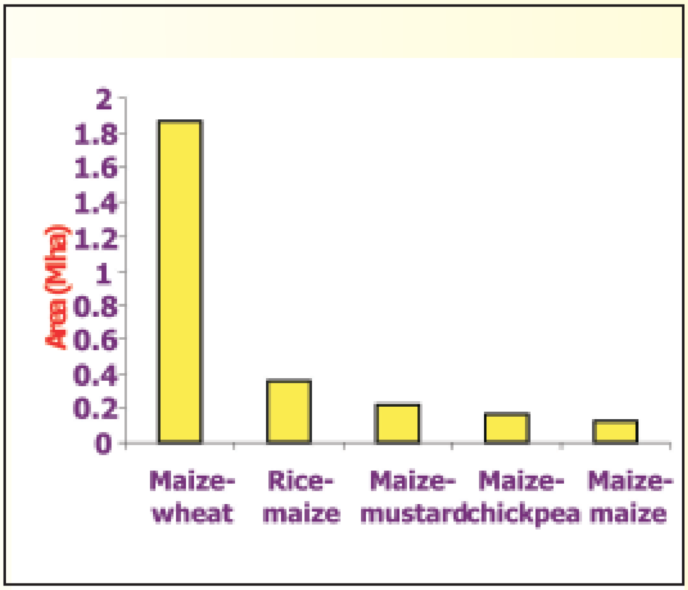
India is the fifth largest producer of maize after USA, China, Brazil and Mexico in the world contributing 3% of the global production. In India, nearly 75% of maize the production is from *kharif* season and remaining 25% during rabi and spring/summer season. Since the maize is primarily grown under rainfed conditions during *kharif* season but in rabi it is grown under assured irrigation.

Maize area, production and productivity in India have seen a phenomenal growth over the last five decades and have emerged from being a net importer to levels of self sufficiency. In the last five decades, India's maize production has increased from less than 4 million tonnes (1950-51) to 19.73 million tonnes (2008-09) today. This is because of growth in improved production technologies coupled with rising demand for the produce.

2. Major maize based production systems in India

Shift in traditional crops and cropping sequences to maize based systems are gaining importance in view of changing resource base under the current farming scenario. With the development of high yielding varieties and hybrids of maize and efficient resource use production techniques that are competitive with rice and wheat with respect to farm profitability and are efficient under diverse soil, season and climatic conditions have led to development of several maize based cropping systems (Table 1& 4). Furthermore, under the emerging limitations of natural resource base with the existing intensive cropping systems and excessive use of external inputs lead to degradation of soil, water and genetic resources. Under situations of declining water table and natural resource base degradation and market driven modern agriculture under peri-urban interface maize is emerging as an alternative option for crop diversification. In peri-urban interface, maize based high value intercropping systems are also gaining importance due to market driven farming. Further, maize have compatibility with several other crops of different growth habit that led to development of various intercropping systems (Table 4).





Among different maize based cropping systems, maize-wheat ranks 1st and it is the 3rd most important cropping system after rice-wheat and rice-rice having 1.8 m ha area that contributes about 3% in the food grain production of India. Studies carried out at various soil and climate conditions under All India Coordinated Research Project on Cropping System revealed that compared to existing cropping systems maize based cropping systems are better user of water and available resources at different locations.

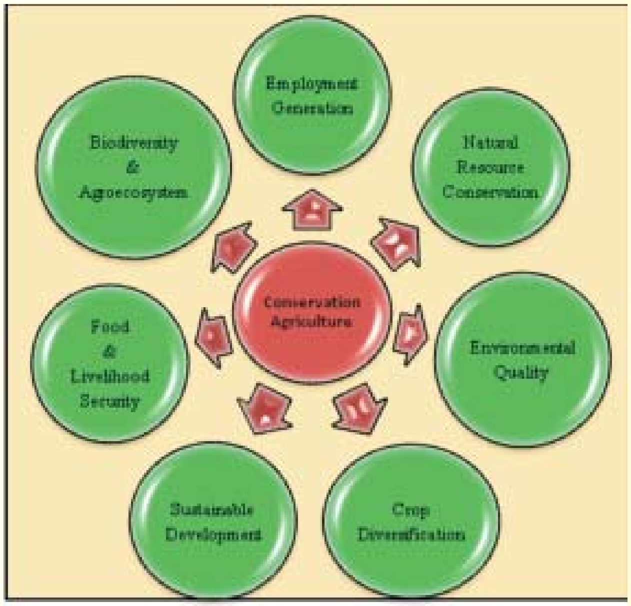
3. Conservation agriculture (CA) in maize based cropping systems

Traditionally, maize, wheat and other crops in maize based crop sequence are grown either in row geometry or by random broadcasting, mostly after thoroughly tilling the field till proper tilth is obtained for good seedling emergence. The traditional practices of growing these crops has several limitations such as inconvenient input management when sown by broadcasting, improper plant geometry, and uneven plant population resulting in inefficient utilization of space and plant competition leading to low productivity and input use efficiency. But, now evidences of second generation problems that includes declining factor productivity, stagnating crop productivity, declining soil organic matter (SOM) receding ground water table, diminishing farm profitability, environmental pollution etc. started appearing mainly attributed to monoculture of intensive conventional production systems. At

Table 1. Maize based sequential cropping systems in different ago-climatic zones of India

Agro-climatic region	Cropping systems	
	Irrigated	Rainfed
Western Himalayan Region	Maize-wheat Maize-potato-wheat Maize-wheat- mungbean Maize-mustard Maize-sugarcane	Maize-mustard Maize-legumes
Eastern Himalayan Region	Summer rice-maize-mustard Maize-maize Maize-maize-legumes	Sesame-rice+maize
Lower Gangetic Plain region	Autumn rice-maize Jute-rice-maize	Rice-maize
Middle Gangetic Plain region	Maize-early potato-wheat-mungbean Maize-wheat Maize-wheat-mungbean Maize-wheat-urdbean Maize-sugarcane-mungbean	Maize-wheat
Upper Gangetic Plain region	Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Maize-potato-sugarcane-ratoon Rice-potato-maize	Maize-wheat Maize-barley Maize-safflower
Trans Gangetic Plain region	Maize-wheat Maize-wheat-mungbean Maize-potato-wheat Maize-potato-sunflower Maize-potato-onion Mungbean-maize-toria-wheat Maize-early potato-late potato-Mungbean	-
Eastern plateau & hills region	Maize-groundnut-vegetables Maize-wheat-vegetables	Rice-potato-maize Jute-maize-cowpea
Central plateau & hills region	Maize-wheat	Maize-groundnut
Western plateau & hills region	Sugarcane + Maize	
Southern plateau & hills region	Maize-rice Rice-maize	Sorghum-maize Maize-sorghum-Pulses Maize-potato-groundnut
East coast plain and hills region	Rice-maize-pearlmillet Maize-rice, Rice-maize Rice-rice-maize	Maize-maize-pearlmillet Rice-maize + cowpea
West coast plain and hills region	Maize-pulses Rice-maize	Rice-maize Groundnut-maize
Gujarat plains & hills region	Maize-wheat	Rice-maize
Western dry region	Maize-mustard Maize-chickpea	Maize+legumes
Island region	Rice-maize	Maize-rice Rice-maize + cowpea Rice-maize-urdbean Rice-rice-maize

