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## Research Article

# SYSTEM PRODUCTIVITY AND ENERGY BUDGETING OF RICE-BLACKGRAM CROPPING SYSTEM UNDER CONSERVATION AGRICULTURE TECHNOLOGIES IN HILLY ZONE OF KARNATAKA

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**Abstract:** The aim of this experiment was to determine the energy efficiency indices in the rice-blackgram cropping system under various conservation tillage and crop management practices for hilly zone of Karnataka during 2014-15 and 2015-16. Minimum tillage with BBF or no tillage with flat bed with crop residues retained on the surface combined with RPP (Recommended package of practices) + brown manuring of sunnhemp significantly improved crop growth and yield of rice and blackgram and increased system productivity to the tone of 36.25 and 30.94 percent compared to conventional tillage with inorganic nutrients and pest management. The higher energy output (1,52,364 and 1,43,838 MJ $ha^{-1}$), energy use efficiency (10.03 and 9.72), energy productivity (0.689 and 0.667) and net energy (1,37,039 and 1,28,945 MJ $ha^{-1}$) were recorded in minimum tillage with BBF or no tillage with residue retention on the surface as compared to rest of the tillage practices. Among the crop management practices, recommended package of practices + brown manuring of sunnhemp ($CM_1$), integrated nutrient and pest management + brown manuring of sunnhemp ($CM_2$) and organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) noticed higher output energy (9.60 to 17.91 %), energy use efficiency (11.09 to 20.74 %), energy productivity (9.46 to 20.83 %) and net energy (12.55 to 19.27 %) as compared to inorganic nutrient and pest management.

**Keywords:** *Conservation tillage, Crop management practices, Green and brown manuring, Rice equivalent yield and energetics*

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### Introduction

Energy is the basic driving force in human development. The history of civilization is largely a story of man's progress in harnessing energy, i.e. converting energy to a more useful form. In agriculture, energy is important in terms of crop production and agro-processing for value adding [1]. In the evolution from traditional to modern farming, the commercial energy use was increased sharply [2]. This trend led to ecstatic impacts of environmental immensity e.g. degradation and erosion of the soil structure and environmental pollution brought about carbon dioxide emissions, loss of quality food and risk of their toxicity and high energy costs created. As a result, these systems reduced energy efficiency more than traditional systems making instability of these systems [3]. Since efficient use of the energy resources is vital in terms of increasing production, productivity, competitiveness of agriculture as well as sustainability of rural living, energy auditing is one of the most common approaches to examining energy efficiency and environmental impact of the production system. Agricultural activities like output-input ratio, relevant indicators and energy use patterns can be calculated by researchers. Also, the energy audit provides sufficient data to establish functional forms to investigate the relationship between energy inputs and outputs. Estimating these functional forms is very useful for determining elasticity of inputs on yield and production [4].

### Material and Methods

An experiment was carried out at Agriculture Research Station, Mundgod, Uttara Kannada District of Karnataka on conservation agriculture for the rice-blackgram system for hilly zone of Karnataka in 2014-15 and 2015-16. Main plot consists of conservation tillage (CT) practices, CT (minimum tillage) with BBF (135 cm) with residue retention on the surface (CT1), CT (no tillage) with flat bed with residue retention on the surface (CT2), CT (minimum tillage) with incorporation of all crop residues (with rotavator) (CT3) and conventional tillage (CT4). Sub plots consists, RPP + brown manuring of sunnhemp ($CM_1$), integrated nutrient and pest management (INM + IPM: 50 % organic + 50 % inorganic) + brown manuring of sunnhemp ($CM_2$), organics (FYM 50 % + VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) and inorganic nutrient and pest management (CM4) along with control (conventional tillage + sunnhemp green manure with hodta operation) was conducted in strip-block design consists of sixteen treatments with control and three replications. The inputs in the calculation of energy use in labour, machinery, diesel oil, fertilizers, seeds, while rice and blackgram yield were included in the output as presented in [Table-1].

