RESEARCH ARTICLE Legume Research- An International Journal, Volume 45 Issue 3: 334-340 (March 2022)

Conservation Agriculture Practices: Impact on Productivity, Energy Utilisation and Profitability of Legume-based Cropping System

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10.18805/LR-4627

ABSTRACT

Background: Conservation agriculture (CA), an agricultural production system with optimum inputs, high returns and sustainability while conserving environment is primarily required for command areas and rainfed uplands. CA helps to improve and conserve soil health through crop rotation, mulching, minimum field traffic and mechanical soil disturbance etc and conserve water to achieve economically and ecologically sustainable crop production.

Methods: The field experiment was conducted for two years during 2019-21 to evaluate the influence of conservation agricultural practices on the system productivity, production efficiency and energy use under legume based cropping system in a command area. Treatments comprised of four cropping systems as Groundnut-foxtail millet (C_1), Groundnut-barnyard millet (C_2), Daincha-foxtail millet (C_3) and Daincha-barn yard millet (C4) in main plots and foliar application of organics, 3% panchagavya, 1% PPFM and 0.1% humic acid formed subplots.

Result: System productivity in terms of groundnut equivalent yield (GEY) was significantly higher (8395 kg/ha) in the Groundnut-Barnyard millet cropping system with foliar application of PPFM 1% in CA system than that of conventional method. The production efficiency was maximum in Groundnut-barnyard millet system (34.41 kg/ha/day) and Groundnut-foxtail millet recorded the highest energy use efficiency (6.8%) which shows that maximum energy was effectively utilized under the system. Daincha-foxtail millet system had highest energy productivity of 0.91 kg M/J. Thus, the conservation tillage based Groundnut-barnyard millet system recorded more system productivity, highest resource use efficiency (both production and land use efficiency) and the highest energy use efficiency.

Key words: Conservation agriculture, Conventional tillage, Cropping system, Energy use, System productivity.

INTRODUCTION

Sustainability of the rice-based cropping systems in command areas is nowadays questionable as release of water from the dam is uncertain and subject to lot of disparity. At present, the major cropping system followed in India is Rice-Rice or Rice-Wheat system. In rice monoculture system, nearly 40-50 per cent of total water is used for field preparations *viz*., ploughing and puddling alone as observed by Singh *et al*. (2014). Hence, there is an urgent need for development of alternate cropping system and cultivation practices with resource conservation efficiency and sustainable crop production. Conservation agriculture (CA), an agricultural production system with optimum inputs, high returns and sustainability while conserving environment is primarily required for command areas and rainfed uplands. CA helps to improve and conserve soil health through crop rotation, mulching, minimum field traffic and mechanical soil disturbance *etc* and conserve water to achieve economically and ecologically sustainable crop production. Das *et al*., (2016) reported that plots under CA had significantly higher WUE and significantly lower water use than conventional tillage plots and positive impacts in permanent broad beds with residue over conventional tillage was observed in pigeonpea-wheat cropping system.Soil carbon sequestration and retention by zero/minimum tillage and cover crops, nutrient and weed management conjoined with crop rotations are significant characteristics of CA and has been recommended for resource conservation, soil health restoration and sustaining crop productivity (Nandan *et al*., 2021; Selvakumar and Sivakumar, 2021). The present study aimed to evaluate alternate cropping systems according to the water release pattern and number of days of water release from the dam *viz*., water release for 100-125 days and more than 140 days with two legume based system with CA practices have been evaluated.

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How to cite this article: Sobhana, E., Swaminathan, C., Kannan, P. and Gurusamy, A. (2022). Conservation Agriculture Practices: Impact on Productivity, Energy Utilisation and Profitability of Legume-based Cropping System. Legume Research. 45(3): 334-340. DOI: 10.18805/LR-4627.

