Conservation Agriculture in Rice and Maize Based Cropping Systems:
Principle and Practices for NEH Region

Anup Das
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G.C. Munda
P.K. Ghosh
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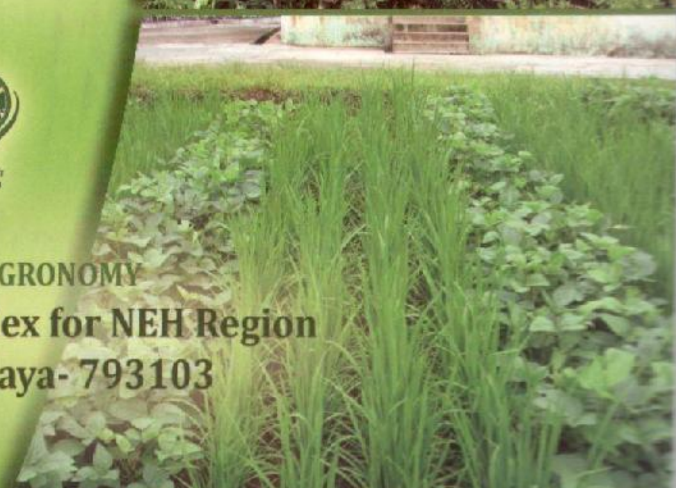

DIVISION OF AGRONOMY
ICAR Research Complex for NEH Region
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The authors feel that the present publication will be of much help to the extension functionaries including KVK personnel and farmers in effective management of natural resources in rice and maize based cropping systems of the region.

Authors

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Introduction

In NEH region, the farmer's immediate concern is crop yield improvement, diversity of crops, and enhancement of basic income to meet their individual needs. The basic social concept of sustainable management of land is based on balance among the different segments of the society as well as a balance between individual and institutional values. The land of this region is suffering from various kinds of land degradation as a result of different activities to meet the increasing demand of population.

Intensive agriculture and excessive use of external inputs lead to degradation of soil, water and genetic resources. Wide spread soil erosion, nutrient mining, depleting ground water table and eroding biodiversity are the global concern which are threatening the food security and livelihood opportunities of farmers, especially the poor and underprivileged. About 10 million hectares of good quality land is lost annually for agricultural uses, due to soil degradation which adversely affect agricultural production and profitability. Therefore, there is urgent need to reverse the trend of natural resource degradation.

Soil (land) health degradation is a major problem, especially in intensive agriculture. Physical and biological deterioration of land with associated fertility depletion occurs due to poor agronomic management, waterlogging, acidification etc. Intensive cultivation along with poor or no addition of manure, residue removal/burning etc. is further aggravating the situation. Crop production is becoming uneconomical due to higher input cost, low input responsiveness, high labour requirement and poor diversification.

Due to growing resource degradation problems worldwide, conservation agriculture (CA) has emerged as an alternative strategy to sustain agricultural production. It is a concept for resource – saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently promoting the environmental balance (FAO, 2007). Conservation agriculture is based on enhancing natural biological processes above and below the ground. Intervention such as mechanical soil tillage are reduced to an absolute minimum and use of external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum level and in a way and quantity that doesn't interfere with or disrupt the biological processes.

Therefore, it is essential to incorporate suitable resource conservation technologies (RCTs) in agronomic practices, which is not only economical and helpful for better growth and development but also enable to utilize valuable resources efficiently and conserves them. Blending of modern technology with indigenous resource conserving technologies would help to achieve such goals with people's participation. In the recent years, a lot of emphasis has been given in resource conservation in agriculture, as a result of which a number of technologies are developed /evaluated in agriculture with the ultimate objective of improving productivity and conservation of ecosystems.

Conservation agriculture is practiced in over 95 million hectare (mha) worldwide (Derpsch, 2005) and currently this area is likely to approach 120 mha (Lumpkin and Sayre, 2009). It is sobering however, to realize that over 90% of the current area under conservation agriculture based technologies occurs in just 5 countries (Argentina, Australia, Brazil, Canada and USA).

Agro-ecological scenario of the NE region

The North Eastern Region of India, comprises the states of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura (Fig 1), lies between 22^{0}05' and 29^{0}30' N latitudes and 87^{0}55' and 97^{0}24' E longitudes. The region is characterized by diverse agro-climatic and geographical situations. The region has remained economically backward, though there is an ample potential for development due to the presence of abundant natural resources. Valleys are rich in organic matter but mostly unpurified. On steep slope, because of continuous removal of topsoil, organic matter status is poor to medium. In this region, around 56% of the area is under low altitude (valley or lowland), 33% mid altitude (flat-upland) and the rest under high altitude (upland terrace). Traditionally, farmers both at upland terrace and valley land follow the mono-cropping practice in rain fed agriculture, where rice is the major crop occupying more than 80 % of the cultivated area followed by maize. Presently, the cropping intensity of the NE region is only about 120 %. It is therefore, apparent that about 70 – 90 % of the areas remain vacant during the *rabi* season due to severe water scarcity as most of the rainwater goes waste by runoff through sloppy land. Farming in rainfed North-East India is a high risk activity. Intensive natural resources mining and continuous degradation of natural resources (soil, water, vegetation) under conventional agriculture practices will not ensure farm productivity and food security for the coming years.

Fig 1. Political map of NE region

Status of cropping system in the NE region

The net and gross cultivated area in NE region is about 3.9 mha and 5.5 mha, respectively. The state of Assam is having maximum cultivated area (4 m ha) followed by

Tripura (0.44 m ha) and Nagaland (0.29 m ha). Cropping intensity is highest in the state of Tripura (160%) and lowest in Mizoram (106%).The share of total cultivated area under food grain production as against total cropped area is highest in Manipur (78.7%) followed by Nagaland and Arunachal Pradesh. Except Sikkim and Tripura, all other NE states are having higher share of area under food grain production compared to national average (65%). This indicates that there is scope for diversification of food crop based cropping systems.

Rice is the main staple food of people in the North Eastern Region of India. The productivity of rice in the region is only about 1.7 t/ha compared to national average of 2.2 t/ha (2008-09). The demand for rice is growing with ever-increasing population. The region is in deficit of about 1 million tonne (mt) of rice (2005). Therefore, there is need for steady increase in productivity with limited resources like land, water etc.

Cropping systems in the NER is also predominantly rice based with the little exception in the state of Sikkim where maize is the main food crop. Rice cultivation in the region is under low-input low-risk and low yield condition. In the low land mostly monocropping of rice is practiced with the little exception in Tripura, Assam, parts of Garo hills etc. where rice - rice system is practiced. The present production of food grains in NE region is 5.97 million tones and the requirement is 7.6 mt in 2001 and would be 12.12 mt 2011 and 15.24 mt in 2021 (Sharma and Datta, 2006).In order to make the region self sufficient in food grain production, the productivity of rice and maize has to be increased from the present low level. Rice is also cultivated in Jhum under zero external input supply and gives very low level of yield (1-1.5 t/ha).

The area production and productivity of rice and maize in the NE region are presented in Table 1. The productivity of rice in the state of Tripura and Manipur are higher than the national average, whereas all other states have lower productivity compared to national average. In case of maize, only the state of Mizoram has comparatively better productivity than national average. Simply by adopting low cost agro-techniques like improved variety, proper time of sowing, intercultural practices, effective recycling of resources etc. yield can be increased significantly. Thus, it is clear that there is lot of potential for improving crop productivity in the region.

Some of the pre-dominant rice based indigenous farming systems of the region are *Pani kheti* system of rice cultivation in Sikkim, Nagaland, Manipur, Rice +fish cultivation in *Apatani* plateau, *Zabo* farming and Alder based farming system of Nagaland. The major rice based cropping systems of the NE region are indicated in Table 2. Important maize based cropping systems of the region are Maize-mustard/Pea, Maize-vegetables (Frenchbean/Carrot/Tomato etc), maize-potato etc.

Problems for enhancing / sustaining system productivity

- High soil and nutrient loss owing to high rainfall and topography
- Widespread prevalence of long duration local varieties and non-availability of suitable short duration varieties.