Table-1 *Energy coefficient used in energy calculation*

| S | Energy source | Energy coefficient (MJ/unit) | Reference |
|---|---|---|---|
| 1 | Human labor | 1.96 MJ $hr^{-1}$ | [5] |
| 2 | N | 60.60 MJ $kg^{-1}$ | |
| 3 | P | 11.10 MJ $kg^{-1}$ | |
| 4 | K | 6.70 MJ $kg^{-1}$ | |
| 5 | Insecticide | 199 MJ $kg^{-1}$ | |
| 6 | Fungicides | 92 MJ $kg^{-1}$ | |
| 7 | Herbicide | 238 MJ $kg^{-1}$ | |
| 8 | Diesel | 56.31 MJ $l^{-1}$ | |
| 9 | Paddy seeds | 14.57 MJ $kg^{-1}$ | [2] |
| 10 | Straw | 12.50 MJ $kg^{-1}$ | |
| 11 | Machinery | 62.7 MJ $hr^{-1}$ | |
| 12 | bullock pair | 10.1 MJ $hr^{-1}$ | [5] |
| 13 | FYM | 0.30 MJ $kg^{-1}$ | |

The rice equivalent yield and energy indices were calculated by using the formulae as follows below.

**Rice equivalent yield (REY)**

REY (q $ha^{-1}$) = Crop yield (q $ha^{-1}$) X Price of crop (Rs. $q^{-1}$) / Price of rice (Rs. $q^{-1}$)

Table-2 *Rice equivalent yield and total output energy as influenced by conservation practices in rice-blackgram system for hilly zone of Karnataka*