Submitted: 01-04-2021 **Accepted:** 30-04-2021 **Online:** 17-07-2021

Groundnut (*Arachis hypogaea* L.) cultivated in 5.34 million hectares with production of 7.46 million tonnes and productivity of 1.4 mt/ha (DES 2019) is one of the most important oil seed crop and food grain legume, contains about 50% oil, 25-30% protein, 20% carbohydrate and 5% fiber and ash which make a substantial contribution to human nutrition (Gobarah *et al*., 2006). While harvesting, whole plant uprooted to separate pods (economic part) from the plant which removes both above and below ground biomass and thereby if affects the soil organic C negatively. Such reduction in soil organic matter and soil carbon on regular basis leads to continuous cultivation of groundnut which resulted in effect on soil health, quality and productivity (Srinivasa Rao *et al*., 2012). Though uprooting of groundnut plant loosens the surface soil, still farmers go for two to three ploughing to cultivate the succeeding crops which may leads to increase in cost of cultivation (Jain *et al*., 2021). Farmers raise green manure, daincha as a preceding crop and plough the field intensively for incorporation of daincha before sowing the succeeding crop. After sowing of green manure also they plough the field to favour germination which enhances cost of cultivation.

The best alternative to such situation is replacing rice monoculture with legume based cropping systems *viz*., growing groundnut or daincha during August-September (as per no. of days of water release) followed by nutricereals such as foxtail millet and barnyard millet during the *rabi* season would provide conservation of all available resources. Further, cultivation of foxtail millet and barnyard millet with CA practices will reduce cost of cultivation and gives higher yield than conventionally grown these crops. With this backdrop, the study has been designed with the following objectives i) utilizing soil disturbance for harvesting Groundnut and incorporation of daincha in establishing subsequent crop of nutri-cereals, ii) ensuring time saving between two successive crops and also to reduce the total cropping period in the farm and iii) to know the system productivity and energy conservation with this system in comparison to conventional cultivation practices.

MATERIALS AND METHODS

Experimental Site characteristics

The field experiment was conducted at Agricultural College and Research Institute, Tamil Nadu Agricultural University, Madurai, India during 2019-21. The experimental site is geographically located at 9°54′ N latitude and 78°80′ E longitude at an altitude of 147 m above mean sea level representing the Periyar-Vaigai command area. The meteorological parameters averaged over 25 years revealed that a mean annual rainfall of 850 mm was received in 46 rainy days. Out of which, 39.8 per cent was distributed during South West Monsoon (SWM), 42.0 per cent during North East Monsoon (NEM), 2.1 per cent during winter and 16.1 per cent during summer. The daily mean maximum and minimum temperatures were 33.7 and 23.8°C, respectively. The mean daily pan evaporation was 6.2 mm with a mean relative humidity of 81 per cent.

Experimental details of CA practices

The experiment was laid out in a split plot design with three replications. The main plots consist of four cropping systems *viz*., groundnut-foxtail millet (C_1), groundnut-barnyard millet (C_2), daincha-foxtail millet (C_3) and daincha-barnyard millet (C_4) and three subplot consist of foliar application of organics 3% panchagavya, 1% PPFM and 0.1% humic acid. The crop details and field opretions of different crop were given in Table 1.

Cultivation details

Conservation tillage (Zero-till) cropping sequence

Cropping sequence followed in this cropping system, which means that sowing of the subsequent crop immediately after the harvest of first crop *i.e.* under zero tillage. Immediately after the harvest of first crop the subsequent crops are sown without ploughing and cultivated. Harvesting of preceding crop and sowing of succeeding crop was done instantly.

Groundnut-foxtail millet or barnyard millet

The whole plant of groundnut was harvested manually by pulling out from the soil. It disturbed the top soil and uprooting of groundnut plant loosened the surface soil to a minimum depth of 10-15 cm, that favoured sowing of subsequent crops. The millet seeds were sown in soil openings formed by the manual pulling of whole plant of groundnut.

Daincha-foxtail millet or barnyard millet

Similarly in this system also during incorporation the daincha, soil is ploughed and opened up. Seeds of the subsequent crops were sown in the soil openings.

In both the above systems, the succeeding crops were sown and cultivated purely under Zero-till (ZT) condition.

Permanent organic soil cover

The weeds removed were used as mulch in between the crop rows. This mulch will helps to maintain the soil moisture and temperature, reduces the evaporation loss from the soil surface and add nutrients to the soil by decomposition.