Table 1. Area, production and productivity of rice and maize in the NE Region

States	Rice (2008-09)*			Maize (2002-03)**		
	A	P	Y	A	P	Y
Arunachal	127	164	1293	41	56	1365
Assam	2484	4008	1614	20	14	700
Manipur	168	397	2357	5	11	2200
Meghalaya	108	204	1886	17	26	1529
Nagaland	173	345	1994	40	80	2000
Sikkim	14.7	21.7	1476	40	56	1400
Tripura	243	627	2586	2	2	1000
Mizoram	52	46	885	8	15	1875
Total NE	3370	5813	1725	173	260	1503
All India	43900	96700	2202	6557	12068	1841

Source: *Directorate of Rice Research, Hyderabad 2008-09,
**Basic Statistics of NER 2006, A= Thousand hectare, P= Production in thousand tones, Y= Yield in kg/ha.

Table 2. Zone wise prominent crop sequences of NEH Region

Climatic zones	Crops/cropping sequence
Zone-1. Alpine Zone	Pasture (No rice)
Zone-II Temperate alpine zone	Potato-rice, rice monocropping
Zone-III Subtropical hill zone	Rice monocropping,
Zone-IV Subtropical plain zone	Rice monocropping, rice-rice (Irrigated),
Zone-V Mid-tropical hill zone	Rice monocropping
Zone-VI Mid-tropical plain zone	Rice-rice (Low land), rice monocropping

- Locals' choice for traditional varieties for colour, taste, aroma etc. does not allow large scale adoption of high yielding short duration varieties.
- Excess moisture in lowland does not allow growing any crop other than rice.
- In upland areas there is acute shortage of moisture during dry sesaon and growing a second crop becomes difficult without proper moisture conservation strategies.
- Lack of irrigation facilities restricts a second crop after rice in other areas.
- Small and marginal farmers and lack of resources.
- Lack of credit facilities and technical know-how among the farmers.

Productivity constrains and farmers way to overcome them

The main reason of low productivity of rice in the region is non-utilization of improved technology including improved and recommended varieties. The farmers in the NE hills farmers (excluding major parts of Assam, Tripura and Manipur) are still practicing age old wet land direct seeding (>90 % of total area).

After rice harvest in valley lands, soil moisture remains very high mainly due to seepage from surrounding hillocks. Therefore, with proper land configuration the residual soil moisture could be effectively utilized for vegetable cultivation. This would not only increase the farmer's income but would also double the cropping intensity in valley land. Making raised bed or *bun*, a local practice, where all the crops and weed residues are kept on the surface of the soil and the biomass is covered with soil to make raised beds. This type of cultivation not only improves the soil physico-chemical properties but also improves productivity. Cropping system such as upland rice-mustard, rice-vegetable is practiced to some extent, but the productivity of *rabi* crop is very low due to low soil moisture and lack of irrigation.

The rice cultivators in plains of Tripura, Assam, Manipur etc. makes a small water harvesting pit in the corner of the field. The water harvested in such small pond is used for life saving irrigation to crops as well as for fish cultivation. In Manipur, farmers are growing mustard in rice fallow adopting zero tillage and getting substantial income.

On the other hand, after harvest of maize in upland, the residual moisture is utilized by mustard if sown in the month of September/October. Thereafter, the soil moisture status depletes drastically, making it almost impossible to grow a crop. Simple practices like mulching and conservation tillage provides opportunity for a successful *rabi* crop in maize fallow under rainfed terrace situation.

Opportunity of conservation agriculture in the NE region

Farming in rainfed North-East India is a high risk activity and characterized as complex-diverse-riskprone (CDR) type (Bhatt and Bujarbaruah, 2006.). An intensive natural resources mining and continuous degradation of natural resources (soil, water, vegetation) under conventional agriculture practices will not ensure farm productivity and food security for the coming years. In order to keep production system in different land situations sustainable, CA based on minimum/ no-till system is an alternative to conciliate agriculture with its environment and overcome the imposed constraints of the climate change and continuous inputs cost. Resource Conserving Techniques (RCTs) using locally available resources encompasses practices that enhance resources or input-use efficiency and provide immediate, identifiable and demonstrable economic benefits such as reduction in production costs, saving in water, fuel, labour requirements, and timely establishment of crops resulting in improved yields (Ghosh *et al.*, 2010).

Some RCTs suitable for terrace upland, flat-upland, valleys and lowland situations of North-East India are discussed in this publication. As per the agro-ecosystems and resources available with the farmers suitable RCTs could be chosen.

The conservation agriculture approach

The term conservation agriculture (CA) refers to the system of raising crops with minimal disturbance to the soil while retaining crop residues on the soil surface. The CA approach encourages retention of at least 30% of crop residues in the field. The key elements of CA include: minimum soil disturbance by adopting minimum/ no-tillage and minimum traffic for agricultural operations, management of crop residues on the soil surface, and adoption of spatial and temporal crop sequencing/crop rotations to derive maximum benefits from inputs and minimize adverse environmental impacts (Aune, 2009). Intensive tillage in conventional systems leads to gradual decline in soil organic matter content through accelerated oxidation, with a consequent reduction in the capacity of soil to regulate water and nutrient supplies to plants. Retention of crop residues on the soil surface in combination with no-tillage initiates processes that lead to improved soil quality and overall enhancement of resource-use efficiency (Abrol and Sangar, 2006). The increase in water conservation and water use efficiency obtained by no-tillage system has tremendous effect on yield improvement and production stability in agriculture. Even though, crop residue have high value and small amount is left after harvesting, a build up over years and change in farmer's behavior toward residue management as a long-term investment on soil quality has been noticed on established farmer's field. Moreover, improvement of grain and straw production encourages farmers to leave more residues on their fields and ensure the long-term benefit of no-till system (Grarras *et al.*, 2009).

The role of CA is well recognized by most of the developed countries and many developing countries. Conservation agriculture which focuses on the complete agricultural system, involves major changes in farm cropping operations from the widely used, traditional tillage – based farming practices.

Basic principles of conservation agriculture

- Dramatic **reductions in tillage** (ultimate goal-zero tillage or controlled till seeding for all crops in a cropping system if feasible).
- Rational **retention of adequate amount of crop residues** on the soil surface (ultimate goal – surface retention of sufficient crop residues to protect the soil from water run-off and erosion, improve water infiltration and reduce evaporation to improve water productivity, increase soil organic matter (SOM) and biological activity and enhance long term sustainability).
- Use of sensible ***crop rotations*** (ultimate goal – employ economically viable, diversified crop rotations to help moderate possible weed, disease and pest problems, enhance soil biodiversity, take advantage of biological nitrogen fixation (BNF) and soil enhancing properties of different crops, reduce labor peaks and provide farmers with new risk management opportunities.
- Farmer conviction towards the potential near-term **improved economic benefits** and livelihoods from sustainable CA systems (ultimate goal - secure farm level economic viability and stability).

Advantages of no/minimum tillage

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

Principle of nutrient management in conservation agriculture

In CA systems, the main principle is 'feed the soil not the plant'. Thus, nutrient management practices in CA systems would need to include paying attention to the following four important aspects-

i. ***Biological processes*** of the soil are enhanced and maintained for soil organic matter and soil porosity built up.
ii. ***Biomass production and biological nitrogen fixation*** for keeping soil energy and nutrient stocks sufficient to support higher levels of biological activity and for covering the soil.
iii. ***Adequate access to all nutrients*** by plant roots in the soil, from natural and synthetic sources, to meet crop needs.
iv. ***Soil acidity*** is kept within acceptable range for all key soil chemical and biological processes to function effectively.

However, the optimum applications of these techniques will vary across different agro-climatic situations. Specific and compatible management components (nutrient management, weed management, land configuration) will be required to be developed along with their adaptive research with active farmer's involvement to facilitate farmer's adoption of conservation agriculture under contrasting agro-climatic conditions and production system. The potential benefits of conservation agriculture are (Lumpkin and Sayre, 2009)

- Increase input (fertilizer, water etc.) use efficiency in crop production.
- Halt and reverse the wide spread degradation of the soil sequence base (improve SOC and carbon sequestration).
- Augment crop and soil biodiversity.
- Confront increasing input prices by boosting input use efficiency to reduce production costs.
- Reduce agricultural – related green house gas (GHG) emission.
- Confront the growing shortage of agricultural labor.
- Reduction in fuel and machinery use.

