Conservation agriculture towards achieving food security in North East India

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Productivity of rainfed monocropping farming system in North Eastern Region of India is low and it is a high economic risk activity. Intensive natural resources mining, continuous degradation of natural resources (soil, water, vegetation) and practice of monocropping under conventional agricultural practices will not ensure farm productivity and food security in the coming years. In order to keep the production system in different land situations sustainable, conservation agriculture based on no-till system is an alternative to reconcile agriculture with its environment and overcome the imposed constraints of climate change and continuous inputs cost. Studies on conservation tillage and residue management in different land situations were conducted during 2006–2009 and they are highlighted in this article. In terrace upland, growing mustard completely on residual moisture following upland rice/maize was possible when it is practised under conservation tillage (crop residue of all crops, including weed biomass incorporated). Similarly, in valley upland, growing second crop of pea in rice fallow is possible if two-thirds or half of rice residues are retained on the soil surface under zero tillage. A long-term study (2006–2009) revealed that double no-till practice in rice-based system is cost-effective, restored soil organic carbon (70.75%), favoured biological activity (46.7%), conserved water and produced yield (49%) higher than conventional tillage. Therefore, conservation tillage practised in terrace upland, valley upland and low-land situations ensured double-cropping, improved farm income and livelihood in rainfed NE India.

Keywords: Conservation agriculture, food security, resource conserving techniques, residue management.

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 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 sequence/crop rotations to derive maximum benefits from inputs and minimize adverse environmental impacts[1]. Intensive tillage in conventional systems leads to gradual decline in soil organic matter through accelerated oxidation, with a consequent reduction in the capacity of the 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[2,3]. 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 residues have high value and a small amount is left after harvesting, a build-up over the years and a change in the farmer's behaviour towards residue management as a long-term investment on soil quality has been noticed in the 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[4].

The North Eastern Region (NER) of India, comprises of Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura and lies between lat. 22°05′N and 29°30′N, and long. 87°55′E and 97°24′E. The region is characterized by diverse agroclimatic and geographical conditions. NER has remained economically backward, though there is ample potential for development due to the presence of abundant natural resources. Valleys are rich in organic matter. On the 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 the upland terrace and valley land follow monocropping practice in rainfed agriculture, where rice is the major crop occupying more than 80% of the cultivated area, followed by maize. Presently, the cropping intensity of NER is 120%. It is the apparent that about 70–90% of the areas remain vacant during the rabi season due to severe water scarcity, as most of the rainwater flows as run-off through sloppy land. Farming in rainfed NE India is a high-risk activity. Intensive natural resources mining and continu-

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ous 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 the production system in different land situations sustainable, CA based on minimum/no-till system is an alternative to reconcile agriculture with its environment and overcome the imposed constraints of climate change and continuous inputs cost. Resource conserving techniques (RCTs) using locally available resources encompass 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. Some RCTs followed in the terrace upland, valley upland and lowland situation of NE India are highlighted here.

RCT for terrace upland

The most efficient and cheapest way of conserving rainfall is to conserve it where it falls. As such, agronomic measures to conserve soil moisture are suitable in the region because of their low cost and capability to reduce soil erosion.

Conservation tillage

In general, conservation tillage significantly improves water availability to crops. However, its effect may be dependent on environment and soil conditions. Conservation tillage holds promise because it does not require elaborate tillage and may ultimately reduce animal draught in the hilly regions.

Eight cropping systems (upland rice–mustard, upland rice–pea, rice bean–mustard, rice bean–pea, maize–mustard, maize–pea, soybean–pea and soybean–mustard) were evaluated under conservation and conventional tillage practices with the objective to select a water-efficient cropping system. In conservation tillage residues of all the crops grown in the system along with weed biomass are incorporated. The total biomass addition annually in different systems is given in Table 1. In conventional tillage, crop residues and weeds are removed.

The periodic soil profile moisture status (0–90 cm soil depth) under various cropping sequences is depicted in Figure 1. It shows that the profile moisture content decreases with cropping season, with little fluctuation among cropping sequences. It is noticeable that conservation tillage had higher (14–22%) soil moisture than conventional tillage irrespective of the cropping system, which has direct bearing on soil moisture recharge and its uptake by a crop. Except for the soybean-based system, in all other systems profile soil moisture never reached below 50% of the initial value, and maize–mustard was found to be most suitable cropping system for soil moisture recharge. In the soybean-based system, profile moisture content reached 50% of the initial value during 90–105 days after sowing (Figure 1). This could be the possible reason of higher mustard and pea yield following maize crop and kharif upland rice.