Conventional tillage practice

All the four crops tested were grown in separate plots and were cultivated as per the standard recommendation given in crop production guide of the State Government. The test varieties of groundnut, foxtail millet and barnyard millet were VRI 8 (125 days), Co (Te) 7 (85-90 days) and MDU 1 (100 days) were respectively, used. The groundnut was sown with a seed rate of 125 kg/ha and the fertilizer was applied at 25:50:75:60 NPKS kg/ha. Foxtail millet and barnyard millet were sown with a seed rate of 10 kg/ha. The recommended dose of fertilizer for Foxtail millet and barnyard millet were 44:22 NP kg/ha and 40:30:50 NPK kg/ha, respectively.

System indices

system productivity

The system-level productivity of different cropping systems

Table 1: Crop details and field operations from sowing to harvest of different crops under tillage system.

Particulars	Conventional tillage				CT	Conservation tillage				CA
	Groundnut based cropping system		Daincha based cropping system			Groundnut based cropping system		Daincha based cropping system		
	Groundnut	Foxtail millet / Barnyard millet	Daincha	Foxtail millet / Barnyard millet		Groundnut	Foxtail millet / Barnyard millet	Daincha	Foxtail millet / Barnyard millet	
Field preparation	25.07.2019 Ploughing twice	09.12.2019 Ploughing twice	Ploughing twice	30.10.2019 Ploughing twice	Ploughing twice in a year	25.07.2019 Ploughing twice	No Ploughing	Ploughing once for incorporation	No Ploughing	Ploughing once in a year
Date of sowing	02.08.2019	13.12.2019	02.08.2019	04.11.2019	No labour saving	02.08.2019	05.12.2019	02.08.2019	02.11.2019	20 labour charge and labourenergy was saved
Labourers used	20	20	1	20		20	NIL*	1	20	
sowing irrigation	Done	Done	Done	Done	Water, Labour, motor and Done electricity energy was not yet saved	NIL**	Done	Irrigation immediately after sowing		1. 20 mm sowing water is saved 2. Labour, motor and electricity energy was saved
Life irrigation (3 DAS)	05.08.2019	16.12.2019	05.08.2019	07.11.2019		05. 08.2019	08.12.2019	05. 08. 2019	05.11.2019	
Fertilizer recommendation (N-P-K kgha^{-1})	100% RDF	100% RDF	-	Reduction in 25% N RDF	100% RDF	100% RDF	Reduction in 25% N RDF	-	Reduction in 25% N RDF	25% N was saved
Application of weeds as mulch	NIL	NIL	NIL	NIL	No moisture conservation and soil temperature was reduced	Done on 17.08.2019 and 02.09.2019	Done on 20.12.2019 and 05.01.2020	-	Done on 17.11.2019 and 02.11.2019	Soil moisture conservation and soil temperature was reduced
Harvesting	05.12.2019	12.03.2020	17.09.2019 –Daincha incorporated into the soil	02.02.2020 / 12.02.2020		05.12.2019	06.03.2020 / 16.03.2020	17.09.2019 –Daincha incorporated into the soil	01.01.2020 / 11.01.2020	
Time saving	-	-	-	-		Time for field preparation and layout of Foxtail millet / Barnyard millet was not saved				Time for field preparation and layout of Foxtail millet / Barnyard millet was saved

* 20 labourer used for harvesting of groundnut also used for sowing of Foxtail millet / Barnyard millet.

**Irrigation given for harvesting of groundnut will be used was estimated on groundnut equivalent basis in which the economic yield of foxtail millet and barnyard millet were converted into Groundnut equivalent yield (GEY) (kg/ha) based on prevailed market price. It was calculated by using the formula as follows:

$$GEY = Yx\ (Px)/Pj$$

Where,
Yx is the yield of crop x (kg/ha), Px is the price of crop x and Pj is the price of groundnut.

Resource use efficiency

Resource use efficiency of the system was calculated in terms of land use efficiency (LUE). It was calculated from total duration of crop in a cropping system divided by 365 and production efficiency in terms of kg/ha/day and was calculated by dividing total economic yield (GEY) by total duration of the crop in a cropping system.