Managing soil acidity and health in conservation agriculture

Soil pH is critical for several reasons. It has a major influence on the availability of elements, including primary nutrient like N P and K as well as secondary nutrients, micronutrients and potentially toxic elements like aluminum ion (Al^{3+}), most of soil microorganisms are sensitive to soil acidity, which has an influence on nutrient availability (especially N), soil organic matter and general soil health. The most beneficial soil fungi for instance do not like a high pH and soil bacteria have problems at lower pH, one of the main reasons for managing soil pH by application of lime is to reduce such toxic effects. However, soil acidity becomes adjusted at 6.2 or 6.3 when all four contents – Ca, Mg, K and Na are in proper equilibrium (Kinsey and Walters, 2006). Any one of them in excess can push pH up and any one of them in lower amount can take pH down.

Conservation agriculture systems are based on building and breaking down organic matter to maintain soil health and productivity. As microorganisms decompose soil organic matter, organic acids are continuously being formed. If these acids are not neutralized by free bases, then soil acidity will increase. There are other reasons for which soil can be acidic due to leaching of basic cations by rainfall or to soil being formed from acid parent materials or to BNF. Where soils are acidic particularly in humid and sub-humid soils as in case of NE region and may have toxic levels of Al, the effectiveness of broadcast lime application without incorporation has been long proven in CA systems, as lime moves into deeper soil layers, especially when applied in small quantities in each year in CA with green manure crops (Derpsch, 2007). Experience in Brazil showed that Al toxicity tends to disappear over time under conservation agriculture (Kassam and Friedrich, 2009).

Conservation agriculture approach for effective natural resource management and food security

Resource conserving technologies (RCTs) like zero tillage, minimum tillage, residue management, green manuring, green leaf manuring and application of weed biomass has been tested in rice and rice based cropping systems at mid altitude of Meghalaya over past 5 years (2006-10). The significant results from those conservation agriculture (CA) approaches are described in the next few pages.

Land leveling: a must for effective resource conservation

Land leveling is a prerequisite for enhancing the benefits of other resource conservation technologies. In a well leveled field, less amount of water and nutrients are required than an uneven field. The benefits of applying same amount of input will be much higher in a leveled field due to their even distribution. In plains of North India, laser land leveler is used that level land to a perfection of ± 2cm from the average elevation. Only by leveling land, the yield can be increased by 10-25%, saves water to the tune of 40%, increase nutrient use efficiency by 15-25 % and increases land area by 2 to 6 % due to reduction in area required for bunds and channels (Jat *et al.*, 2004).

Conservation agriculture approach in upland rice based cropping system

Two cropping systems (upland rice-toria and upland rice-pea) were evaluated under conservation and conventional tillage, practices with the objective to conserve soil and moisture.

In conservation tillage, residue of all the crops grown in the system along with weed biomass was incorporated. In conventional tillage, crop residues and weeds were removed. It is noticeable that conservation tillage had higher (18%) soil moisture than conventional tillage irrespective of cropping systems which have direct bearing on soil moisture recharge and its uptake by crop.

The growth and yield of all crops (*kharif* and *rabi* season) under conservation tillage was higher than that under conventional tillage. The productivity of toria (TS 36) in rice fallow was significantly higher (35%) under conservation tillage compared to conventional tillage. This might be ascribed to the effect of incorporation of plant biomass under conservation tillage which enhanced water retention capacity of soil during crop growing season. Quick build-up of organic matter in conservation tilled plots was possible through incorporation of crop residues and weed biomass in high rainfall area. Based on soil moisture profile, it is revealed that upland rice grown during rainy season under conservation tillage could support second crop of toria and pea without any protective irrigation.

The results of another field experiment revealed that rice yield was similar under conventional tillage (2.72 t/ha) and minimum tillage (2.67 t/ha). In-situ green manuring with *Crotolaria tetragonaloba* (Fig 2) could produce about 5t/ha of green biomass which was recycled in the system. However, there was significant effect of residue (nutrient) management practices on rice yield (Table 3). Application of 100 % RDF produced significantly higher

Fig 2. In-*situ* green manuring in upland rice with *Crotolaria* spp.

grain yield (3.48 t/ha) of rice compared to all other treatments. Among the residue management practices, application of 50 % RDF + rice straw 5t/ha (applied 2 months before sowing and incorporated) recorded maximum grain yield (2.71 t/ha) followed 50 % RDF + fresh biomass *Eupatorium* 10t/ha (2.61 t/ha). The productivity of succeeding toria was better under plots where minimum tillage was done for *kharif* rice followed by zero tillage (563 kg/ha) compared to conventional tillage for *kharif* crop and zero tillage in *toria* (506 kg/ha). Among the subplot treatments, *toria* yield was maximum where 100 % RDF was applied to preceding rice (652 kg /ha) followed by application of 50 % RDF + Rice straw 5t/ha (624 kg/ha) to *kharif* rice (Fig 3).

Table 3. Productivity of rice-toria system as influenced by tillage and residue management practices

Treatments	Rice (t/ha)	Toria (kg/ha)
Tillage		
Conventional tillage	2.72	506
Minimum tillage	2.67	563
Residue management practices		
100% recommended dose of fertilizer (RDF 60 :60 : 40 kg/ha)	3.48	652
50 % RDF	2.47	514
50 % RDF + rice straw 5t/ha	2.71	624
50 % RDF + green manuring (1:1)	2.66	613
50 % RDF + fresh biomass of *Eupatorium* 10t/ha	2.61	423
Farmers practice (FYM 5t/ha)	1.98	398

Conservation agriculture approach for rice based system in valley upland

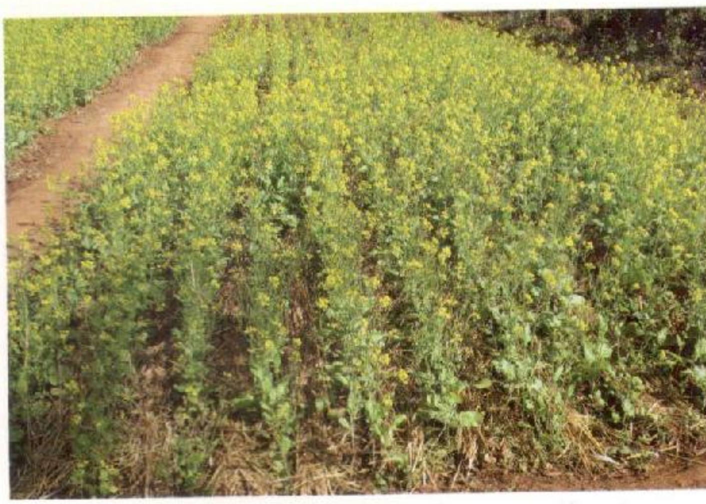

Fig 3. Zero tillage *Toria* (TS 38) in terrace after rice

In flat upland or valley upland, rice is the common crop. Because of water stress, second crop is not grown in rice fallows. In a field study, pea was sown without any tillage (zero tillage) by dibbling after harvest of rice. At the time of rice harvest, three residue levels (1/3 residue, ½ residue and complete removal of residue) were maintained with the hypothesis that residue kept in the field could maintain soil moisture required for pea. Zero-tilled peas were sown by hand dibbler in all the plots. In rice fallow, better pea performance was found under 75% rice residue retention plots, followed by 50% rice residue retention (Fig 4). In case of complete removal of rice residue, seeds of pea germinated but failed thereafter to grow due to insufficient soil moisture to support crop growth. Zero tillage system without crop residue left on the soil surface have no particular advantage because of the water loss from the surface, as was evident from soil moisture and yield data (Fig 5).