present, the real challenge in Indian Agriculture is to produce more quality food for burgeoning population from the same land and water resources, besides sustaining soil health and environmental quality. India alone needs to produce additional 64 million tonnes of food over the next decade to achieve targeted 294 million tonnes by 2020. Here the important question is where will be the future productivity gain come from? Will germplasm improvement research repeat the progress achieved in last four decades? To us it seems that future growth in productivity in intensively cultivated systems will come increasingly from adoption of improved natural resource management practices designed to increase the efficiency of inputs in irrigated semi-arid and sub-humid tropics and improving the productivity in rainfed agro-eco systems. Thus, the major challenge in future for the researchers will be to develop an alternative system that produce more at less cost with low water and energy and improve farm profitability and sustainability. Incidentally these are the areas where single cross maize hybrid based technology in combination with improved natural resource management practices *viz.,* conservation agriculture based resource conservation technologies (RCTs) act as a driver in enhancing the crop productivity and farm profitability. This indicates that agriculture systems needs a combination of new technologies that are capable to knock new sources of production growth and are of more sustainable. This necessitates pay more attention on issues of sustainability and Conservation Agriculture (CA) in intensive production systems. The efforts by researchers made since mid 1990's on developing, refining, accelerating and enhancing the adoption of CA technologies in the India has brought a *"Revolution in tillage techniques"*.



Conservation agriculture (CA) aims to achieve sustainable and profitable agriculture and subsequently aims at improved livelihoods of farmers through the application of the three CA principles: minimal soil disturbance, permanent soil cover and suitable crop rotations. CA holds tremendous potential for all sizes of farms and agro-ecological systems, but its adoption is perhaps most urgently required by small-holder farmers, especially those facing acute shortage of labour. It is a way to combine profitable agricultural production with environmental concerns and sustainability and it has been proven to work in a variety of agro-ecological zones and farming systems. The benefits of maintaining crop residue on the soil surface are well documented and include reduced soil loss as a result of water or wind erosion, as well as increased infiltration of water and soil water storage efficiency. Other benefits of conservation tillage (CT) systems include reduced labour, fuel, and machinery wear, improved soil tilth, increased soil organic matter, improved water and air quality, and increased biodiversity/wildlife.

4. Why CA is needed in Indian Agriculture?

- Due to intensive production system,
- Excess withdrawal of tubewell water for irrigation,
- Residue removal and burning,
- Degradation of soil structure due to excess puddling in rice,

- Depletion of soil organic matter,
- Nutrient imbalance,
- Soil salinity and sodicity,
- Specialization of pest problem due to monoculture,
- Small farm sizes with each farm operating as integrating farming system, and
- In certain situation, where tillage operations caused delay in sowing and add to the cost of production.

5. Current status of CA in the world

Presently no-till is practiced on about 105 m ha globally for improving crop productivity and conserving natural resources through very effective control of soil erosion, controlling soil evaporation, sequestering C in soil and reducing energy needs. Recent estimates on acreage under CA based resource conserving technologies (RCTs) in South Asia is 3.89 m ha.

Table 2. Area under CA in the world

Country	Million ha
USA	25.30
Brazil	23.60
Argentina	18.27
Canada	12.52
Australia	9.00
Rest of the South America	3.04
Indo-Gangetic-Plains	3.20
Europe	0.45
Africa	0.40
China	1.00
Others	1.00
Total	**98.00**

Hence, conservation tillage practices, such as zero and minimum tillage and permanent beds, may offset the production cost and other constraints associated with land preparation. The farmers in India are yet to grow maize based cropping systems with conservation agriculture (CA) technology packages, though it is a common practice in many western countries. Bed planting of maize helps in proper plant establishment, increases input efficiency, increases yields, and opens up avenues for double no-till system. Adoption of no-till practice helps in timely seeding either of the crops in sequence, hence leads to increase in productivity.

The main driving forces at farm level were cost saving, flexibility in time of planting, less water requirement and favourable support from government. However, the major bottle neck in large scale adoption appear more toward socio-economical and policy related rather than technical. It has also been experienced that dissemination of these technologies are more complex because managing CA based cropping system is a round the year activity rather demonstrating a simple technology eg. seeds of a new variety or a pesticide. The main reasons for slow adoption are:

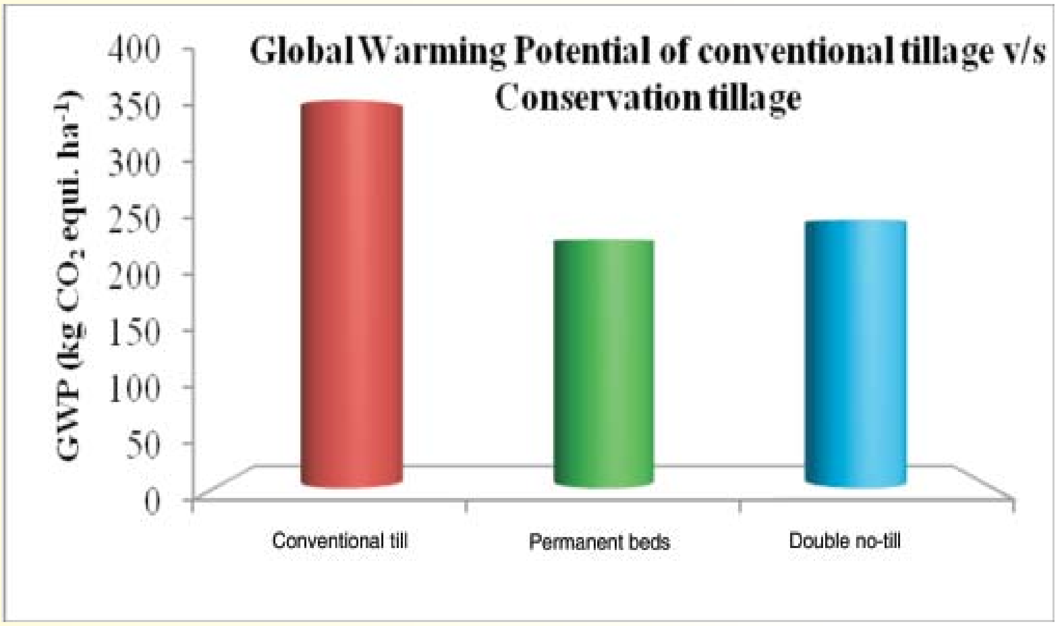
- Lack of trained human resources on CA as till now CA is not in the course curriculum of the State Agriculture Universities.
- Traditional mindset problem not only with farmers but also of the researchers and extension agents and they mainly have a belief of business as usual.
- Lack of appropriate policies that support quality machinery and open access to quality machinery on subsidies as limited vendors have been authorized for subsidies. There exists policy mismatch as well.
- Lack of local artisans, machinery manufacturers in different states for repairing and spares.
- Lack of availability of certain herbicides and knowledge about its proper use.
- Lack of regional system based information on long term basis.
- Initial field appearance without tillage and in presence of residues is disliked by farmers.
- There are limited efforts on long-term system based research on CA for generating information for location/ region/ecology specific fine tuning in the technologies before rolling them out by the extension machinery for wide scale adoption by the farmers.