Energy auditing

The energy formulas pertaining to agriculture as (Mittal and Dhawan, 1988) are listed below:

$$\text{Energy use efficiency (\%) (output: input ratio)} = \frac{\text{Output energy (MJ/ha)}}{\text{Input energy (MJ/ha)}}$$

$$\text{Energy productivity (kg/MJ)} = \frac{\text{Grain yield (kg/ha)}}{\text{Energy input (MJ/ha)}}$$

Methods of energy calculation

Evaluation of manual energy input

Manual energy (Em) was calculated using the following formula:

$$Em = 1.96\ Nm\ Tm\ MJ$$

Where,
Nm = Number of labour spent on a farm activity.
Tm = Useful time spent by a labour on a farm activity (h).

Evaluation of mechanical energy use

The mechanical energy input was determined by the amount of diesel fuel consumed during the field operation (Umar, 2003). Total time required and diesel consumption in pump was also recorded during irrigation.

The diesel fuel energy was worked out by using the formula as

$$Ef = 56.31\ DMJ$$

Where,
56.31 = Unit energy value of diesel (MJ/L).
D = Amount of diesel consumed (L).

Software

The IRRI-STAR SOFTWARE was used for analysis. Groundnut equivalent yield in different legume based cropping system were analyzed using IRRI-STAR software.

Other inputs

The data on inputs used for different field operations in various stages and output obtained in terms of yield were used for determining energetics of the system. All the inputs in the form of labour, diesel, seed, chemicals and fertilizers were taken into consideration with use of energy conversion factor, the input energy was calculated and expressed as input energy in Mega Joule (MJ).

RESULTS AND DISCUSSION

System productivity

The productivity of groundnut was highly influenced by different cropping systems. The highest groundnut productivity (2563 kg/ha) was recorded in groundnut - foxtail millet cropping system with foliar application of PPFM 1% in the zero tillage than conventional tillage method (Table 2). This might be owing to improvement in soil biochemical properties with conservation agriculture practices (Jain *et al.*, 2021). The lowest yield of groundnut (1584 kg/ha) was recorded under the Groundnut-barnyard millet cropping system with the foliar application of 0.1% humic acid (C_2F_3).

System productivity in terms of groundnut equivalent yield (GEY) was significantly higher (8395 kg/ha) in the groundnut - barnyard millet cropping system with the foliar application of PPFM 1% (C_2F_2) in CA system than that of conventional method (Table 3). Reasons behind the higher GEY were higher productivity of groundnut and barnyard millet in CA based groundnut-barnyard millet system and stable market price during experimentation period. Besides, groundnut being a leguminous crop, fixes about 150 kg N into the soil (Toomson *et al.*, 1995) and it increases soil aeration during the time of harvest (uprooting) which ultimately increases the yield of barnyard millet. The lower GEY was recorded in the conventional tillage with Daincha-foxtail millet system. Because daincha is a green manure crop grown and *in-situ* incorporated on 45 DAS. Hence, its economic yield was equal to zero in first cropping period. Only foxtail millet and barnyard millet were contributed to the equivalent yield of groundnut in both the daincha based system (Single cropping).

Resource use efficiency

Resource use efficiency is expressed in terms of land use efficiency and production efficiency (Table 3). Among the different cropping system, the highest land use efficiency (57. 8%) was recorded in the groundnut-barnyard millet system in both conservation and conventional tillage system denotes that highest land area was occupied because of its maximum duration compare to other systems. The production efficiency was higher in the groundnut - barnyard millet system (34.41 kg/ha/day) which was significantly higher than the conventional tillage system. This might be owing to improvement in soil biochemical properties with conservation agriculture practices (Jain *et al.*, 2021). With regards to foliar application, 1% PPFM registered the highest production efficiency of up to 40.99 kg/ha/day while compare to 3% panchagavya and 0.1% humic acid. The lowest land use efficiency (37.0%) and production efficiency (20.19 and 17.6 kg/ha/day in CA and CT, respectively) were recorded in the daincha-foxtail millet system. This may be due to the lesser productivity and adoption of single cropping system.

Table 2: Yield of individual crop in a legume based cropping system under tillage systems.