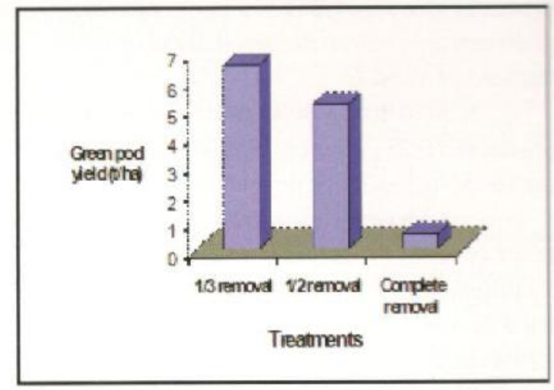

Fig 4. Green pod of pea under varying degree of residue removal

Zero tilled pea crop with 75% rice residue | **Zero tilled pea crop with 50% rice residue** | **Zero tilled pea crop after complete removal of rice residue**

Fig 5. Performance of pea under zero tillage with varying degree of residue retention

Conservation agriculture approach for lowland rice based system

Harvesting of rice at ground level is common practice in North East region and rice straw is mostly used for fodder. Those farmers who does not keep any livestock, usually burn residue after its harvest. Similarly, in traditional rice cultivation farmers plough the field several times before sowing, particularly during puddling which leads to destruction of soil structure and loss of organic carbon from the soil. As soil carbon is designated as *blank gold* of soil, an optimum level of soil organic carbon (SOC) is needed to conserve soil, water and nutrient; favour biological activity and high productivity in any system. Many a times sowing of *rabi* crops is not possible after harvest of puddled rice either because of poor soil structure and soil fertility. Tillage affects soil physical, chemical and biological properties and can play an important role in enhancing the yield potential of crops. Resource conserving practices like zero tillage can help farmers to grow crops sooner after rice harvest so that the grain matures before the onset of pre-monsoon shower besides being conserves soil moisture, nutrient and soil-C.

A field study was conducted for four years in rice (*kharif* season) with four tillage practices *viz*; T_1 conventional tillage, (3-4 passes of power tillage and residue removal), T_2 double no-till and residue retention (1/3), T_3 no-tillage for *rabi* crops and residue retention (1/3), T_4 residue incorporation (minimum tillage) (one power tillage before sowing) and 3 *rabi* crops (wheat, linseed and mustard). Except no till double plots, puddling was done in other treatments. In double no-till, transplanting of 25 days old 3-4 seedlings/hill with the help of cone of manual dibbler at spacing of 25 x 10 cm row-to-row and plant-to-plant was done in moist field (Fig 6). Ponding of water was avoided at the time of transplanting. Glyphosate (Roundup) @ 3 ml/ liter was applied two weeks before the transplanting. After transplanting, 5-6 cm water was maintained through proper bunding.

Fig 6. Transplanting of rice with manual dibbler under zero tillage

The results revealed that maximum grain yield of rice (rainy season) and following crops (wheat, toria and linseed) were recorded under double no till followed by no till (for *rabi* crop only) along with residue retention (Table 4).

Zero tillage - at a glance

- Crop is sown/transplanted in undisturbed/unploughed fields
- Weeds are killed by using a total weed killer e.g., glypohosate @3ml/litre water
- Herbicides should be applied at least 10-15 days prior to sowing/planting operations.
- Fertilizers and seeds are placed in the narrow slits created by a 'V' shaped or knife type furrow opener mounted behind a tractor. Simultaneously the seeds are covered by the soil.
- Attachments like happy seeders are used in North India to perform all the three operations i.e. opening the furrow, placing the fertilizer/ seeds and covering of seeds while chopping the stubbles in one go.
- In the absence of adequate machinery in NEH Region, animal drawn or manual furrow opener can be used.
- Rest of the cultural operations are done as followed in conventional agriculture.

Table 4. Seed/grain yield (kg/ha) under different tillage practices (average of 4 years)

Crop	Conventional tillage (Residue removal)	Zero tillage (Residue retention and double no-till)	Zero tillage (Residue retention and no-till for *rabi* crop)	Minimum tillage (Residue incorporation)	CD (P=0.05)
Rice	3166	4564	4371	4176	632
Wheat	2257	3452	3317	2761	493
Toria	512	832	775	625	220
Linseed	300	479	421	375	134

Significant difference in SOC was found among tillage treatments. In the field study, no-till also recorded higher soil microbial biomass carbon (SMBC), dehydrogenase activity and earthworm population (Table 5), which in turn resulted in growth and higher yield of all crops (Fig 7) under zero tillage. When zero tillage combined with residue on soil surface, C –sequestration was higher than conventional tillage which favoured more number of earthworm population in the field (Table 4).

In another study the effect of tillage and plant biomass management practices was studied on productivity of lowland rice (var. Shahsarang-1). The main plot treatments included tillage practices *viz.* conventional (4 ploughings) and minimum tillage (2 ploughings), while the sub-plot treatments were plant biomass management *viz.* 50 % NPK, 50% NPK + fresh weed biomass 10t/ha (*Ambrossia* + *Eupatorium*), 100 % NPK (80: 60: 40 kg/ha), 50% NPK + green leaf manure (fresh *Tephrosia* biomass 10t/ha) and 50% NPK + *in-situ* residue management (rice straw 6 t/ha approx.) and FYM 10t/ha + weed biomass 10t/ha + Rock Phosphate 30 kg P/ha (100 % organic). Among the two tillage practices, minimum tillage (Fig 8) gave the higher yield of rice in terms of grain, straw and total plant biomass yield. On

Table 5. Organic carbon and biological activity under different tillage practices

Treatment	0C (%)	SMBC (µg/g soil)	Earthworm population	Dehydrogenase activity (µgTPF/g/24h)
Conventional tillage	1.47	91.3	60,000	29.5
Zero tillage	2.23	128.5	1,60,000	131.5
double no-till	2.51	134.1	3,80,000	166.6
Minimum tillage	2.17	121.3	1,00,000	127.5
CD (P=0.05)	0.78	12.1	-	27.5

SMBC- soil microbial biomass carbon

Zero tillage (crop residue retention and double no-till)

Conventional tillage (crop residue removal)

Rice (Shahsarang 1)

Toria (TS 36) in rice fallow

Fig 7. Performance of various crops under conservation tillage

an average, minimum tillage recorded 15 % higher grain yield over conventional tillage. Among the nutrient management practices, 100% NPK (5.45 t/ha) was the most efficient in increasing grain yield of rice followed by 50% NPK + fresh weed biomass 10t/ha (*Ambrossia* + *Eupatorium*) (5.37t/ha) both of which were significantly superior to 50 % NPK alone and 100 % NPK through organic sources (Table 6).

Table 6. Productivity (t/ha) of rice as influenced by tillage and residue management practices in lowland

Treatments	Grain	Straw
Tillage		
Conventional tillage	4.78	6.40
Minimum tillage	5.53	6.66
CD (P =0.05)	0.09	0.12
Residue management practices		
50 % RDF	4.52	6.47
50 % RDF + fresh biomass of *Eupatorium* 10t/ha	5.37	6.57
100% RDF (80 :60 : 40 kg/ha)	5.47	6.89
100 % organic (Rice straw 5t/ha + *Eupatorium* 10t/ha + Rock phosphate 150kg/ha)	4.94	5.98
50 % RDF + green leaf manuring (1:1)	5.35	6.58
50 % RDF + Rice straw (insitu) 5t/ha	5.25	6.72
CD (P =0.05)	0.15	0.21
CD (T x R)	0.22	0.30

Fig 8. Good crop of rice under minimum tillage

Conservation agriculture in rice for enhancing resource use efficiency and crop diversification

The growth attributes of rice crop has been presented in table 7, where Furrow and Raised Bed (FRB) showed superior results compared to the other treatments, irrespective of the growth stage, for both the above ground as well as below ground growth. This indicates a favourable effect of the furrow in providing a better environment for growth of the crop as compared to the other treatments.

Table 7. Yield attributes and yield of rice under various tillage systems

Treatment	Panicle/m^2	Effective grains/panicle	1000 grain wt. (gm)	Grain yield (kg/ha)
Conventional - Conventional	322	94.4	23.7	4250
FRB – FRB	350	69.6	24.9	3850
Conventional - FRB	272	108.8	23.2	4125
Conventional – Zero Tillage	248	107.6	24.1	4750

The conventional-zero tillage showed superior results compared to the other treatments and was followed by conventional-conventional and conventional-FRB. This resulted in a similar trend in the yield of the crop (Fig 9) where conventional-zero tillage was the highest yielder followed by conventional-conventional and conventional-FRB.