| Conservation Tillage (CT) | Rice equivalent yield (q ha$^{-1}$) | | | Total output energy (MJ ha$^{-1}$) | | |
|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $CT_1$ | 107.10 $^{a}$ | 102.04 $^{a}$ | 104.57 $^{a}$ | 156052 $^{a}$ | 148677 $^{a}$ | 152364 $^{a}$ |
| $CT_2$ | 100.87 $^{b}$ | 96.58 $^{b}$ | 98.72 $^{b}$ | 146963 $^{b}$ | 140712 $^{b}$ | 143838 $^{b}$ |
| $CT_3$ | 91.37 $^{c}$ | 86.63 $^{c}$ | 89.00 $^{c}$ | 133127 $^{c}$ | 126220 $^{c}$ | 129673 $^{c}$ |
| $CT_4$ | 86.96 $^{d}$ | 78.79 $^{d}$ | 82.88 $^{d}$ | 126706 $^{d}$ | 114796 $^{d}$ | 120751 $^{d}$ |
| SEm± | 1.05 | 1.00 | 0.66 | 1523 | 1456 | 964 |
| Crop Management (CM) Practice | | | | | | |
| $CT_1$ | 104.48 $^{a}$ | 99.79 $^{a}$ | 102.13 $^{a}$ | 152223 $^{a}$ | 145389 $^{a}$ | 148806 $^{a}$ |
| $CT_2$ | 99.50 $^{b}$ | 93.44 $^{b}$ | 96.47 $^{b}$ | 144969 $^{b}$ | 136145 $^{b}$ | 140557 $^{b}$ |
| $CT_3$ | 95.85 $^{c}$ | 89.62 $^{c}$ | 92.73 $^{c}$ | 139653 $^{b}$ | 130570 $^{b}$ | 135111 $^{c}$ |
| $CT_4$ | 86.48 $^{d}$ | 81.20 $^{d}$ | 83.84 $^{d}$ | 126002 $^{c}$ | 118301 $^{c}$ | 122152 $^{d}$ |
| SEm± | 1.07 | 1.12 | 0.57 | 1564 | 1634 | 837 |
| Interactions (CT*CM) | | | | | | |
| $CT_1$ $CM_1$ | 118.16 $^{a}$ | 112.65 $^{a}$ | 115.41 $^{a}$ | 172165 $^{a}$ | 164132 $^{a}$ | 168149 $^{a}$ |
| $CT_1$ $CM_2$ | 110.74 $^{b}$ | 104.88 $^{b}$ | 107.81 $^{b}$ | 161355 $^{b}$ | 152809 $^{b}$ | 157082 $^{b}$ |
| $CT_1$ $CM_3$ | 104.59 $^{bc}$ | 98.90 $^{bc}$ | 101.74 $^{c}$ | 152393 $^{bc}$ | 144091 $^{bc}$ | 148242 $^{c}$ |
| $CT_1$ $CM_4$ | 94.92 $^{d-f}$ | 91.75 $^{de}$ | 93.33 $^{de}$ | 138294 $^{d-f}$ | 133677 $^{de}$ | 135985 $^{de}$ |
| $CT_2$ $CM_1$ | 108.61 $^{b}$ | 104.44 $^{b}$ | 106.53 $^{b}$ | 158241 $^{b}$ | 152173 $^{b}$ | 155207 $^{b}$ |
| $CT_2$ $CM_2$ | 104.68 $^{bc}$ | 98.96 $^{bc}$ | 101.82 $^{c}$ | 152525 $^{bc}$ | 144182 $^{bc}$ | 148354 $^{c}$ |
| $CT_2$ $CM_3$ | 100.10 $^{cd}$ | 96.81 $^{cd}$ | 98.45 $^{c}$ | 145845 $^{cd}$ | 141048 $^{cd}$ | 143447 $^{c}$ |
| $CT_2$ $CM_4$ | 90.08 $^{fg}$ | 86.10 $^{e-g}$ | 88.09 $^{fg}$ | 131242 $^{fg}$ | 125443 $^{e-g}$ | 128342 $^{fg}$ |
| $CT_3$ $CM_1$ | 98.72 $^{c-e}$ | 96.56 $^{cd}$ | 97.64 $^{cd}$ | 143832 $^{c-e}$ | 140692 $^{cd}$ | 142262 $^{cd}$ |
| $CT_3$ $CM_2$ | 94.49 $^{d-g}$ | 88.51 $^{ef}$ | 91.50 $^{ef}$ | 137667 $^{d-g}$ | 128965 $^{ef}$ | 133316 $^{ef}$ |
| $CT_3$ $CM_3$ | 89.97 $^{fg}$ | 83.04 $^{f-h}$ | 86.50 $^{g}$ | 131082 $^{fg}$ | 120985 $^{f-h}$ | 126034 $^{g}$ |
| $CT_3$ $CM_4$ | 82.31 $^{hi}$ | 78.41 $^{h}$ | 80.36 $^{h}$ | 119928 $^{hi}$ | 114236 $^{h}$ | 117082 $^{h}$ |
| $CT_4$ $CM_1$ | 92.42 $^{e-g}$ | 85.49 $^{e-g}$ | 88.95 $^{e-g}$ | 134656 $^{e-g}$ | 124557 $^{e-g}$ | 129606 $^{e-g}$ |
| $CT_4$ $CM_2$ | 88.08 $^{gh}$ | 81.42 $^{gh}$ | 84.75 $^{gh}$ | 128330 $^{gh}$ | 118625 $^{gh}$ | 123477 $^{gh}$ |
| $CT_4$ $CM_3$ | 88.74 $^{fg}$ | 79.72 $^{gh}$ | 84.23 $^{gh}$ | 129293 $^{fg}$ | 116155 $^{gh}$ | 122724 $^{gh}$ |
| $CT_4$ $CM_4$ | 78.62 $^{i}$ | 68.53 $^{i}$ | 73.57 $^{i}$ | 114545 $^{i}$ | 99849 $^{i}$ | 107197 $^{i}$ |
| SEm± | 2.01 | 1.96 | 1.55 | 2930 | 2862 | 2256 |
| Control | 92.94 | 85.14 | 89.04 | 135414 | 124049 | 129732 |
| SEm± | 2.24 | 2.05 | 1.96 | 2975 | 2879 | 2249 |
| CD (P=0.05) | 7.51 | 6.21 | 6.05 | 8742 | 8414 | 6517 |