The growth and yield of all crops (kharif and rabi season) under conservation tillage were higher than those under conventional tillage (Figure 2 and Table 2). This may be ascribed to the incorporation of plant biomass under conservation tillage, which enhances the water retention capacity of the 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 areas. Conventional tillage practised in kharif upland rice and winter rice resulted in lower yields than zero tillage or minimum tillage[5]. This could be attributed to more water loss from tilled soil in comparison to zero or minimum tillage[6].

Based on soil moisture profile, it has been revealed that maize and upland rice grown during rainy season under conservation tillage could support a second crop of mustard and pea without any protective irrigation.

Table 1. Amount of crop residue and weed biomass (t/ha) on dry wt basis incorporated annually in conservation tillage

	Residue (t/ha) recycled			
Crop season	Kharif	Rabi	Weed biomass	Total
Maize–mustard	10.5	5.3	5.3	21.1
Maize–pea	9.3	3.2	6.5	19.0
Upland rice–mustard	7.6	8.2	6.5	22.3
Upland rice–pea	6.9	3.8	7.9	18.3
Rice bean–mustard	4.3	7.9	3.2	15.4
Rice bean–pea	4.7	2.7	3.0	10.4
Soybean–mustard	3.8	3.9	3.5	11.2
Soybean–pea	3.6	2.4	4.6	10.6

Table 2. Yield of mustard and pea under four preceeding crops

Cropping system	Conservation tillage		Conventional tillage
Seed yield of mustard (t/ha)			
Maize–mustard	0.56		0.41
Upland rice–mustard	0.50		0.38
Rice bean–mustard	0.45		0.34
Soybean–mustard	0.40		0.30
Mean	0.48		0.36
CD (P = 0.05)		0.11	
Green pod yield of pea (t/ha)			
Maize–pea	0.87		0.74
Upland rice–pea	0.69		0.65
Rice bean–pea	0.60		0.64
Soybean–pea	0.47		0.35
Mean	0.66		0.6
CD (P = 0.05)		0.21	

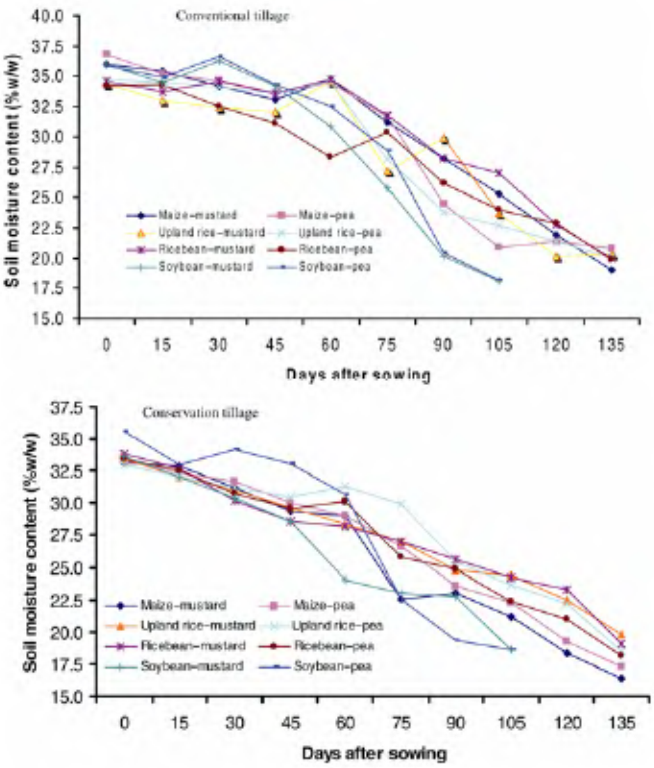

Figure 1. Seasonal soil profile moisture status in various cropping systems under conservation and conventional tillage.