6. Climate change and CA based technologies

CA based practices provides an integrated approach aimed at adaptive and mitigation strategies to face the risk of climate change on agriculture. Adaptive strategies includes improved use efficiency of water and nutrients; improved ability to cope with extreme events - drought, excess rain period, soil temperature variation, changed pest/disease scenario; opportunity to develop a biologically mediated approach aimed at sustainable productivity enhancement; ensuring timely sowing due to saving of time spent on tillage and opportunities offered for crop intensification in the face of resource constraint. The CA based mitigative strategies for the impact of climate change on agriculture are enhanced sequestration of carbon through soil and biomass; reduced dependence on chemicals and reduced GHG emissions on account of practices like minimal tillage, crop residue retention, carbon sequestration etc.

Conservation tillage fields act as a sink for CO_2 and conservation farming applied on a global scale could provide a major contribution to control air pollution in general and global warming in particular. The conservation of resources (land, water, energy) saves cost of water, energy and protects environment while leading to improved productivity on sustainable basis. Targeting the resource conserving technologies offers newer opportunities of better livelihood for the small and marginal farmers. Hence, adoption of resource conserving technologies *viz.,* new cultivars, reduced or minimum pre-planting tillage, soil water management practices is essentially needed to revert the damage done to the natural resources. Resource conservation technologies improve input use efficiency at low cost and preserve ecological integrity of crop production system.

In the conventional system involving intensive tillage, there is a gradual decline in soil organic matter through accelerated oxidation and burning of crop residues causing pollution, green house gases emission and loss of valuable plant nutrients. When the crop residues are retained on soil surface in combination with no tillage, it



initiates processes that lead to improved soil quality and overall resource enhancement. Tillage aims to create a soil environment favourable to plant growth. Appropriate tillage practices are those that avoid the degradation of soil properties but maintain crop yields as well as ecosystem stability.

7. Machinery development and CA

The real success of conservation agriculture in South Asia started with the development of second generation planters included the précised seed metering and furrow opening system in addition to seeding in the loose and standing residue.

i. Zero till seed drill:

Seed drill which is conventionally used 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 components except that the wide furrow openers are replaced with chisel or "inverted T" type openers to place seeds and fertilizers in narrow slits with minimal soil disturbance. To facilitate seeding into loose residues, double disc type furrow openers and star-wheel (dibble) type openers can also be used with the existing zero-till seed-cum-ferti-drill. Farmers are doing planking after seeding to cover seeds planted with the conventional seed drills. 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 factor received in significant amounts which facilitates germination in rabi crops.

ii. Double disc coulters:

This is one of the second generation machines having double disc-coulters fitted in place of tynes to place the seed and fertilizer into the loose residues. The problem being faced 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. This machine may efficiently works up to a residue load of about 4 to 5 tonnes/ha.

iii. 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 a days to make CA more successful in Andhra Pradesh.

iv. Rotary disk drill (RDD):

This machine was developed by Directorate of Wheat Research, is based on the rotary till mechanism. The rotar 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.

v. 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.

vi. Combo happy seeder:

It is a compact, light weight, 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.

8. CA based resource conservation techniques

i. Laser land levelling:

Traditionally levelled farmer's field have 5-15 cm undulation in general within the field, which often result poor seedling germination, seedling mortality due to water logging and uneven initial crop growth. Laser land levelling improves crop establishment by facilitating planters for uniform seeding depths and also even water application across the fields. Laser land levelling also enables the farmer to apply water and nutrient uniformly facilitating a uniform crop stand and maturity through improved nutrient-water interactions. Therefore, laser land-levelling is a pre-requisite technology and rather an entry point for permanent zero tillage or permanent beds through improved water and crop management. It requires initial high investment on equipment cost so the small and marginal farmers can go for custom hiring of this technology.

Advantages of laser land levelling:

- Reduces weed problems and improves weed control efficiency
- Improved efficiency of applied fertiliser, herbicides
- Approximately 35-45 % saving in irrigation water

- Reduction in salinity problems
- Uniformed crop maturity
- Improved crop establishment
- Approximately 4-5 % increase in cultivable area
- Easy farm operation due uniform tilth
- Increase crop yields by 10%

ii. Zero-tillage:

The no-till system is a specialized component technology for conservation tillage consisting of a single-tractor operation by using specially designed seed cum fertilizer drill without any field operation due to which the soil and the surface residues are minimally disturbed.

The surface residues of such a system are of critical importance for soil and water conservation. Weed control is generally achieved with herbicides or in some cases with crop rotation. No-tillage systems eliminate all pre-planting mechanical seedbed preparation except for the opening of a narrow (2-3 cm wide) strip or small hole in the ground for seed placement to ensure adequate seed/soil contact.

iii. Permanent beds:

In bed planting 67 cm wide beds (37 cm ridge and 30 cm furrow) are prepared with the help of bed planter. Bed planter with incline plate seed mattering system can precisely place the maize seed at required depth 3-4 cm. After preparing the fresh beds during first year these can keep as permanent beds for subsequent year with keeping crop residue and reshape if required after harvest of the crop. On permanent beds punch planter can be used to plant maize. One line of maize on each bed is desirable when sole crop of maize is planted keeping seed to seed spacing at 20 cm. optimum plant density (30000-35000/acre) should be maintained to tap potentials of hybrids.

Zero tillage or permanent bed for maize has several advantages such as prevent delay in sowing, requires low fuel and labour costs, requires little draft power, most suitable for coarse soils, improves soil health and quality, reduce erosion and conserve soil moisture with higher water use efficiency (15-20%) and yield enhancement. Sometimes temporary water lodged conditions affects the growth of maize crop. In bed planting that temporary water lodged conditions can be avoided by draining out excess water in furrows and better infiltration and aeration than conventional till (CT) condition. It was observed that standing water remains for longer time in CT due surface crust formation or soil compaction while, in ZT there is more infiltration rate due natural soil aggregation which helpful in avoiding anaerobic conditions due to water lodging. Zero till or permanent beds have better availability of water for maize especially in residue retained conditions.