$CT_1$. CT (minimum tillage) with BBF (135 cm) with residue retention on the surface; $CT_2$. CT (no tillage) with flat bed with residue retention on the surface.
$CT_3$. CT (minimum tillage) with incorporation of all crop residues (with rotavator); $CT_4$. Conventional tillage.
$CM_1$. RPP (Recommended package of practices) + brown manuring of sunnhemp; $CM_2$. Integrated nutrient and pest management (INM + IPM: 50 % organic + 50 % inorganic) + brown manuring of sunnhemp.
$CM_3$. Organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5t ha$^{-1}$.
$CM_4$. Inorganic nutrient and pest management; Control. Conventional tillage + sunnhemp green manure with hodta operation; Means fallowed by the same alphabet do not differ significantly by DMRT (P=0.05)

Table-3 *Energetics in (Rice equivalent yield) rice-blackgram cropping system as influenced by conservation practices in rice-blackgram system for hilly zone of Karnataka*

| Conservation Tillage (CT) | Energy use efficiency | | | Energy productivity (kg MJ$^{-1}$) | | | Net energy (MJ ha$^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled | 2014-15 | 2015-16 | Pooled |
| $CT_1$ | 10.28 $^{a}$ | 9.79 $^{a}$ | 10.03 $^{a}$ | 0.705 $^{a}$ | 0.672 $^{a}$ | 0.689 $^{a}$ | 140727 $^{a}$ | 133352 $^{a}$ | 137039 $^{a}$ |
| $CT_2$ | 9.93 $^{b}$ | 9.51 $^{a}$ | 9.72 $^{b}$ | 0.682 $^{a}$ | 0.653 $^{a}$ | 0.667 $^{b}$ | 132071 $^{b}$ | 125820 $^{b}$ | 128945 $^{b}$ |
| $CT_3$ | 7.91 $^{c}$ | 7.48 $^{b}$ | 7.69 $^{c}$ | 0.543 $^{b}$ | 0.514 $^{b}$ | 0.528 $^{c}$ | 116215 $^{c}$ | 109307 $^{c}$ | 112761 $^{c}$ |
| $CT_4$ | 6.31 $^{d}$ | 5.71 $^{b}$ | 6.01 $^{d}$ | 0.433 $^{c}$ | 0.392 $^{c}$ | 0.413 $^{d}$ | 106537 $^{d}$ | 94628 $^{d}$ | 100583 $^{d}$ |
| SEm± | 0.10 | 0.09 | 0.07 | 0.007 | 0.006 | 0.005 | 1523 | 1456 | 964 |
| Crop Management (CM) Practice | | | | | | | | | |
| $CM_1$ | 8.20 $^{b}$ | 7.84 $^{b}$ | 8.02 $^{b}$ | 0.563 $^{b}$ | 0.538 $^{b}$ | 0.550 $^{b}$ | 133353 $^{a}$ | 126518 $^{a}$ | 129936 $^{a}$ |
| $CM_2$ | 9.30 $^{a}$ | 8.75 $^{a}$ | 9.02 $^{a}$ | 0.638 $^{a}$ | 0.600 $^{a}$ | 0.619 $^{a}$ | 128969 $^{a}$ | 120145 $^{b}$ | 124557 $^{b}$ |
| $CM_3$ | 9.45 $^{a}$ | 8.87 $^{a}$ | 9.16 $^{a}$ | 0.649 $^{a}$ | 0.609 $^{a}$ | 0.629 $^{a}$ | 124485 $^{b}$ | 115402 $^{c}$ | 119944 $^{c}$ |
| $CM_4$ | 7.47 $^{c}$ | 7.04 $^{c}$ | 7.26 $^{c}$ | 0.513 $^{c}$ | 0.483 $^{c}$ | 0.498 $^{c}$ | 108742 $^{c}$ | 101041 $^{d}$ | 104892 $^{d}$ |
| SEm± | 0.10 | 0.11 | 0.05 | 0.007 | 0.008 | 0.004 | 1564 | 1634 | 837 |
| Interactions (CT*CM) | | | | | | | | | |
| $CT_1$ $CM_1$ | 9.46 $^{c}$ | 9.02 $^{c}$ | 9.24 $^{c}$ | 0.649 $^{c}$ | 0.619 $^{c}$ | 0.634 $^{c}$ | 153963 $^{a}$ | 145930 $^{a}$ | 149947 $^{a}$ |