RCT for valley upland

Zero tillage in rice-based system

By definition, zero tillage which is also known as the conservation-tillage system consisting of one-pass operation which places the seeds and fertilizers into an undisturbed seedbed, packs the furrow and retains adequate surface residues to prevent soil erosion. Zero-tillage seeding offers the benefits of retaining surface residues and reduces soil-water losses. With zero-tillage technology, farmers can harvest higher yields and production cost is reduced up to 10%. Zero tillage also improves soil condition and its fertility status.

In flat upland or valley upland, rice is the common crop. Because of water stress, the 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 treatments (only panicle harvested, 50% crop residue cut 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 crop performance was found under 75% rice residue retention (only panicle harvested), followed by 50% rice residue retention (Figure 3). In case of complete removal of rice residue, the seeds of pea germinated but failed to grow thereafter (Figure 4) due to insufficient soil moisture (Figure 5).

Zero-tillage system without crop residue left on the soil surface has no particular advantage because of water loss from the surface, as was evident from soil moisture data (Figure 5) and yield data (Figure 4). Similar result was also reported by Suraj Bhan[7]. Relatively higher soil moisture availability to mustard grown after kharif rice under zero tillage with stubble mulch was also reported in sandy loam soil at Jorhat[8].

RCT for lowland situation

Harvesting of rice at the ground level is common practice in the NER and rice straw is mostly used for fodder. Farmers who do not have any livestock usually burn the 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

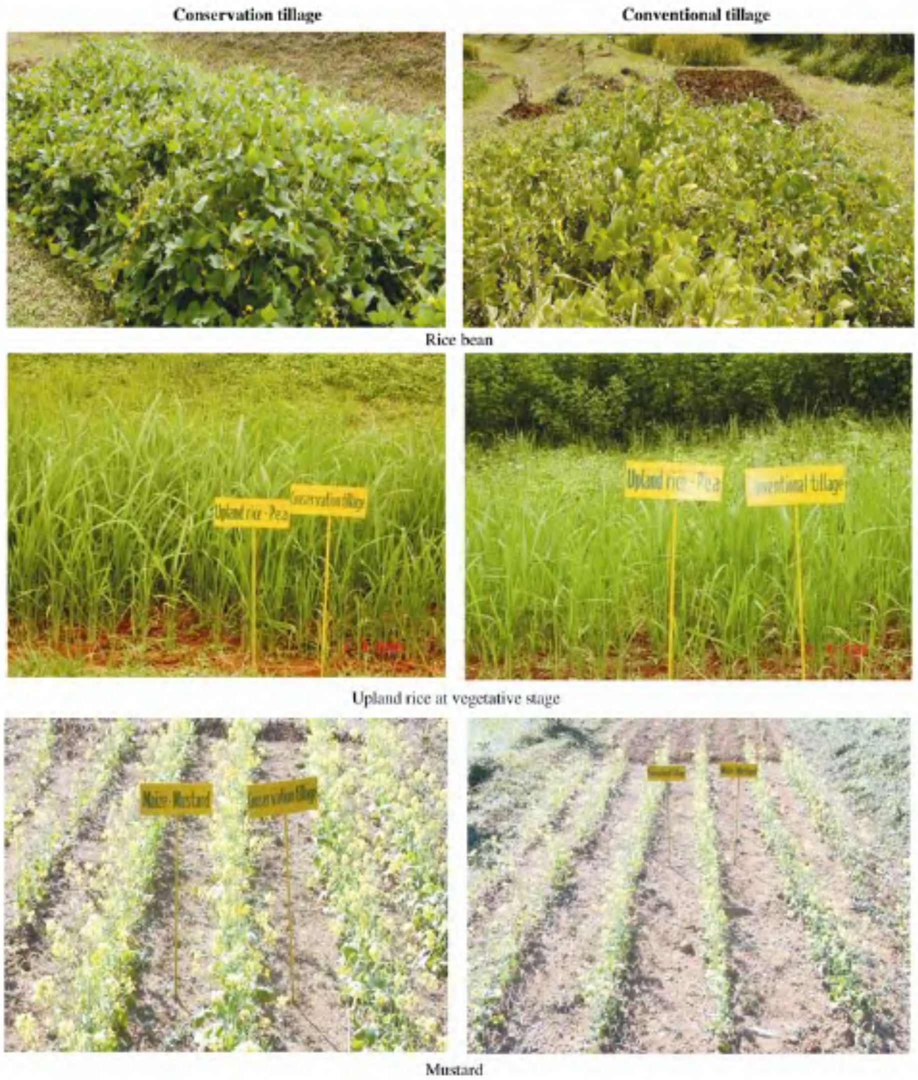

Figure 2. Performance of various crops under conservation and conventional tillage.