Furrow and raised bed (FRB)- at a glance

- Beds and furrows of 70cm and 30cm width (15-20cm height) are formed by bed former in North India.
- In hills of NEH, small implements like spade, shovel etc. could be used to make FRB.
- Beds could be permanent or formed every time after rice harvest.
- In permanent beds, only repairing is done every year.
- FRB configuration helps to conserve moisture during dry season and facilitate drainage during water logging.
- Generally 2-3 rows of crops are grown on the beds.
- Irrigation water is applied only in the furrow and therefore saves about 20-30% water.
- Under valley condition of NEH, FRB encourages crop diversification by the way of favourable soil conditions.

Conventional - FRB

FRB - FRB

Conventional - Conventional

Conventional – Zero tillage

Fig 9. Performance of rice under various tillage practices

After rice harvest, pulses like pea and lentil and mustard (TS 36) were sown as per the treatment. The productivity of all the *rabi* crops were highest under FRB (Fig 10) followed by Zero tillage. The soil moisture status was also higher under FRB followed by zero tillage plots compared to conventional tillage plots. Therefore, RCTs like FRB and zero tillage improved productivity, conserved soil moisture, promotes crop diversification and reduced cost of cultivation.

Fig 10. Pea and lentil on FRB

Zero tillage – a viable option for pulse production in rice fallow

Conventionally after *kharif* rice, fields remain fallow in lowland, mainly due to excess moisture owing to seepage from surrounding hillocks in mid altitude. Draining water from rice field completely at physiological maturity creates favourable condition for cultivation of a successful *rab*i pulses like pea, lentil etc. A simple drainage around the rice fields/plots with appropriate outlets creates the desirable situations. To study the performance of pulses like pea and lentil, 4 varieties each of pea and lentil were obtained from IIPR, Kanpur, UP during 2009. Pea and lentils (Fig 11) were grown under zero tillage in lowland rice fallow using recommended dose of NPK (20:60:40kg/ha). One weeding cum hoeing was given manually at 30 DAS. In another trial, different lentil varieties were also grown as utera crop. The lentil seeds were broadcasted a day before rice harvest and the seeds were partially incorporated into the soil during harvesting, carrying of rice etc. A seed yield of about 5 q/ha has been obtained from utera lentil (Fig 11d).

Fig 11. a. Opening narrow furrow by manual furrow opener, placing fertilizer, seeds and covering of seeds b. Good lentil crop in between rice stubbles, c. Good pea crop under zero tillage d. Lentil as utera crop in rice fallow

Among various pea varieties tried, IPFD 99-13 (Fig 12) recorded maximum green pod yield (41 q/ha) followed by IPFD 1-10- (32.9 q/ha), IPFD -99-25 (30.32 q/ha) and HUDP (17 q/ha). Among the lentil varieties tried, DPL-15 (Fig 13) recorded maximum seed yield (10.9 q/ha) followed by DPL 62 (8.71 q/ha) and IPL 406 (4.8 q/ha).

Therefore, pea and lentil increased the system productivity and farm income. With appropriate agronomic interventions and varietal screening, pea and lentil could be popularized at mid altitude for food and nutritional security of small and marginal farmers especially the tribal farmers of the region.

In-*situ* residue management- an effective RCT for rice based systems

Effective management of residues, roots, stubbles, and weed biomass can have a beneficial effect on soil fertility through addition of organic matter and plant nutrients, and improvement in soil condition (Munda *et al.*, 2006). Rice straw contains organic materials and nutrients such as N 0.5–1.5%, P 0.2–1.0% and K 0.8– 1.0% (Mongkol and Anan, 2006).

Fig 12. Pea variety IPFD 99-13 (left) under zero tillage in rice fallow

Fig 13. Lentil var. DPL 15 under zero tillage in rice fallow

It is well documented that the incorporation of organic manure or crop straw into soil improves soil fertility and increases crop yield (Singh *et al.*, 2001). The residual effect of incorporating rice straw into the soil provides a significant increase in grain yield after three years of practicing this method (Prasert and Vitaya, 1993). Chutiwat and Direk (1997) have reported that incorporating rice straw into soil has increased grain yield by 15–18 % over burning. It has been reported that the application of cattle manure to low fertile soil at a rate of 10 ton/ha has increased grain yields by 108–106 % over no-fertilizer application in long term (Kanika, 1998).

In a study at Umiam, Meghalaya (Subtropical condition) rice (Fig 14) -vegetables were grown with minimum tillage. All the weed biomass and crop residues available were recycled into the field. Highest grain yield was recorded in cv. Shahsarang 1 (3.70 t/ha) followed by cv. Vivek Dhan 82 (3.2 t/ha) and Mendri (3.1 t/ha) and found significantly superior to cv. Manipuri (2.66 t/ha) (Munda *et al.*, 2006). The nutrients recycled though rice straw ranged from 35.1 kg N/ha with rice –carrot sequence to 42.5 kg N/ha with rice-frenchbean, 9.6 kg P/ha with rice-carrot to 12.5 kg P/ha with sole crop of rice and 78.6 kg K/ha with rice-carrot to 91.9 kg K/ha in-case of a sole crop of rice. The nutrient recycled through vegetables residue varied from 3.3 kg N/ha with rice-carrot to 87.9 kg N/ha with

Fig 14. Rice under in-*situ* fertility management

rice-potato. In other hand, the nutrient recycled through incorporation of weed biomass ranged from 53.6 to 75.9 kg N, 7.1 to 9.6 kg P and 45.7 to 61.7 kg K/ha. Microbial population (cfu/ g dry soil) in in-*situ* fertility management experiments (Bacteria, 129 x 10^4/g, *Rhizobium*, 61.6 x 10^4/g and PSM, 39.9 x 10^4/g) were found much higher than that found under inorganic fertility management (Das *et al.*, 2008).

In-*situ* residue management in low land rice

- Rice is harvested by leaving at least 2/3rd stubbles in the field.
- The stubbles are chopped down by using sickle and incorporated into the field during ploughing/spading.
- All the weed biomass area also periodically incorporated into the field.
- Through residue recycling it is possible to recycle about 60-80 kg N, 20-30.kg P_2O_5 and 100-120 kg K_20/ha, respectively.

Direct dry seeded rice

Direct seedling has advantages of faster and easier planting, reduced labour and less drudgery with earlier crop maturity by 7-10 days, more efficient water use and high tolerance of water deficit, less methane and often higher profit in areas with an assured water supply. Thus the area under direct seeded rice has been increasing to offset increasing costs and scarcity of farm labour (Balasubramanian and Hill, 2002). Weed control is a major issue in direct seeded rice and to overcome this problem, intensive efforts are being made by the agricultural scientist. In some soil, spray of micronutrient like Zn and iron may be needed to remove their deficiency.

Direct seeding of rice using zero till drill, rotary till drill, drum seeder as well as broadcasting under various field preparation or puddling options are tried at research farm. Seeding depth was kept at 2-3 cm while using drill for seeding. For comparison purposes transplanting was also done under conventional puddling as well as under zero tillage and after field preparation with rotary tiller (Sharma *et al.*, 2003a). The rice variety used was IR 64. Direct seedling was done in the first week of June on the same day when nursery was sown for transplanting. For weed control Sofit @ 1500 ml/ha was applied after four days of direct seeding followed by one weeding at around 35 days after seeding. Among the direct seeding options, the yield recorded was highest where rice was seeded using rotary till drill followed by broadcasting sprouted rice seed after preparation by rotary tillage and lowest when broadcasted under zero tillage. The mean yield in rotary tillage was significantly higher compared to zero tillage. Direct drilling by zero till drill and rotary till drill was at par and as good as transplanting under zero tillage or after file preparation by rotary tillage wand was significantly better than broadcasting and drum seeder but statistically at par with other transplanting or seeding options. The yield was marginally higher in conventionally puddled conditions compared to transplanting without tillage. After field preparation by rotary puddle conditions compared to transplanting without tillage, after field preparation by rotary tillage or direct drilling by zero or rotary till drill.