Permanent beds conserve moisture during prolong dry spell in water scarcity areas for longer availability of moisture to sustain plant life and act as a drainage channel in high rain fall/waterlogged areas and provides better microclimate for plant growth and root development. Following prerequisites should be kept in mind during making permanent beds and planting on it:

- ✓ Prepare ridges in East-West direction
- ✓ Sowing on side of ridge
- ✓ Row to row (60-75 cm) plant to plant (20 cm)
- ✓ Maintain proper plant spacing: for easy movement in field, rouging and removal of tassels

Advantages of ridge and furrow sowing:

- ➢ Conserves moisture in water scarcity areas
- ➢ Provide conserve moisture for the crop during prolonged dry spell
- ➢ Provide microclimate for better plant growth and better root development
- ➢ Prolong availability of moisture to sustain plant life

Atrazine treated

iv. Mulching:

The use of live mulch and crop residue retention on soil surface using special mulch tillage techniques or practices is an important component of CA. *In situ* mulch formed by the residue of a dead or chemically killed cover crop left in place is generally becoming an integral component of mulch tillage techniques which provides favourable microclimate for the crop growth and development and avoids extremes. Evaporation loss from the maize crop field can be arrested by covering the soil with organic farm waste like straw or retention of crop residues. This improves water economy by 10-20 % therefore it is viable technology under moisture stress condition. Important crops suitable for mulching in maize are *Sesbania*, Sunhemp, Green gram, Black gram, etc.

The advantages of mulching in CA are as follows:

- Reducing soil erosion and conserve moisture
- Control weed growth
- The saving of water particularly in arid zones
- Yield of crops may not necessarily be substantially increased directly by usage of mulching, but more land can be cultivated with the available amount of water and thus overall cultivation of crops can be increased.
- Less salt accumulation on soil surface

- Maintain/moderate soil temperature
- Increase water use efficiency

9. CA and nutrient management

On a large-scale, N:P:K ratio of 4 : 2 : 1 has come to known as an ideal ratio, and a deviation in NPK consumption pattern, would suggest imbalanced fertilizers use pattern, greater the departure, more the imbalance. This is not entirely true as there is hardly any basis for the suggested single valued ideal N:P:K ratio. The ratio will be further widening with mismatch in the demand and supply of major nutrients across the country. The NPK ratio is likely to vary with crops, cropping systems, crop management practices, soils and their reactions. It appears that there is need to work out new NPK ratios for fertilizer allocations for different zones/regions of the country. In the demand and supply of fertilizer nutrients, use of organics in agriculture seems inevitable particularly for correcting the N: K imbalances. From plant nutrition point of view, the importance of the concept of balanced fertilizer use lies in adjusting the level of fertilizer use, taking into account available soil nutrients, crops requirement for targeted production levels under specific soil-water-crop management practices. New information seems to strengthen our understanding that CA has a distinct influence on soil quality and nutrient dynamics as compared with the traditional agriculture based on intensive tilled systems. The current nutrient prescriptions are (i) age old, (ii) area general- not site-specific (iii) designed for the component crops of the cropping system and (iv) better suited to tilled agriculture. Therefore, the focus should be *"feed the soil and let the soil feed the plant"*. The key elements of CA have direct and indirect bearing on the nutrient availability/supplying capacity of soil which are described as below.

A. Minimum disturbance of optimum porous soil architecture

- Optimum proportions of respiration gases in the rooting-zone
- Moderates organic-matter oxidation
- Porosity to water movement, retention and release at all scales
- Limits re-exposure of weed seeds and their germination

B. A permanent covering of sufficient organic matter over the soil surface

- Buffering against severe impact of solar radiation and rainfall
- A substrate for soil organisms' activity
- Raised cation-exchange capacity for nutrient capture, retention and slow-release;
- Smothering of weeds

C. Cropping sequences and rotations which include legumes

- Minimal rated of build-up of populations of pest species, through life cycle disruption
- Biological N-fixation in appropriate conditions, limiting external costs
- Prolonged slow-release of such N from complex organic molecules derived from soil organisms
- Range of species, for direct harvest and/or fodder
- Soil improvement by organic-matter addition at all depths reached.

The important point that emerges from studies in USA is the accumulation of soil organic matter (SOM), phosphorus and even potassium in 0-10 cm surface soil layer. Accumulation of SOM is advantageous but calls for heavier doses of fertilizer N. Accumulation of P in soil surface may not be of much use to the crops in the succeeding years, and it may reduce the availability of surface applied Zn and other micronutrients. In depth studies are therefore needed on nutrient management in ZT drilled crops. It is also advisable to apply higher basal dose of N i.e. 40 to 45% of total recommended for better crop under CA practices due to initial immobilization of applied N in residue decomposition process.

There are several questions about nutrient management in permanent bed planted crops. When nutrients are applied uniformly before the beds are made, some amounts of nutrients are left in furrows and can remain unutilised. When applied on the beds, the nutrients will remain on the surface and there could be a problem of reduced availability, especially for less mobile nutrients such as phosphorus. Over the years accumulation of phosphorus in surface soil layer may reduce the availability of other nutrients such as Zn. If applied in furrows, a part of nutrients such as nitrogen can be lost by leaching (Prasad, 2011).

It is only prudent that new fertilizer recommendations should be able to mimic significant effect of residue retention *vis-a-vis* incorporation of organics having differential soil moisture and thermal regimes. Therefore, the paradigm shift from tilled to no-till CA systems require a serious thrust on nutrient management research to improve soil and crop productivity and environmental quality. Carefully planned experiments are needed to develop the nutrient (primary, secondary and micro) management practices for different CA based technologies in various maize based cropping systems in India.

10. CA and weed management in maize

i. Weed flora of maize based cropping systems:

In general, weed flora varied between the two nearest fields due to differentiated management practices as well as cropping and herbicide use history. *Cyprus rotundus*, *Bracharia reptans, Dactyloctynium aegyptium*, *Digera arvensis Digitaria ciliaris*, *Cucumis spp* are the dominant weed flora of maize during rainy season (Table 1). The weed pressure during winter season is comparatively less than that appears during rainy season, the major winter season maize weeds are Cyprus *rotundus*, *Cannabis sativa, Anagallis arvensis* and *Chenopodium album.* Weeds cause huge yield losses in maize especially during rainy session. Farmers use hand weeding which becomes difficult due to rains, wet soils and bright sun, moreover, manual weeding effective only for short period due to favourable environments and requires repeated weeding.