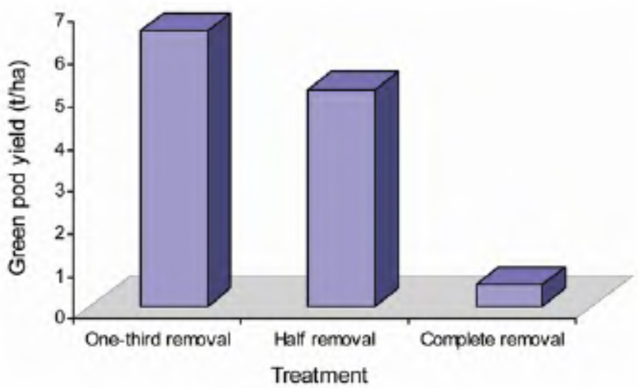

Figure 3. Green pod of pea under varying degrees of residue retention.

structure and loss of soil organic carbon (SOC). As soil carbon is considered as 'blank gold', an optimum level of SOC is needed to conserve the soil, water and nutrients, and favour biological activity and high productivity in any system. Resource-conserving practices like zero tillage provide an opportunity to the farmers to grow crops soon after rice harvest so that the grain matures before the onset of pre-monsoon showers, besides conserving soil moisture, nutrient and SOC[9].

A field study was conducted for four years 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 (one-third), T_3: no-tillage for rabi crops and residue retention (one-third), T_4: residue incorporation (minimum tillage; one power tiller before sowing) and with three rabi crops (wheat, linseed and mustard). Except double no-till plots, puddling was done in other treatments. In double no-till, transplanting of 25-day-old, 5–6 seedlings/hill using the cone of a manual dibbler at a spacing of 25 × 10 cm row-to-row and plant-to-plant was done in the moist field. Ponding of water was avoided at the time of transplanting. Glyphosate (Roundup) @ 2.5 ml/l/10 m^2 was applied two weeks before transplanting. After transplanting, 5–6 cm water depth was maintained through proper bunding.

Table 3. Organic carbon and biological activity under different tillage practices (at the end of four cropping cycles)

Treatment	OC (%)	SMBC (μg/g soil)	Earthworm population	Dehydrogenase activity (μg TPF/g/24 h)
Conventional tillage	1.47	91.3	60,000	29.5
Zero tillage	2.23	128.5	160,000	131.5
Double no-till	2.51	134.1	380,000	166.6
Minimum tillage	2.17	121.3	100,000	127.5
CD (P = 0.05)	0.78	12.1	–	27.5

OC, organic carbon; SMBC, Soil microbial biomass carbon.

Table 4. Seed/grain yield (kg/ha) under different tillage practices (at the end of four cropping cycles)

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
Mustard	512	832	775	625	220
Linseed	300	479	421	375	134

Figure 4. Performance of pea under zero tillage with varying degrees of residue retention.

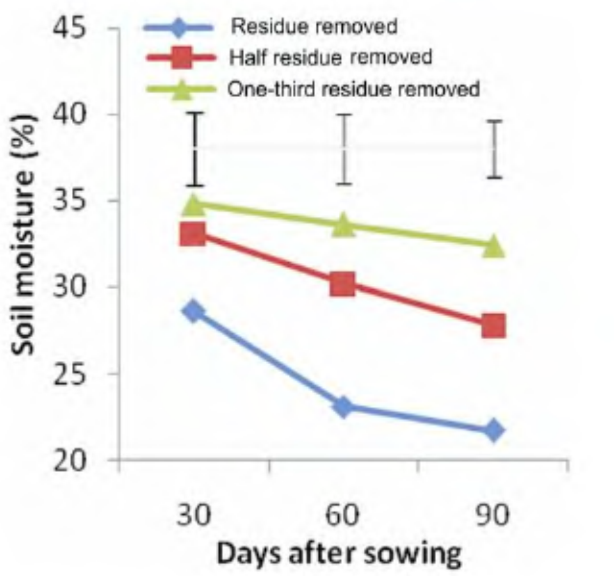

Figure 5. Soil moisture at different growth stages of pea under varying degrees of residue retention.