Direct dry seeded rice in low land-at a glance

- Field is prepared before onset of monsoon
- Rice is sown directly in dry bed as done in case of wheat.
- After onset of monsoon, water management is done similar to common puddled rice.
- Varieties like Shahsarang 1 and IR 64 are found promising for mid altitude of Meghalaya

Direct seeding of rice under lowland unpuddled condition at Umiam gave promising results (Fig 15). Varieties like Shahsarang 1, IR 64 performed well. This technology can overcome the problem of water supply for rice transplanting during pre-*kahrif* season and thereby save resources.

Fig 15. Direct dry seeded pre-*kharif* rice (Shahsarang 1)

Leaf colour chart- for efficient N management in Rice

Leaf colour is a fairly indicator of the nitrogen status of plant. Nitrogen use can be optimized by matching its supply to the crop demand as observed through change in the leaf chlorophyll content and leaf colour. The leaf colour chart (LCC) developed by International Rice Research Institute (IRRI), Philippines can help the farmers because the leaf colour intensity relates to leaf nitrogen status in rice plant. The monitoring of leaf colour using LCC helps in the determination of right time of nitrogen application. Use of LCC is simple, easy and cheap under all situations. The studies indicate that nitrogen can be saved from 10 to 15 percent using the LCC (Sharma *et al.,* 2008).

SRI/ICM approach - for effective resource conservation in rice production

In India System of Rice Intensification (SRI) technology started picking up. States like Andhra Pradesh; Tamil Nadu has done a good progress in this technology. Even in North East a lot of works are undertaken in SRI and Integrated Crop Management (ICM). In Tripura on an average about 20% higher yield are obtained from SRI compared to conventional practice. The state has covered about 15% of its area under SRI. ICAR Research Complex for NEH Region, Umiam, Meghalaya also initiated work on SRI and ICM since 2004. The results however, indicated that ICM recorded the highest productivity, followed by SRI and standard practice. These practices could improve rice productivity by 15-20 % over conventional practice. In Garo Hills, Meghalaya also similar results were obtained. However, since the region falls under high rainfall zone, no systematic study on water economy is yet undertaken. The SRI and ICM are effective in improving productivity, save resources like seed, time, water etc. and improve soil health. On an average, rice and SRI and ICM establishment methods matures in about 15 and 7 days earlier compared to conventional

SRI practice – at a glance

- Younger seedlings (10-12 days), wider spacing (25 x 25cm^2) and single seedling/ hill is transplanted.
- Frequent mechanical disturbance (10 days interval) with cono-weeder is performed to improve root respiration.
- Irrigation/drainage channel is provided after every 8-10 rows.
- A thin film of water (soaked field) is maintained instead of flooded field.
- Irrigation is given when hairy cracks develops at field.
- To produce robust healthy seedlings adequate organic manure is applied in nursery bed.
- A low seed rate of 25-50 g/m^2 is used in nursery.
- About 50 -100 m^2 nursery area is sufficient for 1 ha transplanting.
- Seedling from nursery are scooped out (not pulled) with seeds and some soil attached.
- The seedlings should be transplanted within 20-30 minute of scooping from nursery.

practice. Therefore, such practices not only conserve resources but also promote crop intensification by early vacating the land for next crop.

Aerobic rice cultivation for resource conservation in water stress areas

International Rice Research Institute (IRRI) developed the "aerobic rice technology" to address the water crisis problem in tropical agriculture. In aerobic rice systems rice is grown like an upland crop with adequate inputs and supplementary irrigation when rainfall is insufficient (Bouman 2001). The new concept of aerobic rice may be an alternate strategy, which combines the characteristics of rice varieties adopted in upland with less water requirement and irrigated varieties with high response to inputs. In China, the water use for aerobic rice production was 55 - 56 % lower than the flooded rice with 1.6 - 1.9 times higher water productivity. Net return to water use was also two times higher (Bouman 2001). It indicates that aerobic rice may be a viable option where the shortage of water does not allow the growing of lowland rice. Lafitte *et al.* (2002) reported that most lowland cultivars could survive in well-watered aerobic soils. Several technologies have been developed to reduce water loss and increase the water productivity of the rice crop. They are saturated soil culture (Borell *et al.,* 1997), alternate wetting and drying (Tabbal *et al.,* 2002), ground cover systems (Lin *et al.*, 2002) and system of rice intensification (Stoop *et al.*, 2002). However, the fields are still kept flooded for some periods in most of these systems, so water losses remain high. Aerobic rice is high yielding rice grown under non-flooded conditions in non-puddled and unsaturated (aerobic) soil. It is reported that these rice are responsive to high inputs and tolerates (occasional) flooding (Bouman and Tuong 2001). Aerobic rice promises substantial water savings by minimizing seepage and percolation and also greatly reducing evaporation (Bouman *et al.,* 2002). Experimentally growing high-yielding lowland rice varieties under aerobic conditions has shown great potential to save water, but with severe yield penalty (Peng *et al.*, 2006). High yields could be sustained when aerobic rice is grown once in four crops, but not under continuous monocropping in Brazil (Guimaraes and Stone 2000) and Philippines (Ventura and Watanabe 1978). Yield decline under monocropping of aerobic rice has also been reported by Peng *et al.* (2006).

Aerobic rice- at a glance

- Combines the characteristics of rice varieties adopted in upland with less water requirement and irrigated varieties with high response to inputs.
- Rice is grown like an upland crop in unpuddled and non flooded conditions
- Adequate inputs are plied and supplementary irrigation is given when rainfall is insufficient.
- Specific varieties that require less water are to be used.
- IRRI, Philippines has developed specific varieties for aerobic cultivation.

Field experiment was conducted at the ICAR Research Complex for NEH Region farm at Umiam (950 m msl), Meghalaya during rainy seasons of 2006 and 2007 revealed that the yield difference between aerobic (average yield, 1.67 t/ha) and flooded rice (average yield, 2.31 t/ha) ranged from 18.4 to 37.8 % ($P<0.05$) depending on varieties. Cultivation of rice under aerobic condition resulted in 27.5% yield reduction over flooded rice. Among the yield components assessed, sink size (spikelets per panicle) contributed more to the yield and is considered to be most important factor responsible for yield gap between aerobic and flooded rice. The study suggests that, variety Shahsarang 1 with its moderate values of photosynthesis rate, transpiration rate and water use efficiency (WUE) along with higher grain yield seems to be better choice for both stress (aerobic) as well as normal condition (Patel *et al.*, 2010).

In-*situ* moisture conservation in maize-mustard systems

A simple and very low-cost technique of *in–situ* moisture conservation has been developed for *rabi* crop (mustard) using residue of preceding maize crop grown during rainy season. The new technique of *in-situ* residue management for carry over moisture of *rabi* crop ensures double cropping under both upland terrace and flat upland situation using only *Ambrosia* weed as external input where some labour charges are involved for cutting, transporting and applying in the field. Besides, *Ambrosia* leaf and stem being rich in the nutrient particular N, on decomposition may enrich *in- situ* soil fertility in long run maize - mustard system. The treatments comprising six combinations of residue management in main plot, viz. M_0– control, M_1 – Maize stalk cover (MSC), M_2 – MSC + *Ambrosia sp.* @ 5t/ha, M_3 – MSC + *Ambrosia sp.* @ 10t/ha, and two tillage (conservation tillage and conventional tillage) as sub plot, were tested.

- Maize was sown in June with recommended agronomic practices (Fig 16).
- Biomass of a local weed *Ambrosia* spp, the only external input, has been applied between rows of standing maize at 20 days before its harvest in the month of September (Fig 17) to recharge *in-situ* soil moisture profile by preventing run off from the field at the later part of rainy season.
- Immediately after harvest of maize, its stalk is spread all over the field just above the applied *Ambrosia* and kept as such till sowing of mustard. This way *Ambrosia* sp and maize stalk act as **"double mulch"** not only to provide optimum soil moisture for sowing of mustard in October but also to recharge the soil profile for support growth and development of mustard during the whole growing season.
- Mustard was sown in October between maize rows by removing maize stalk and put again between mustard rows on the same day immediately after sowing and kept till harvest of mustard (Fig 18 &19). This ensured good germination, growth and yield of mustard (Fig 21) as compared to control (Fig 20).