| $CT_1$ $CM_2$ | 11.33 $^{a}$ | 10.73 $^{a}$ | 11.03 $^{a}$ | 0.778 $^{ab}$ | 0.736 $^{a}$ | 0.757 $^{a}$ | 147112 $^{ab}$ | 138565 $^{ab}$ | 142838 $^{b}$ |
| $CT_1$ $CM_3$ | 11.38 $^{a}$ | 10.76 $^{a}$ | 11.07 $^{a}$ | 0.781 $^{a}$ | 0.738 $^{a}$ | 0.759 $^{a}$ | 138996 $^{bc}$ | 130694 $^{b-d}$ | 134845 $^{cd}$ |
| $CT_1$ $CM_4$ | 8.95 $^{cd}$ | 8.65 $^{cd}$ | 8.80 $^{d}$ | 0.614 $^{cd}$ | 0.594 $^{cd}$ | 0.604 $^{d}$ | 122836 $^{e}$ | 118219 $^{ef}$ | 120527 $^{f}$ |
| $CT_2$ $CM_1$ | 9.49 $^{c}$ | 9.12 $^{c}$ | 9.30 $^{c}$ | 0.651 $^{c}$ | 0.626 $^{c}$ | 0.639 $^{c}$ | 141560 $^{bc}$ | 135492 $^{bc}$ | 138526 $^{bc}$ |
| $CT_2$ $CM_2$ | 10.76 $^{b}$ | 10.17 $^{b}$ | 10.47 $^{b}$ | 0.739 $^{b}$ | 0.698 $^{b}$ | 0.718 $^{b}$ | 138352 $^{bc}$ | 130009 $^{b-d}$ | 134181 $^{cd}$ |
| $CT_2$ $CM_3$ | 10.94 $^{ab}$ | 10.58 $^{ab}$ | 10.76 $^{ab}$ | 0.751 $^{ab}$ | 0.726 $^{ab}$ | 0.739 $^{ab}$ | 132518 $^{cd}$ | 127722 $^{cd}$ | 130120 $^{de}$ |
| $CT_2$ $CM_4$ | 8.53 $^{d}$ | 8.15 $^{de}$ | 8.34 $^{e}$ | 0.585 $^{d}$ | 0.560 $^{de}$ | 0.572 $^{e}$ | 115854 $^{e-g}$ | 110055 $^{f-h}$ | 112954 $^{gh}$ |
| $CT_3$ $CM_1$ | 7.69 $^{e}$ | 7.52 $^{f}$ | 7.61 $^{f}$ | 0.528 $^{e}$ | 0.516 $^{f}$ | 0.522 $^{f}$ | 125131 $^{de}$ | 121991 $^{de}$ | 123561 $^{ef}$ |
| $CT_3$ $CM_2$ | 8.50 $^{d}$ | 7.96 $^{ef}$ | 8.23 $^{e}$ | 0.583 $^{d}$ | 0.547 $^{ef}$ | 0.565 $^{e}$ | 121473 $^{ef}$ | 112771 $^{fg}$ | 117122 $^{fg}$ |
| $CT_3$ $CM_3$ | 8.54 $^{d}$ | 7.88 $^{ef}$ | 8.21 $^{e}$ | 0.586 $^{d}$ | 0.541 $^{ef}$ | 0.564 $^{e}$ | 115735 $^{e-g}$ | 105638 $^{g-i}$ | 110687 $^{g-i}$ |
| $CT_3$ $CM_4$ | 6.89 $^{f}$ | 6.56 $^{g}$ | 6.73 $^{g}$ | 0.473 $^{f}$ | 0.450 $^{g}$ | 0.462 $^{g}$ | 102520 $^{h}$ | 96828 $^{i}$ | 99674 $^{j}$ |
| $CT_4$ $CM_1$ | 6.15 $^{g}$ | 5.69 $^{h}$ | 5.92 $^{h}$ | 0.422 $^{g}$ | 0.390 $^{h}$ | 0.406 $^{h}$ | 112759 $^{fg}$ | 102660 $^{hi}$ | 107709 $^{hi}$ |
| $CT_4$ $CM_2$ | 6.62 $^{fg}$ | 6.12 $^{gh}$ | 6.37 $^{g}$ | 0.454 $^{fg}$ | 0.420 $^{gh}$ | 0.437 $^{g}$ | 108940 $^{gh}$ | 99236 $^{i}$ | 104088 $^{ij}$ |
| $CT_4$ $CM_3$ | 6.95 $^{f}$ | 6.24 $^{g}$ | 6.60 $^{g}$ | 0.477 $^{f}$ | 0.429 $^{g}$ | 0.453 $^{g}$ | 110692 $^{gh}$ | 97554 $^{i}$ | 104123 $^{ij}$ |
| $CT_4$ $CM_4$ | 5.51 $^{h}$ | 4.80 $^{i}$ | 5.16 $^{i}$ | 0.378 $^{h}$ | 0.330 $^{i}$ | 0.354 $^{i}$ | 93759 $^{i}$ | 79063 $^{j}$ | 86411 $^{k}$ |
| SEm± | 0.19 | 0.18 | 0.14 | 0.013 | 0.012 | 0.010 | 2930 | 2862 | 2256 |
| Control | 6.32 | 5.79 | 6.06 | 0.43 | 0.40 | 0.42 | 113995 | 102630 | 108313 |
| SEm± | 0.20 | 0.16 | 0.12 | 0.012 | 0.010 | 0.009 | 2911 | 2901 | 2316 |
| CD (P=0.05) | 0.61 | 0.40 | 0.36 | 0.037 | 0.030 | 0.018 | 8642 | 8542 | 6948 |