Significant difference in SOC was found among the tillage treatments. After four years, zero tillage (double no-till) recorded the highest SOC. Kuswantha *et al.*[10] and Barman[11] reported that SOC and total N were highest in zero tillage and residue-retained treatments, and lowest in conventional tillage and residue-removed treatments. In the present study, no-till also recorded higher soil microbial biomass carbon (SMBC), dehydrogenase activity and earthworm population (Table 3), which in turn resulted in good growth (Figure 6) and higher yield (Table 4). When zero tillage was combined with residue on soil surface, C-sequestration was higher than conventional tillage[12], which favoured greater earthworm population in the field (Table 3). In a study at Palampur, deep tillage (conventional) to either of the crops in maize–wheat cropping system was not beneficial. However, conservation tillage involving minimum tillage (in wheat) with *Lantana camara* (an obnoxious weed) mulch (in standing maize or at its harvest) conserved more moisture and resulted in higher grain yield of wheat[13]. Minimum tillage + crop

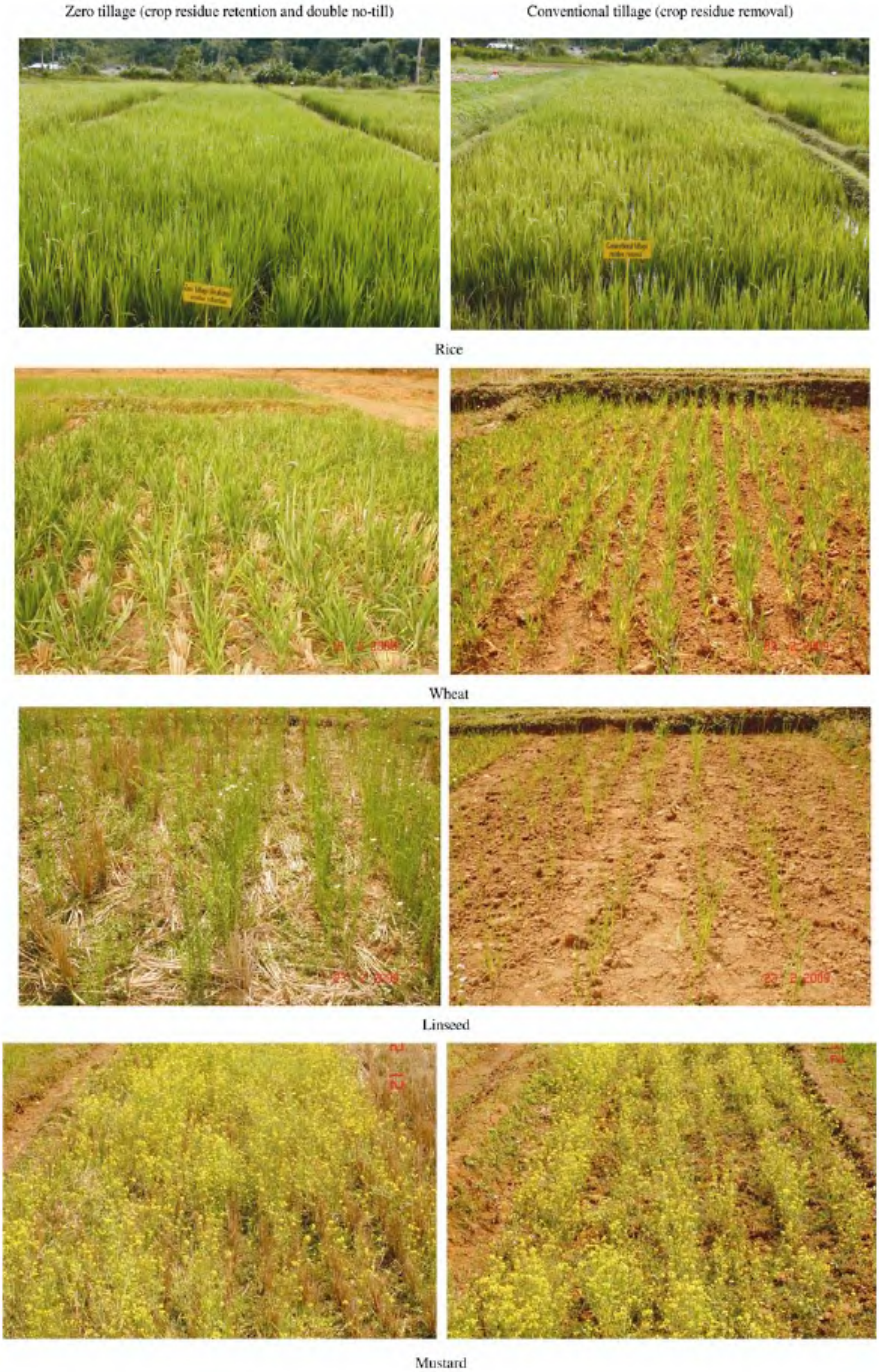

Figure 6. Performance of various crops under conservation tillage.