Fig 16. Maize during *Kharif (sown in June)*

Fig 17. *Ambrosia* application before maize harvest (Sept.)

Fig 18. Maize stalk cover before mustard sowing (Oct.)

Fig 19. Mustard under maize Stalk (Early Nov.)

Fig 20. Control (without cover)

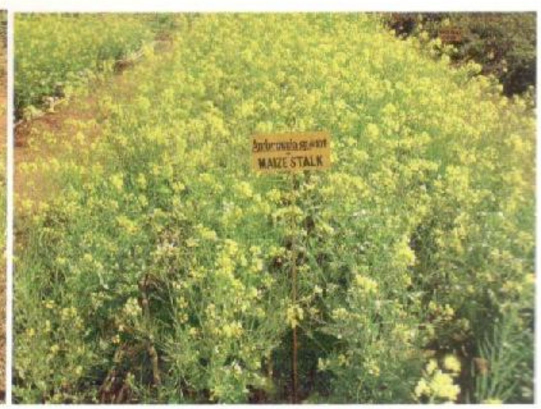

Fig 21. Maize stalk cover + *Ambrosia* sp. @ 10t/ha

In-*situ* moisture conservation in maize-mustard system- at a glance

- Grow maize as usual crop with adequate fertilizer and manures.
- Harvest only the cob and leave the maize stalk standing in the field.
- Collect succulent weed biomass like *Ambrosia/Eupatorium* etc. and use as mulch in between standing maize crop.
- About 15 days before mustard sowing, cut the maize stalk and spread horizontally as mulch over weed mulch.
- Thus forming a double mulch layer of maize stalk and weed biomass.
- On the day of mustard sowing push aside the mulch and sow the crop using zero tillage practice.
- Apply fertilizer and manure in the narrow furrow opened for sowing crop and cover the seed with soil.
- Follow other practices as recommended for the crop.

Water use efficiency (WUE): Water use efficiency of the mustard crop is depicted in Table 5. Retention of maize stalk cover along with Ambrosia 5t/ha and poultry manure 5t/ha was observed to be the most efficient water user followed by MSC + Ambrosia 10t/ha. The WUE under CT and CST were similar with marginally higher values with conservation tillage from second year onwards. In the first year, WUE was significantly higher with conventional tillage. The control had the lowest economic yield per unit of the water used (Table 8).

Table 8. Effect of tillage and conservation measures on yield and water use efficiency of toria

Treatments	Seed yield (kg/ha)					WUE (kg/ha-cm)				
Tillage	2006-07	2007-08	2008-09	2009-10	Mean	2006-07	2007-08	2008-09	2009-10	Mean
Conventional tillage	391.4	457.6	541.6	522.8	476.2	36.68	42.89	50.77	49.00	44.84
Zero tillage	291.2	485.5	570.0	527.8	466.4	27.29	45.5	53.42	49.47	43.92
CD (P=0.05)	30.7	23.6	22.5	NS	NS	2.82	NS	NS	NS	NS
Conservation measures										
Control	194.9	210	192.9	174.4	193	17.45	19.68	18.08	16.35	18.10
Maize stalk cover	269.2	337.8	485.5	441.4	384	25.23	31.67	45.53	41.36	35.94
Ambrosia @ 5t/ha + MSC	288.8	441.0	572.0	554.2	464	27.07	41.33	53.60	51.94	43.48
Ambrosia @ 10t/ha + MSC	359.6	454.0	652.5	655.5	530	33.70	42.55	61.15	61.43	49.71
FYM @ 10t/ha + MSC	460.4	494.5	575.0	588.9	530	43.15	46.36	53.90	55.19	49.65
Poultry manure + MSC + *Ambrosia* @ 5t/ha	475.0	491.8	856.8	737.6	640.2	44.52	46.10	80.30	69.12	60.01
CD (P=0.05)	28.5	33.5	38.7	34.2	31.0	3.73	2.85	2.74	3.16	3.08

Seed yield: The conservation measures brought significant influence on the seed yield of mustard. In conventional tillage, *Ambrosia* @ 10t/ha + maize stalk cover and poultry manure @ 5t/ha + *Ambrosia* @ 5t/ha + maize stalk gave the highest yield, while in zero tillage, MSC + *Ambrosia* 5t/ha + poultry manure @ 5t/ha was the best. The lowest yields in both the tillage systems were obtained from the control plots. Regarding the tillage options, zero tillage recorded higher yield than conventional tillage except for first year, however, the effect was not significant. The interaction of tillage and conservation measures was found to be significantly different (Table 8). Both the conservation measures (poultry manure and *Ambrosia* @ 10t/ha) with conservation tillage (Zero tillage) gave the higher yield than other combinations.

Complementary effects of intercropping in conservation agriculture

Complementary interaction between component crops both in time and space in an intercropping system is called annidation. The canopies of component crops may occupy different vertical layers with taller component tolerant to strong light and shorter component favouring shade. Similarly root system of component crops may occupy different soil layers and exploit nutrients and resources more efficiently. When two crops of widely duration variation are planted in a intercropping system, their peak nutrients demands are likely to occur at different periods. After the harvest of early maturing crop, the situation becomes more favourable for late maturing crops. Eg. Maize + green gram, pigeon pea + amaranthus etc., where green gram and amaranthus are harvested in about 60 days and maize and pigeonpea in 120-130 days.

In an intercropping system, involving a legume and a non- legume crop, part of the nitrogen fixed in the root nodule of the legume may become available to non- legume component crop (Fig 22 & 23). The presence of rhizosphere microflora and micorrhiza on one species may lead to mobilization and greater availability of nutrients not only to the species concerned, but also to the associated species. Another example is the provision of physical support by one species to the other in intercropping system. Erect crop plants may improve the yield of a climber as in the case of coconut + pepper, beetle nut + pepper, maize + french bean etc.

Intercropping systems involving cereal and legume crops are common in India. The intercropped legume, besides increasing the total productivity of the system, also plays an important role in economizing the resource use especially fertilizer N. Farmers in the North East like those in Jaintia Hills, Ri-Bhoi District etc. grows pulses like frenchbean with the maize, where maize supports the frenchbean as climber.

Maize/rice + soybean are a predominant intercropping system in the North eastern hill region of the country, where rainfall ranges from 700 to 2000 mm spreading over 6-7 months. Groundnut is also a good compatible companion crop with maize/rice Farmers in Meghalaya, grows French bean as intercrop in maize where maize acts as staking/supporting material for French bean.

Upland rice which is low yielding due to severe soil moisture stress, weed competition, damage of crop by birds etc. should be grown along with an intercrop. Upland rice can be

Fig 22. Maize + soybean (2:2) intercropping

Fig 23. Rice + soybean (4:2) intercropping systems

intercropped with soybean, French bean, groundnut or black gram/ green gram in 4:2 row ratios for enhancing the total system productivity per unit land area.

De-toping of soybean for nutrient cycling

- To avoid excessive vegetative growth of soybean in maize + soybean (2:2) intercropping systems, detopping of soybean is practiced to prevent lodging of soybean crop and also to improve productivity and promote nutrient cycling (Table 9).
- The pruned biomass of component crop (soybean) can be used as green leaf manure or mulch (Table 9).

Table 9. Effect of de-topping of soybean on nutrient recycling and yield of rice & maize

Cropping system	Fresh wt (t/ha)	Dry wt (kg/ha)	Nutrient content (%)			Nutrient recycled (kg/ha)			Yield of rice/maize (t/ha)
			N	P	K	N	P	K	
Rice sole crop	-	-	-	-	-	-	-	-	3.20
Maize sole crop	-	-	-	-	-	-	-		3.90
Rice + soybean	2.44	292.8	2.69	0.164	1.49	7.87	0.48	4.36	2.61 (0.85)
Maize + soybean	2.18	261.6	3.50	0.253	1.59	9.16	0.66	4.16	3.67 (0.73)

- *In rice + soybean intercropping, yield of rice without detopping = 2.40 t/ha*
- *In maize +soybean intercropping, yield of maize without detopping = 3.30 t/ha*

Resource conservation through indigenous farming systems in North East India

The region is bestowed with rich resources of soil and agro-climate, making it one of the fertile regions of the country. Abundance of natural water resources, well distributed rainfall and good soil, enabling the growing of wide varieties of crops. The biodiversity in NE states remain unexplored to utilize the resources properly for development of agrarian economy and to feed the millions of the region. The people of the region following some indigenous farming systems from time immemorial which are '*Pani- kheti*' system of rice cultivation in Sikkim, Nagaland, Manipur, 'Rice + fish farming' in *Apatani* plateau of Arunachal Pradesh, '*Zabo*' farming and 'Alder based farming' systems of Nagaland and '*Bun*' method of cultivation in Meghalaya. The pest and disease in these systems are management by following indigenous means like crab trap, plant extracts, wood ash etc.