**Energy indices**

Energy use efficiency =Total energy output (MJ $ha^{-1}$)/ Total energy input (MJ $ha^{-1}$)
Energy productivity =Grain yield (kg $ha^{-1}$)/ Total energy input (MJ $ha^{-1}$)
Net energy = Energy output (MJ $ha^{-1}$) – Energy input (MJ $ha^{-1}$)

## Results and Discussion

### Rice equivalent yield

Significantly higher rice equivalent yield was recorded with all conservation tillage systems as compared to conventional tillage (CT4). Conservation tillage with BBF with residue retention on the surface (104.57 q $ha^{-1}$), no tillage with flat bed with residue retention on the surface (98.72 q $ha^{-1}$) and minimum tillage with incorporation of all crop residues (89.00 q $ha^{-1}$) recorded significantly higher rice equivalent yield of 20.74, 16.05 and 6.88 percent over conventional tillage (82.88 q $ha^{-1}$), respectively [Table-2]. Because of optimum soil moisture conditions, conservation tillage with crop residues, could have hastened the decomposition of crop residues and enhanced availability nutrients than conventional tillage. Increased REY in conservation tillage with reduced or no tillage with crop residues retention on the surface or incorporation of crop residue practices might be due to the enhanced and sustained availability of soil moisture for a longer period between the two showers in rice crop and better moisture conservation for blackgram crop in rabi season, it is grown mainly on residual soil moisture conditions. Further, the experimental results showed that, crop residues retention reduce the evaporation of soil moisture, soil erosion and regulates the soil temperature variations help in sustaining crop yield under rainfed conditions. In no tillage or reduced tillage plots lower bulk density, improved soil porosity and high infiltration rate favour the crop root penetration which might have resulted in better crop growth and yield [6 and 7]. Among the crop management practices, application of RPP + brown manuring of sunnhemp ($CM_1$) recorded significantly higher REY (102.13 q $ha^{-1}$) as compared to inorganic nutrient and pest management (CM4) (83.84 q $ha^{-1}$) [Table-2]. Application of FYM and green manuring has positive effect on increasing the soil available nutrients, soil moisture and soil physical properties which had a direct influence on crop growth and yield over application of NPK alone. The application of green manure increased the grain yield of rice over no green manure (NPK alone) [8]. In-situ incorporation of Sesbenia aculeate @ 12 t $ha^{-1}$ remarkably increased the grain (18 %) and straw (16 %) yield of rice over no organic manures, owing to the increased in growth and yield attributing characters of rice (9). Among the interactions, $CT1CM_1$ (CT (minimum tillage) with BBF (135 cm) with residue retention on the surface and RPP + brown manuring of sunnhemp was recorded significantly higher REY (115.41 q $ha^{-1}$) over rest of the treatment combinations [Table-2]. The increase in rice equivalent yield was mainly attributed to more favorable soil physical condition, available nutrient and soil moisture retention improved the crop growth and yield of crops. After three experimental years, they found 9.2 percent higher soil organic carbon stock in no tillage as compared to conventional tillage [10]. Similarly, nutrient stratification in conservation tillage practice was also recorded by many authors. Stratified nutrients especially in 0-15 cm surface soil may be attributed to steady supply of nutrients to crops throughout growing period which enhanced better crop growth and yield parameters as compared to conventional tillage practices.