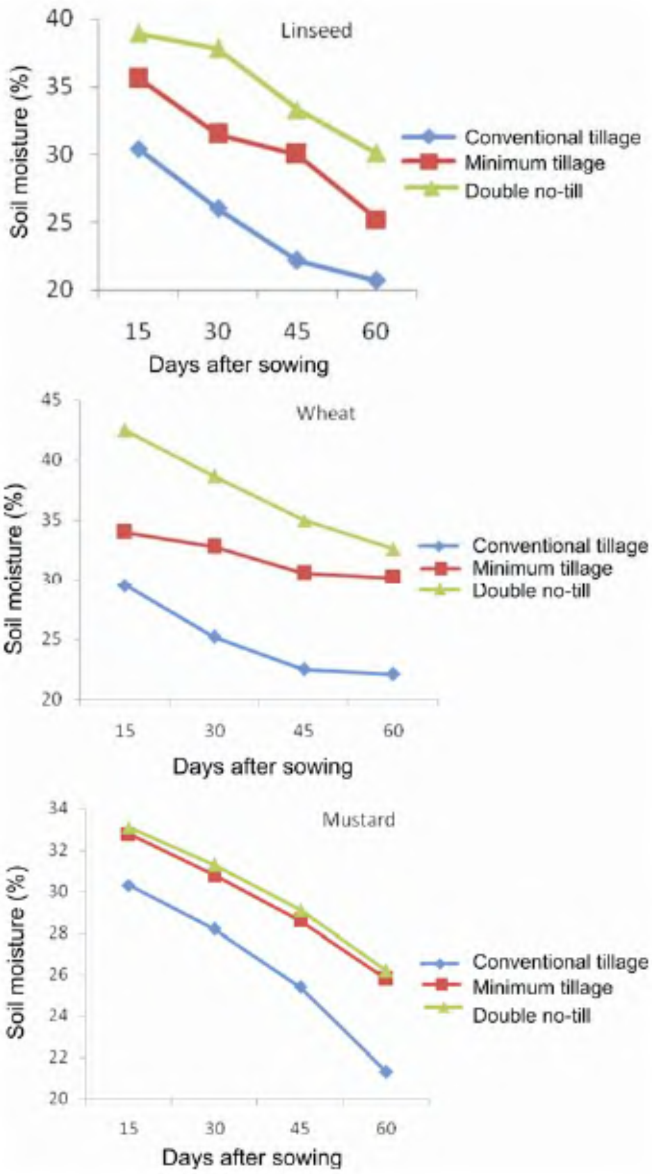

Figure 7. Effect of residue management on soil moisture content (%) in different growth stages.

residue was beneficial for conserving water and improving crop productivity[14,15]. In the present study, double no-till and minimum tillage was found to maintain higher soil moisture (Figure 7).

Conclusion

Field studies conducted on conservation tillage in the terrace upland, valley upland and lowland situations revealed that with appropriate resource conserving techniques, particularly zero/minimum tillage with residue retention, it is possible to use the rice fallow to raise a second crop of wheat, linseed and mustard in lowland, field pea in valley upland and mustard in terraced upland situations. This will improve the farmer's income, put in use on-farm resources and ultimately ensure food security in marginal areas in the hilly ecosystem. Zero-tillage with residue retention not only favourably moderated the soil rhizosphere and produced higher grain yield in long-term perspective, but also made water available for crops during dry periods by permitting downward movement of water across the root boundary.

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