Labour shortage in peak transplanting season delay weeding operation, increasing labour cost and escalating cost of production the other issues in manual weeding. Farmers need effective and economical alternative weed management strategies.

ii. Stale seed bed for weed management in CA:

Stale seed bed with pre-plant herbicides is one of the important technique to control perennial and annual weeds in maize, and in particular in zero tillage. Application of pre-sowing irrigation facilitate weeds to germinate that can be killed by use of non-selective herbicides. If the germinated weeds are annual weeds, than we can apply either Paraquat or Glyphostate @ 1000 g a.i./ha. In case of perennial weeds needs to apply glyphosate @ 1000g a.i. / ha . Tank mixture of glyphosate and 2,4-D is a better strategy to control troublesome weed i.e. *Cyperus rotundus*. It is advised that use clean water for Glyphoste spray @ 150L/ha and use multi-nozzle boom for better efficacy.

Table 3. Major weed spectrum in maize based cropping systems

Botanical Name	Cropping Systems and Seasons	
	Kharif Season	Winter Season
Grassy Weeds		
Brancharia reptans	M[2]-W,R[4]-M	
Cynodon dactylon	M[5]-W ss	M-W[9]
Dactyloctynium aegyptium	M[3]-W,	
Digitaria ciliaris	M[4]-W, M[3]-P+M, M[3]-P	
Echinochloa colonum	M[9]-W	
Eleusine indica	M[6]-W	
Eragostis tenella	R[6]- M	
Panicum repens	R[7]- M	
Broad leaf weeds		
Anagallis arvensis		M-W[3], M-P+M[3], M-P[3]
Cannabis sativa		M-W[4], M-P+M[2], M-P[2]
Celosia argentea	M[7]-W	
Circium arvense		M-W[5]
Caesulia axillaris	R[9]- M, M[8]-W	
Chenopodium album		M-W[1], M-P+M[4], M-P[4]
Commelina bengalensis	M[7]-W, R[9]- M,	
Cucumis spp	R[4]- M, M[4]-W	
Digera arvensis	R-M[3], M[8]W	
Eclipta alba	M[10]-W,	
Euphorbia hirta	M[7]-W	
Launaea nudicaulis		M-W[5]
Melilotus indica		M-W[6]
Phylanthus niruri	M[4]-W	
Physalis minima	R[3]-M	
Parthenium hysterophorus		M-W[7]
Solanum nigrum		M-W[2],
Sedges		
Cyperus iria	R[2]- M, M[3]W	
Cyperus deformis	R[2]- M, M[5]W	
Cyperus rotundus	M[1]-W, R[8]- M, M[1]P+M, M[1]M	M-W[6], M-P+M[1], M-P[1]
Fimbristylis milicea	R[5]W/ M	

R= rice, W= wheat, P= potato, M= maize, PP= pigeonpea , L = lentil, F= Fallow, C=Chickpea

iii. Pre-emergence weed control in CA:

In pre-emergence weed management strategy, by killing germinating weeds, can avoid crop-weed competition during early growth stages. Tank mix application of Atrazine (1000 g a.i./ha), Pendamethalin (1000g a.i. /ha), Atrazine +Pendamethalin (500 g a.i. each/ha) or Alachlor + Atrazine (1250g+ 375g a.i./ha) found effective in controlling annual weeds in summer maize.

iv. Post emergence weed management in CA:

There are limited options for post emergence weed control in maize due to unavailabity of selective herbicides. Atrazine @ 1000 g a.i./ha at 20-30 DAS selective herbicide for maize. As directed spray of Gramoxone in between the row of maize by using covering material (hood) can helpful in managing annual weeds. Simultaneous planting of mungbean as over crop on the either sides of maize row on beds appeared effective in controlling complex weed flora.

11. CA and crop diversification

Intercropping offers potential advantages for increasing sustainability in crop production under various maize based cropping systems. Intercropping of short duration grain legume/flower/vegetable crops can be done successfully with long duration and widely sowed maize crop which largely covers initial ground cover and suppresses the emerging weeds. However, intercropping can increase competition between crops and weeds. Maize-legume intercropping led to a higher soil canopy cover (leaf area index) than sole crops. Thus, in maize-legume intercrops the decrease in available light for weeds led to a reduction of weed density and dry matter, compared to sole crops. Though maize yield under intercropping is not less than that of the sole maize, rather the intercrop yield is a bonus to farmers. This practice is particularly desirable under delayed sowing, following by late harvest.

Due to its erect growth habits and growth period it suited as inter crop with many other crops having different growth habit and growing duration. The prominent maize based inter-crops in India are mentioned in Table 4.

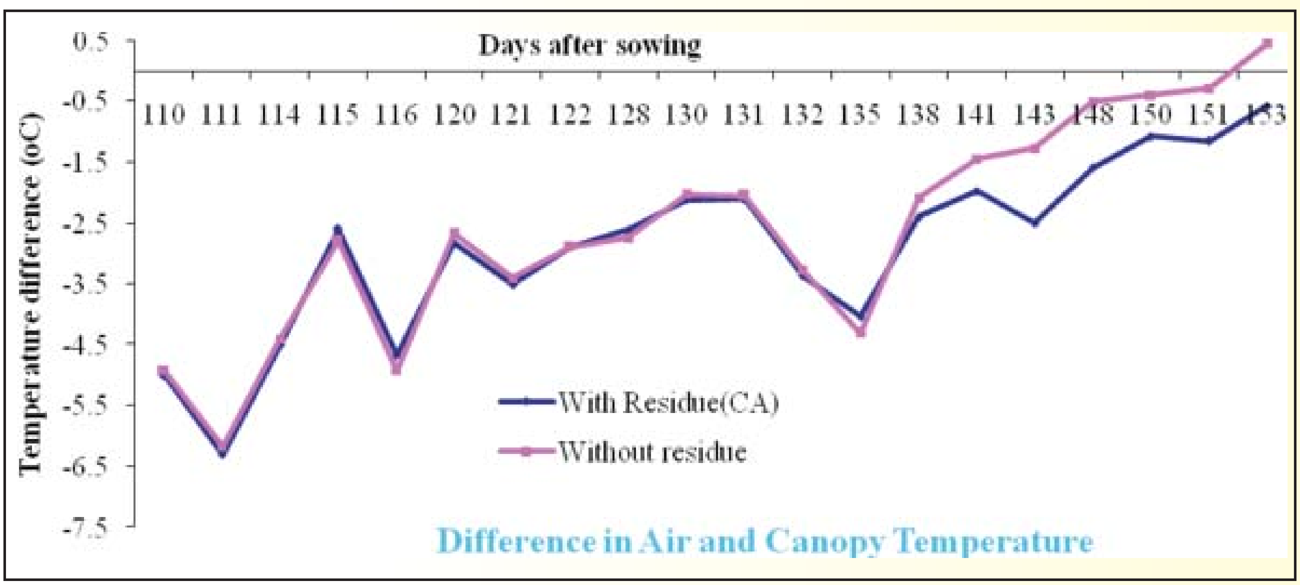
Table 4. Suitable intercrops in maize for various states in India