Treatment	Conservationtillage								Conventional tillage							
	First crop yield (kg/ha)				Second crop yield (kg/ha)				First crop yield (kg/ha)				Second crop yield (kg/ha)			
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean
C_1- Groundnut - foxtail millet	2175	2563	1864	2201	1520	1752	1131	1468	1952	2215	1693	1953	1369	1548	1024	1314
C_2- Groundnut - barnyard millet	2014	2317	1756	2029	1713	2026	1459	1733	1839	2023	1584	1815	1584	1802	1115	1500
C_3- Daincha - foxtail millet	-	-	-	-	1437	1645	1007	1363	-	-	-	-	1257	1392	914	1188
C_4- Daincha - barnyard millet	-	-	-	-	1658	1981	1252	1630	-	-	-	-	1269	1640	958	1289

• First crop- Groundnut, Daincha; Second crop- Foxtail millet, Barnyard millet.

• F_1 - 3% Panchagavya, F_2 - 1% PPFM and F_3 - 0.1% humic acid.

Table 3: System productivity: groundnut equivalent yield (kg/ha) (GEY), production efficiency (kg/ ha/day) and land use efficiency (%) of legume based cropping system.

Treatment	System productivity (GEY)								Production efficiency (kg/ ha/ day)								Total duration of the system CA / CT	Land use efficiency (%)
	Conservation tillage				Conventional tillage				Conservation tillage				Conventional tillage					
	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean	F_1	F_2	F_3	Mean		
C_1- Groundnut - foxtail millet	5215	6067	4126	5136	4690	5311	3741	4581	26.08	30.34	20.63	25.68	23.5	26.6	18.7	22.9	200	54.8
C_2- Groundnut - barnyard millet	7153	8395	6133	7227	6591	7429	4929	6316	34.06	39.98	29.20	34.41	31.4	35.4	23.5	30.1	210	57.5
C_3- Daincha - foxtail millet	2874	3290	2014	2726	2514	2784	1828	2375	21.29	24.37	14.92	20.19	18.6	20.6	13.5	17.6	135	37.0
C_4- Daincha - barnyard millet	4974	5943	3756	4891	3807	4920	2874	3867	34.30	40.99	25.90	33.73	26.3	33.9	19.8	26.7	145	39.7
CD (p=0.05)				640				391										
S.Ed				318.9				194.7										

F_1 - 3% Panchagavya, F_2 - 1% PPFM and F_3 - 0.1% Humic acid.

Table 4: Energy analysis in different Legume based cropping system under tillage systems.

Treatment	Conservation tillage					Conventional tillage				
	Energy input (MJ/ha)	Energy output (MJ/ha)	System yield (kg/ha)	Energy use efficiency (%)	Energy productivity (kg/MJ)	Energy input (MJ/ha)	Energy output (MJ/ha)	System yield (kg/ha)	Energy use efficiency (%)	Energy productivity (kg/MJ)
C_1- Groundnut - Foxtail millet	11325	76591	5136	6.8	0.45	12088	68144	4581	5.6	0.38
C_2- Groundnut - Barnyard millet	11507	76195	7227	6.6	0.63	12269	67438	6316	5.5	0.51
C_3- Daincha - Foxtail millet	5143	20036	2726	3.9	0.53	5906	17459	2375	3.0	0.40
C_4- Daincha - Barnyard millet	5385	23966	4891	4.5	0.91	6148	18948	3867	3.1	0.63

Energy analysis

The relationship between the energy input and energy output were studied, worked out and given in the Table 4. Among the two tillage practices, conservation tillage required lesser amount of energy than conventional tillage. This was mainly due to the energy required for field preparation was equal to zero (Zero tillage) skipping the operations required for seed bed preparations and for sowing irrigation, manures and fertilizers were drastically reduced. Regarding different cropping systems, the highest input energy was required for growing of groundnut and barnyard millet and the lowest input energy was required for growing of daincha and foxtail millet system. This might be due to the requirement of maximum number of variables for the particular crops. Thus the highest input energy was recorded with the groundnut - barnyard millet system (11507 MJ/ha) in CA system and the lowest was recorded in the daincha-foxtail millet in CT system (5143 MJ/ha). Groundnut requires more quantity of seeds, fertilizers compare to other crops and these inputs contributed to most of the input energy requirement.