### Output energy

The total output energy was recorded significantly due to conservation tillage and crop management practices in 2014, 2015 and pooled analysis. Minimum tillage with BBF or no tillage with residue retention on the surface recorded significantly higher output energy (1,52,364 and 1,43,838 MJ $ha^{-1}$, respectively) as compared to conventional tillage (1,20,751 MJ $ha^{-1}$), followed by minimum tillage with incorporation of all crop residues (1,29,673) [Table-2]. Among the crop management practices, recommended package of practices + brown manuring of sunnhemp ($CM_1$), integrated nutrient and pest management + brown manuring of sunnhemp ($CM_2$) and organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) noticed 9.60 to 17.91 percent higher output energy as compared to inorganic nutrient and pest management (1,22,152 MJ $ha^{-1}$) [Table-2]. Interaction effect of minimum tillage with BBF with residue retention on the surface and RPP + brown manuring of sunnhemp recorded 6.58 to 36.25 percent higher output energy as compared to rest of the treatments. This might be due to higher yield was recorded under conservation tillage as compared to conventional tillage.

### Energy use efficiency

The energy use efficiency was recorded significantly due to conservation tillage and crop management practices in 2014, 2015 and pooled analysis. Minimum tillage with BBF or no tillage with residue retention on the surface recorded significantly higher energy use efficiency (CT1), no tillage with flat bed with residue retention on the surface (CT2) and minimum tillage with incorporation of all crop residues (CT3) recorded 21.85 to 40.08 percent higher energy use efficiency as compared to conventional tillage (6.01) [Table-3]. Among the crop management practices, integrated nutrient and pest management + brown manuring of sunnhemp ($CM_2$) and organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) noticed 11.09 to 20.74 percent higher energy use efficiency as compared to inorganic nutrient and pest management [Table-3]. Interaction effect of minimum tillage with BBF with residue retention on the surface and organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ recorded 5.42 to 53.39 percent higher energy use efficiency as compared to rest of the treatments [Table-3]. However, it was found on par with minimum tillage with BBF with residue retention on the surface plus integrated nutrient and pest management + brown manuring of sunnhemp (11.03) and no tillage with flat bed with residue retention on the surface plus organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ (10.76) [Table-3]. This may be because of lesser inputs used at conservation tillage as compared to conventional tillage.