State	Suitable intercrops
North-western region (Punjab, Haryana, Delhi and western UP)	Pea, Rajmash, lentil, gladiolus, carrot, cauliflower
North-eastern region (Bihar, Eastern UP, Orissa , West Bengal, and N-E states)	Pea, Rajmash, potato, lentil, Bakla,onion
Southern region (Maharastra, AP, Karnataka and Tamil Nadu)	Fenugreek, coriander, sunflower, clusterbean
Central region (Rajasthan, MP and Gujarat)	Pea, lentil, onion, garlic, methi

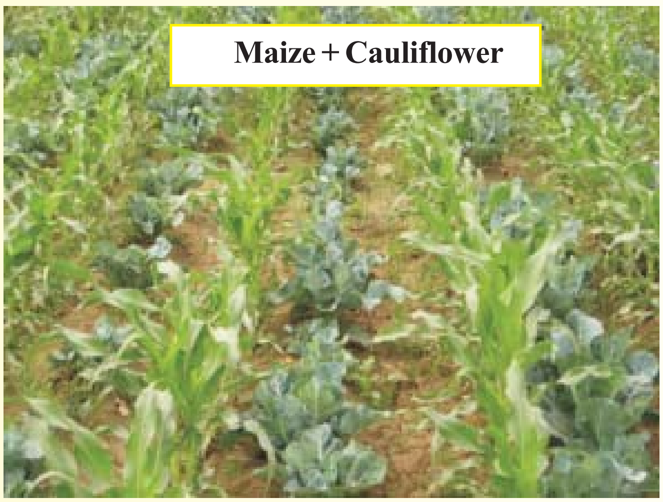
12. Impact of CA practices

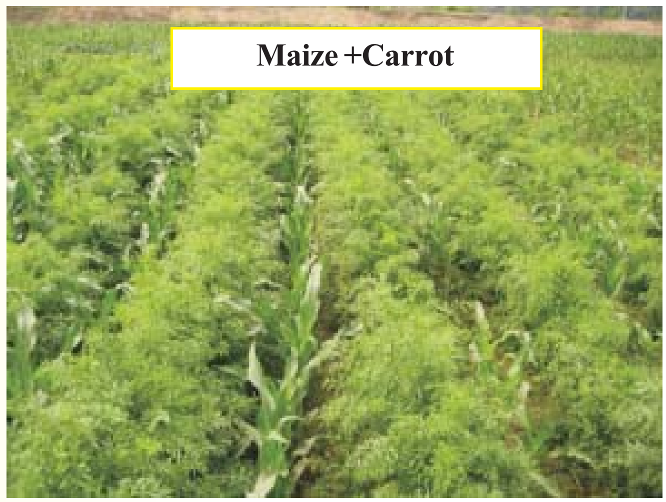
i. Soil health and quality:

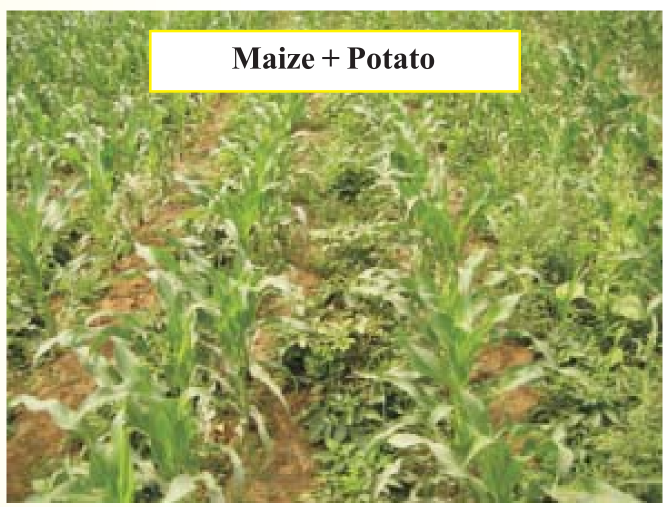
It maintains or enhances the productivity of upland soils by reducing soil erosion. These practices help in maintaining a favourable soil temperature for crop growth.



(Source: Jat *et al*., 2008. In: Proceedings of 10th Asian Regional Maize Workshop, Makassar, Indonesia)

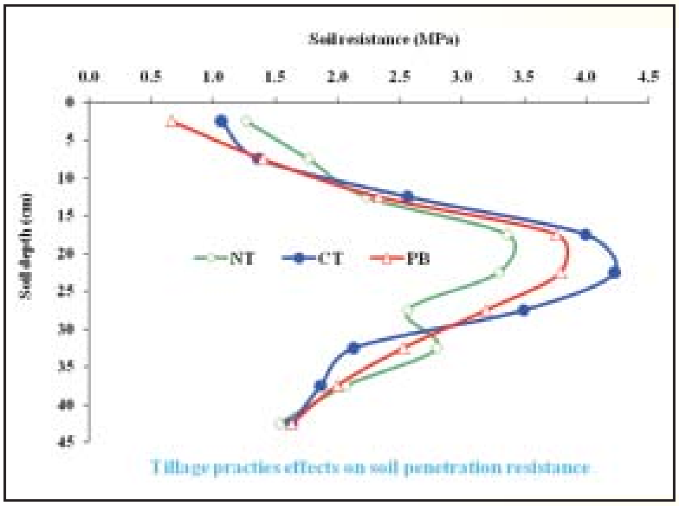




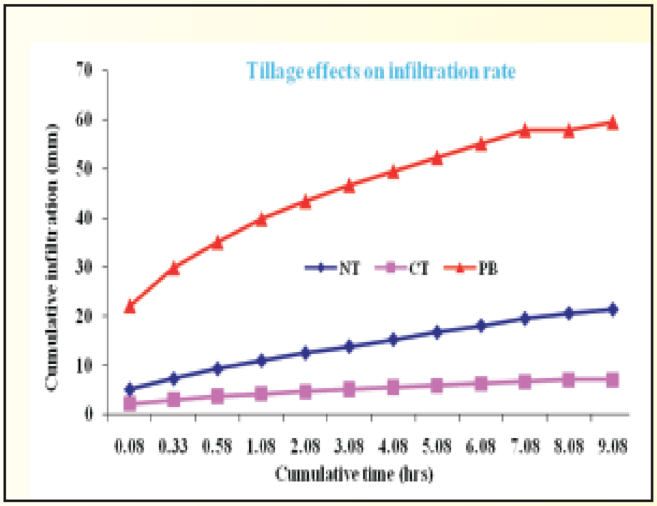


Maize based intercropping systems

CA based practices decreases mechanical impedance, continuity, stability and size distribution of pores, air-water dynamics and the thermal regime of the soil. Infiltration rate of the water increases under permanent beds and zero tillage system as compared to conventional tillage practices. CA practices also help to enhance or sustain soil organic matter and biodiversity.