The highest output energy was recoded under the Groundnut - Foxtail millet system (76591MJ/ha) because of its higher productivity in the conservation tillage compared to CT (68144 MJ/ha). The lowest output energy was obtained in the daincha -foxtail millet under the both CA (20036 MJ/ha) and CT (17459 MJ/ha) system. This might be due to the inclusion of daincha in sequences that required only lesser amount of input energy and gives optimum output energy over the system (Kumar *et al*., 2014; Swaminathan *et al*., 2020).

Energy use efficiency and energy productivity were also higher in the conservation tillage than the conventional method. Among the different cropping system, groundnut-foxtail millet recorded the highest energy use efficiency (6.8%) that shows that maximum energy was effectively utilized under the system. Daincha-foxtail millet system recorded the highest energy productivity of 0.91 kg/MJ with lesser input energy.

Using IRRI star software for analysis of groundnut equivalent yield in different legume based cropping system showed significant variations between the GEY and different cropping systems were represented in Box plot diagram (Fig 1). In the box-plot the median is presented in the right side corner. The GEY box plot indicated that the upper quartile was more than 5000 kg/ha and lower quartile was 2000 kg/ha. The median was fixed slightly towards right side of box mid-point indicating that only a few data for GEY is greater than median and the rest of the data were lower than that. Further, it is understood from the figure that as the median is not in the middle of the box and the whiskers were not the same on both sides of the box indicating the distribution may not be symmetric.

CONCLUSION

From the above results, compared to conventional tillage, conservation tillage based groundnut-barnyard millet system recorded more system productivity, highest resource

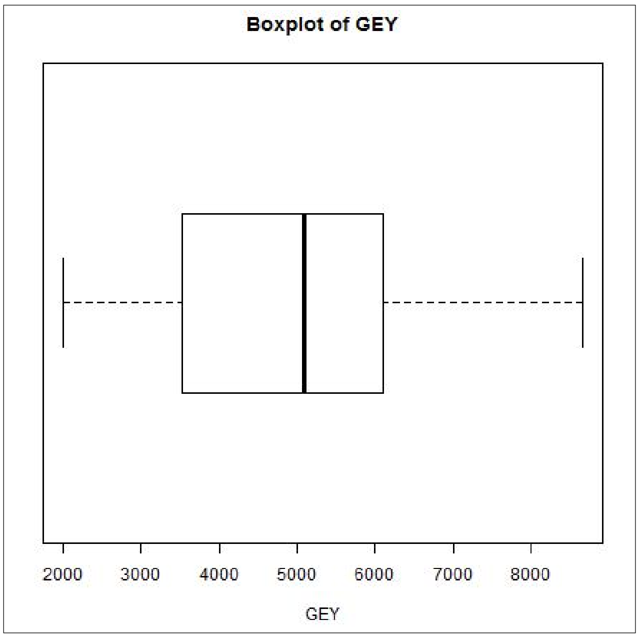

Fig 1: Box-plot analysis of groundnut equivalent yield under tillage systems.

use efficiency (both production and land use efficiency) and the highest energy use efficiency while, the highest energy productivity was recorded in daincha-foxtail millet system and despite depending on rice alone and conventional method of crop cultivation, the famers can go for cultivating the legume based cropping system along with proper conservation agricultural practices will helps to enhances the overall system productivity, resource use efficiency and saves the energy utilization.

Resorting to CA practices would not only augment crop yields, income and lessen the usage of natural resources, but would also bestow climate change benefits. The idea of doubling farmers' income could be made possible by changing the mindset of farmers, exploring the opportunities like this type of technology and newer agronomic practices would certainly result in a paradigm shift from conventional crop production to intensive yet sustainable production system through adoption of various CA practices according to the natural and soil environments. Ever increasing food demand for the growing population with limited resources, enhancing farm productivity by adoption of CA practices is the most efficient and sustainable pathway for doubling farmers' income and environment.

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