### Energy productivity

Minimum tillage with BBF or no tillage with residue retention on the surface recorded significantly higher energy productivity (0.689 and 0.667 kg $MJ^{-1}$) as compared to conventional tillage (0.413 kg $MJ^{-1}$) [Table-3]. This could be attributed to lesser energy (operation time, manual labour and fuel) requirement under zero tillage than conventional tillage. It is congruous to the findings of [11]. Among the crop management practices, organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) noticed significantly higher energy productivity (0.629) as compared to rest of the treatments. But it was found on par with integrated nutrient and pest management + brown manuring of sunnhemp ($CM_2$) (0.619) [Table-3]. Interaction effect of minimum tillage with BBF with residue retention on the surface plus organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ recorded 5.40 to 53.36 percent higher energy productivity as compared to rest of the treatments. However, it was found on par with $CT1CM_2$ (0.757) and $CT2CM_3$ (0.739) [Table-3]. Higher energy output in conservation tillage systems is mainly due to maximum energy produced with lower energy expenditure by saving energy in tillage practices and burning of fossil fuels as well as reducing weeding operations than conventional tillage practices [12]. Tillage before planting which require about one third of the total operational energy could be saved without affecting the crop yields [13].

### Net energy

On pooled analysis, minimum tillage with BBF or no tillage with residue retention on the surface recorded significantly higher net energy (1,37,039 and 1,28,945 MJ $ha^{-1}$) as compared to conventional tillage (1,00,583 MJ $ha^{-1}$), followed by minimum tillage with incorporation of all crop residues (1,12,761 MJ $ha^{-1}$) [Table-3]. Among the crop management practices, recommended package of practices + brown manuring of sunnhemp ($CM_1$), integrated nutrient and pest management + brown manuring of sunnhemp ($CM_2$) and organics (FYM 50 % +VC 50 %) equivalent 100 % RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ ($CM_3$) noticed 12.55 to 19.27 percent higher net energy as compared to inorganic nutrient and pest management (1,04,892 MJ $ha^{-1}$) [Table-3].

Interaction effect of minimum tillage with BBF with residue retention on the surface and RPP + brown manuring of sunnhemp noticed 4.74 to 42.37 percent higher net energy as compared to rest of the treatments [Table-3]. This might be due to higher yield was recorded under conservation tillage as compared to conventional tillage.

**Conclusion**

The experiment was undertaken with the aim to find the influence of conservation tillage on energy saving in rice-blackgram system with minimum tillage with BBF or no tillage with flat bed with crop residue retention on surface plus recommended package of practices + brown manuring of sunnhemp or organics (FYM 50 % + VC 50 %) equivalent 100 percent RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ or integrated nutrient and pest management + brown manuring of sunnhemp for sustainable and eco-friendly agriculture. On the basis of two years field study it may be safely concluded that the minimum tillage with BBF or no tillage with flat bed with crop residue retention on surface plus recommended package of practices + brown manuring of sunnhemp recorded higher energy output, energy use-efficiency energy productivity and net energy than conventional tillage plus inorganic nutrient and pest management. Conservation tillage practices increasing energy use efficiency and energy productivity from 5.42 to 53.39 percent over conventional tillage. Recommended package of practices + brown manuring of sunnhemp or organics (FYM 50 % +VC 50 %) equivalent 100 percent RDN and biological pest management + green leaf manuring (Gliricidia) @ 5 t $ha^{-1}$ or integrated nutrient and pest management + brown manuring of sunnhemp increased energy use efficiency and energy productivity from 11.09 to 20.74 percent as compared to inorganic nutrient and pest management.

**Application of research:** The research highlights are useful to apply it by the farmers where, rice-blackgram cropping system will be cultivated under conservation agriculture technologies in hilly zone of Karnataka.

**Research Category:** Agronomy.

**Abbreviations:** ha- hectare, cm- centimetre, kg- kilograms, DMRT- Duncan's multiple range test, SEm- Standard error mean.

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**Study area / Sample Collection:** ARS, Mundagod Farm, UAS, Dharwad

**Cultivar / Variety / Breed name:** Rice- Rashi and Blackgram- DU-1.

**Conflict of Interest:** None declared

**Ethical approval:** This article does not contain any studies with human participants or animals performed by any of the authors.
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