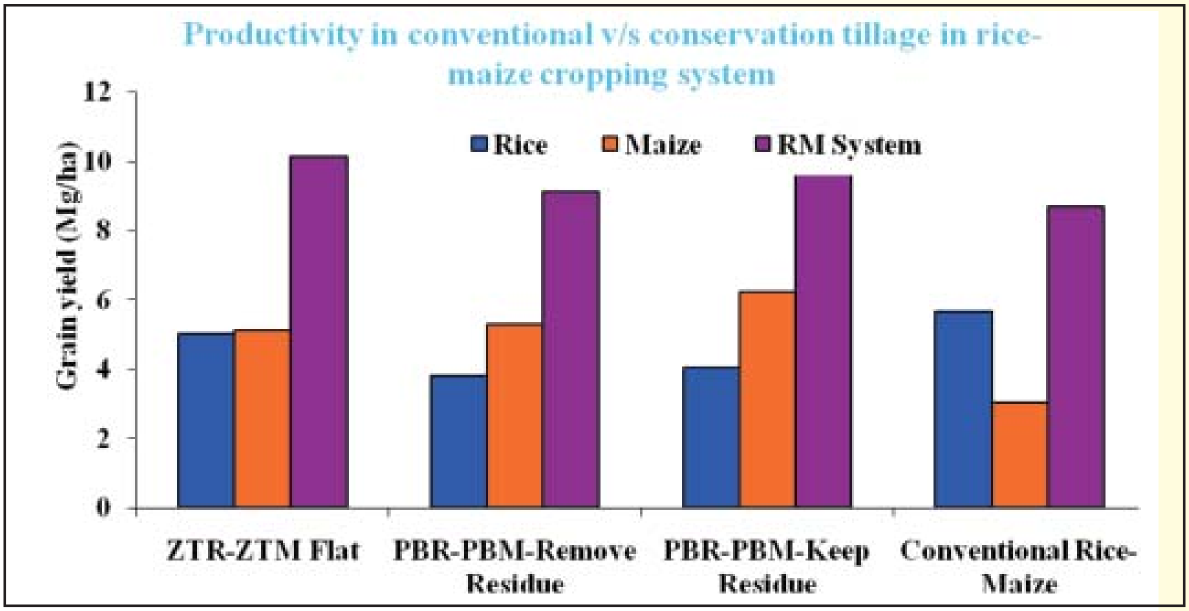
(Source: Jat, 2007)



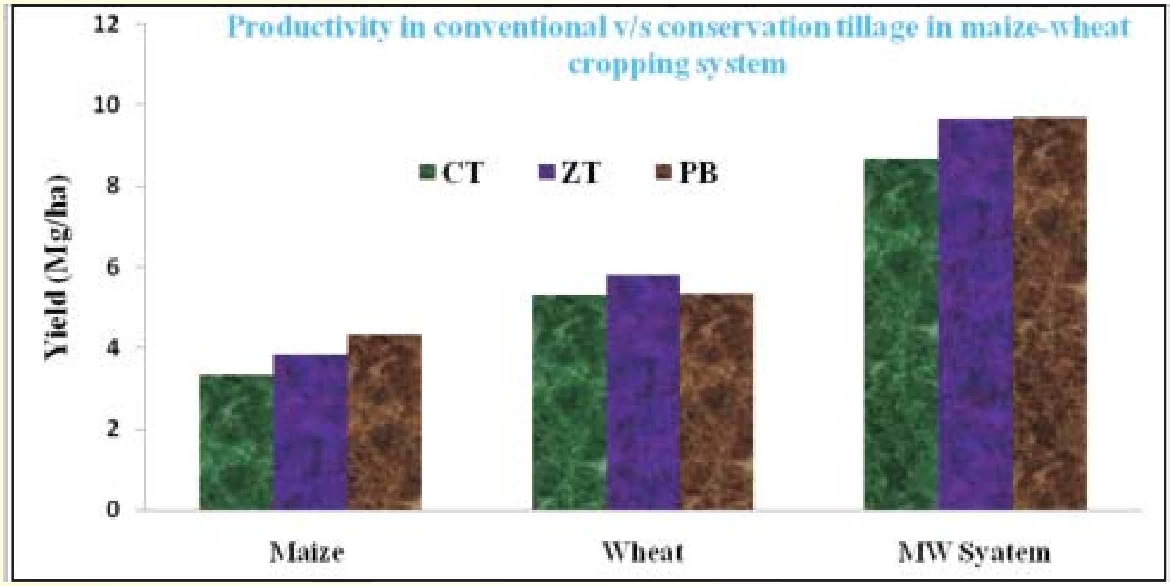
(Source: Jat *et al*., 2008. In: Proceedings of 10th Asian Regional Maize Workshop, Makassar, Indonesia)

ii. System productivity:

Several conservation agriculture based RCTs option (zero/reduced tillage, fresh and permanent beds, etc) for various maize systems under different situations have been evaluated and found promising for improving crop productivity, resource use efficiency and farm profitability. Results of various on-farm participatory trials under maize-wheat and rice-maize cropping systems conducted in Indo-Gangetic plains and peninsular India revealed



ZTR-Zero till rice, ZTM-Zero till maize, PBR-Rice on permanent beds, PBM-Maize on permanent beds (Source: Jat *et al.*, 2009)

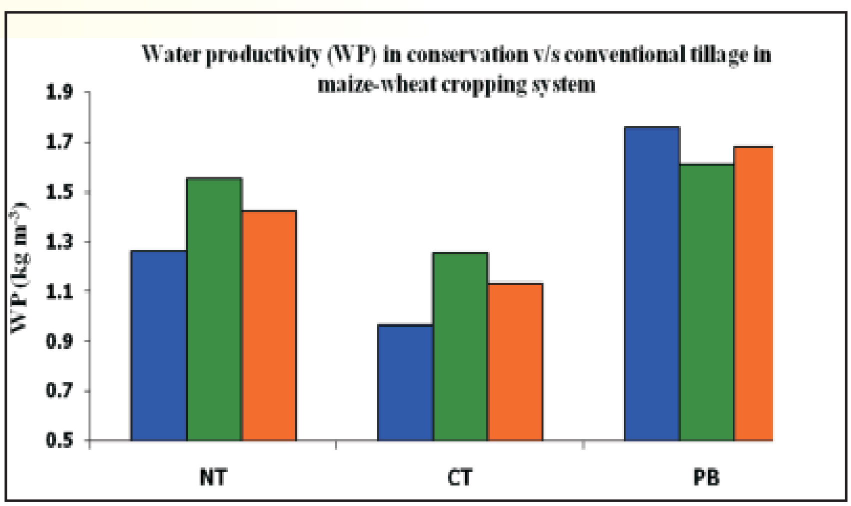


CT= Conventional Tillage, ZT= Zero Tillage and PB= Permanent Bed
(Source: Jat *et al*., 2008. In: Proceedings of 10th Asian Regional Maize Workshop, Makassar, Indonesia)

little or no difference in zero-till maize was observed when compared to best managed conventional tilled crop and despites the similar yields, the economic advantage with zero-till maize to the farmers was recorded to the tune of US$ 50 ha^{-1} due to saving in tillage, labour, fuel and energy. The results of the experiment carried out on conservation tillage techniques in maize-wheat cropping systems on a sandy loam soil indicated that maize productivity was highest (4.34 t ha^{-1}) under permanent beds (PB) followed by no-till (NT) (3.84) and lowest (3.35) in conventional-tillage (CT). Whereas, wheat yield was highest (5.79 t ha^{-1}) under NT followed by PB (5.32) and CT (5.31). Overall maize-wheat system productivity was similar under PB (9.67 tha-1) and NT (9.64) and the lowest being under CT (8.66).