In *pani- kheti* system of cultivation, water is diverted from hilltops and allowed to stand in the terraces. This is done mainly for management of weeds in rice. The weeds and other plant biomass available are incorporated into the soil for nutrient management.

Rice + fish farming is a multi-purpose water management system practiced in Lower Subansiri district of Arunachal Pradesh that integrates land, water and farming system by protecting soil erosion, conserving water for irrigation and paddy-cum-fish culture. Every stream rising from the hill is trapped soon after it emerges from forest, canalized at the rim of valley and diverted by network of primary, secondary and tertiary channels. This system is eco-friendly and the rice productivity in this system is very high (4-4.5 t/ha) compared to the states average.

Water application on hill slopes for irrigation of plantation crops poses a serious problem of soil erosion. The tribal farmers in Muktapur, Jaintia hills district of Meghalaya have developed the indigenous technique of bamboo drip irrigation for irrigating crops in hill slopes. Betel vines planted with arecanut as the supporting tree are irrigated with this system, in which water trickles or drips at the base of crop. In this system water from the natural streams located at higher elevation is conveyed with the use of bamboo channels, supports to the site of plantation through gravity flow. Discharge of water up to 25 litres/min. can be easily managed by manipulating the distribution systems.

In some pockets of Nagaland, the farmers use *Alnus nepalensis* (Alder) tree for agriculture. In this system the Alder seedlings are planted on the sloppy land intended for cultivation and the alder grows fast till attain six to ten years old. The ability of the alder trees to develop and retain fertility of the soil has been fully utilized by farmers in Angami, Chakhesang, Chang, Yimchunger and Konyak area in Nagaland at varying altitudes.

The "Zabo" is an indigenous farming system of Nagaland. It has a combination of forest, agriculture and animal husbandry with well-founded soil and water conservation base. It has protected forest land towards the top of hill, water harvesting tanks in the middle and cattle yard and paddy fields for storage for the crops as well as for irrigation during the crop period. Special techniques for seepage control in the paddy plots are followed. Paddy husk is used on shoulder bunds and puddling is done thoroughly.

Under bun system, the crops are grown on a series of raised beds locally referred to as "Buns" formed along the slope of the hills and in low lands after rice beds. The phytomass available in and around are placed on the ground and covered with soil, which are either burnt or allowed for decomposition inside the soil to meet the nutritional requirements of the crops. In upland it conserves moisture whereas, in lowland it facilitates the drainage. The productivity of crops in general are much higher in buns compared to flat fields. Farmers of Arunachal Pradesh practice monocropping of rice. Since there is a less demand of rice residue for cattle feed in Arunachal Pradesh, farmers leave about 2/3 residue of rice in the field at harvest; only panicle is cut (Fig 24). After harvest of panicle they are kept for a week for drying over the left-over rice residue. The left-over residue remains in the field, and no tillage practice is done before puddling the field (up to May). Residues are incorporated during puddling. Weeds that grow in rice field between harvest of rice and land preparation for succeeding rice are also incorporated along with left-over rice residue. This is a common practice of rice farmers in this belt to ensure long-term soil health of rice field. As a result farmers realize good yield of rice without applying any chemical fertilizer since the beginning of rice cultivation (may be 30-40 years) in a particular rice field. This was also evident from higher yield of rice varieties practiced in Lohit district which is much higher than the average rice yield of NE region (15.7 q/ha). Similarly, in Tripura farmers leave about 50% of rice stubble after each harvest and the field is left for grazing by cattle. The remaining stubbles are incorporated into the soil and never burnt even if it creates difficulty in their agricultural operations. This may be the reason why the rice productivity is comparatively higher in plains of Tripura and soil health is sustaining over centuries.

Fig 24. Farmer leave rice residue in field which is also used as grazing field for cattle

Economic, social and environmental benefits

In NE region of India animal or human energy is used for field preparation. Human energy is the only source for agricultural practices in hills, where steep slopes and undulating topography and very small holdings doesn't allow mechanization. Power tiller is used by some farmers in valleys for field preparation. Enormous energy is put by men and women to prepare the field. Generally 3-4 spadings are given to prepare a fine tilth. Fine field preparation following heavy rains results in enormous loss of soil and nutrients from the fields. The average soil loss from the region is more than 40 t/ha as against 16t/ha of all India average. Zero and minimum tillage save human energy, reduces production cost by at least Rs. 2000-3000/ha (Considering a minimum of 10 labour per spading), conserves, soil, nutrients and moisture. Under optimum management practices, the productivity of conservation tillage comes equal or higher than conventional tillage from first year for *rabi* crops and 3rd year onwards for *kharif* crops.

Implications and likely constrains for wider adoption

The experimental results have clearly brought out the benefit of RCTs in conserving natural resources and improving productivity and income. The CA practices needs to be popularized in all the states of NE to arrest degradation of natural resources and sustaining productivity. The farmers' needs to be trained in this new area of agriculture and proper counseling should be given to them for change of their mind set. During the demonstrations and visit of farmers to the experimental sites farmers showed their interest in adapting in such technologies. Unlike north India, here in North East Most of the agricultural practices are done with bullock or human energy. There is good scope for popularizing small equipments and tools like power tiller, paddy weeder, furrow opener and animal drown seed drill etc for easy field operations. Farmers in Manipur are cultivating toria (M27) in a big way in rice fallow and more number of farmers are coming forward for such practices in mustard and pea. In South Garo Hills also farmers are slowly adopting zero tillage option in mustard especially under rice fallow.

Summary

Globally, about 120 m ha area is under concepts and technologies of conservation agriculture. In India more than 2 mha area under the rice-wheat system in the Indo Gangetic Plain (IGP) is under resource conservation technology (RCT). The Indian experiences are slowly spreading to other South Asian, Central Asian and many African countries. The field experiments conducted in rice and maize based cropping systems at ICAR Research Complex for NEH Region, Umiam, Meghalaya brought out a number of useful information on conservation agriculture. The productivity of *kharif* crops like rice and maize was either similar or higher under zero tillage in comparison to conventional tillage from fourth year onwards. Whereas, for *rabi* crops like pea, lentil, mustard etc. the productivity was higher under zero tillage compared to conventional tillage in the first year itself. Realizing the beneficial effect of conservation agriculture, farmers in Manipur are cultivating toria (var. M 27) in a big way in rice fallow and more number of farmers are coming forward for such practices in mustard and pea. In South Garo Hills also farmers are slowly adopting zero tillage option in mustard especially under rice fallow. Farmer in Tripura and Arunachal Pradesh recycles maximum amount of rice straw in the field for soil fertility management. There are ample numbers of such examples of CA practices in the region.

In the proceedings of the recently held "4th World Congress on Conservation Agriculture" during 4-7 Feb, 2009 a number of benefits have been highlighted. Farmers who adopted CA technologies are saving labour, water and energy cost, attaining higher yields and getting more returns. The CA practices also helps in carbon sequestration, act as a sink for carbon dioxide and alleviate the problem of global warming. Large scale trials and farmers experiences show that the available technologies can be adopted in a wide range of rainfed and irrigated environments. The CA strategies are aimed to revert land degradation, improve carbon sequestration and reduce GHG emissions which have a direct bearing on the Millennium Development Goals. It was concluded in the congress that CA technologies can lead to significant increases in food production, if practiced scientifically. Overall, the CA practices would help in providing a climate resilient agriculture in the complex-diverse and risk prone (CDR) ecosystem of the region. However, more research and extension \efforts on various components of CA are required for realizing better results.

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