iii. CA and water productivity:

Water productivity functions showed that PB had significantly higher water productivity and water use in both maize and wheat crops but the benefits were more in maize than wheat. Remarkably higher water productivity (kg grain m^{-3} water) of either crop of maize and wheat was recorded in PB (2.79 and 1.98) followed by NT (1.74 and 1.89) and the lowest (1.36 and 1.38) in CT. The increase in water productivity was the resultant of both increase in yield and saving in irrigation water.



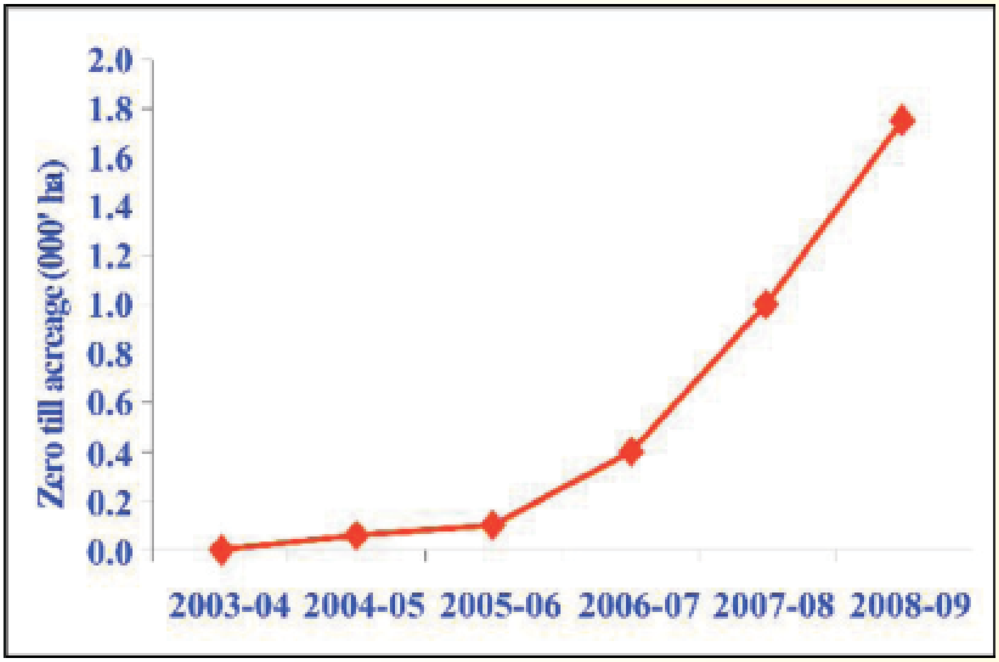
Source: Jat et al. (2008) Proc. 10th Asian Regional Maize Workshop, Makassar, Indonesia.

iv. Benefits of CA to the Farmers:

- Reduced cost of cultivation through savings in labour, time and farm power.
- Improved and sustainable yield with lower use of inputs (fertilizers, pesticides).
- In mechanized farming, longer life and minimum repair of tractors and other farm machineries and less water, power and much lower fuel consumption.

13. Success story of CA in India

The trends in area, production and productivity of maize in Andhra Pradesh have shown a remarkable increase during past six decades. During 1950-51, the maize acreage in the state was very less (1.4 lakh ha) that has grown up by 5.7 times to the present (2007-08) level of 7.9 lakh hectares. However, the production has increased dramatically from merely 40 thousand tonnes during 1950-51 to 41.4 lakh tonnes during 2007-08 which is nearly 109 times higher. Similarly the productivity of maize in the state was merely 275 kg ha^{-1} during 1950-51 that has increased to 5240 kg ha^{-1} during 2007-08 which is highest state average in the country and in some of the district it is > 10 tonnes. The Andhra Pradesh though is a non-traditional maize growing state but has emerged as one of the potential maize growing state that contributes nearly 21 % of the total maize production in the country. For over a decade during 1980-81 to 1990-91, there was a decreasing trend in area, production and productivity of maize in the state. Trends shows that till 1990's the growth in area, production and productivity of maize was very slow but thereafter it took momentum. However, the major increase was achieved during past few years mainly due to adoption of single cross hybrids and shift in acreage under non-traditional areas. Since 1990's there has been a perceptible increase in area, production and productivity of maize mainly due to adoption of single cross hybrids and zero till in rice maize system since past 2 years in the state. These two technologies are able to address the issues of water scarcity in intensive irrigated regions of Krishna and Godavari zones and also the SCHs experiences better productivity even in the scarce rainfall areas like Ananthpur.



Adoption of zero-tillage technology in maize under rice-maize cropping systems of Andhra Pradesh

Appendix: Common weed flora in maize field

1. Narrow Leaved Weeds:

Sanva (*Echinochloa crusgalli*)

Goosegrass (*Acrachne racemosa*)

Crowfootgrass (*Eleusine indica*)

Viper grass (*Dinebra retroflexa*)

Makra *(Dactyloctenium aegyptium)*

Green bristlegrass (*Setaria viridis*)

Banchari (*Sorghum halepense*)

Bandra (*Setaria gluca*)

Doob (*Cynodon dactylon*)

Narkul (*Phragmites karka*)

Crabgrass (*Digitaria sanguinalis*)

Little Lovegrass (*Eragrostis tenuifolia*)

2. Broad Leaved Weeds:

Kundra (*Digera arvensis*)

Cholai (*Amaranthus spp.*)

Desert horsepurslane (*Trianthema portulacastrum*)

Day Flower (*Commelina benghalensis*)

Hazardana(*Phyllanthus niruri*)

Jungli Jute (*Corchorus acutangulus*)

White cock's comb (*Celosia argentina*)

Black Nightshade (*Solanum nigrum*)

Hulhul (*Cleome viscosa*)

Puncture vine (*Tribulus terrestris*)

Congress grass (*Parthenium hysterophorus*)

Wildflower (*Xanthium strumarium)*

3. Sedges:

Motha (*Cyprus rotondus*)

Yellow nutsedge (C*yprus esculentus*)

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