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Energetics and profitability of peanut (*Arachis hypogaea*)-based cropping systems as influenced with conservation agricultural practices

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ABSTRACT

Increasing energy use efficiency and reducing greenhouse gases (GHGs) emissions from agriculture are major challenges to achieve sustainable development goals (SDGs). An experiment, comprising 14 treatments, viz. sole peanut (*Arachis hypogaea* L.), peanut-fallow-sesbania, peanut-fallow-green gram (GG), peanut-conventional tilled wheat (CTW), peanut-CTW-sesbania, peanut-CTW-GG, peanut-CTW-wheat straw incorporation (WSI), peanut-zero tilled wheat (ZTW), peanut-ZTW-sesbania, peanut-ZTW-GG, peanut-ZTW-WSI, peanut+pigeonpea, peanut+pigeonpea-sesbania and peanut+pigeonpea-GG was laid out in randomized block design with three replications for five consecutive years (2011–12 to 2015–16) at Junagadh, Gujarat, at fixed site to study the influence of conservation agricultural practices on energetics and profitability of peanut-based cropping systems. Green manuring with sesbania significantly improved the pod yield of peanut (12.8%) and seed yield of pigeonpea (8.9%). Zero tillage (ZT) improved wheat yield by 4.8% over Conventional tillage (CT). The energy requirement of peanut+pigeonpea intercropping was 16.7% lower than peanut–wheat cropping system irrespective of GM and WSI. Peanut–ZT wheat with sesbania green manure recorded highest energy output (251.2×10^3 MJ/ha) and net energy (201.0×10^3 MJ/ha). This cropping system also fetched the highest system productivity (4551 kg/ha), and system profitability (₹ 125.7×10^3/ha) followed by peanut–ZT wheat (INR 120.6/ha $\times 10^3$/ha). Therefore, peanut–ZT wheat–green manuring (sesbania/greengram) cropping system was found as productive, economical and energy efficient which might be promoted to intensify the sole peanut cropping in Saurashtra region of Gujarat.

Keywords: Energetics, Green manuring, Profitability, System productivity, Zero-tillage

Energy is an important and valuable input used in various forms, viz. mechanical, chemical, seeds and electrical, for agriculture production systems (Singh and Ahlawat 2015). Most of the farming practices rely upon energy derived from burning of fossil fuels which is the source of greenhouse gases (GHGs) emission to environment (Ashoka *et al*. 2017). The rising cost of fossil fuels has emphasized to conserve energy particularly in the country like India, which is facing energy crisis caused by fuel shortage and continuous rising prices of diesel.

Globally, peanut (*Arachis hypogaea* L.) is the fourth most important source of edible oil and third most important source of protein (Anonymous 2015). Due to uprooting of peanut, soil gets loosened but still the farmers ploughed field 2-3 times to cultivate succeeding *rabi* crops under irrigated conditions that increases the cost of cultivation. To reduce variable cost of cultivation, conservation agriculture (CA) systems, viz. crop residue retention at the surface, adopting zero tillage, and use of green manure crops in rotations have gained importance in the recent years as field preparation and crop establishment utilizes about 25–30% of total energy (Prashanth 2013, Choudhary *et al*. 2017). In irrigated areas, cultivation of wheat (*Triticum aestivum* L.) without disturbing the soil, can be an alternate to minimize cost of cultivation and obtaining at par or even higher yield under zero tillage than under conventionally grown wheat. Residue retention is an important component of conservation agriculture and is a challenge where crop straw and fodder are used for animal feed (IARI 2012). Since the other organic manures are available in very limited quantity, therefore, green manuring remains the only economical alternative. Cultivation of more than one crop in a rotation can enhance the productivity and profitability but at the same time may escalate energy inputs. Therefore, energy input-output analysis and economic auditing are indispensable for effective management and utilization of scarce resources for improved agricultural production. Since very limited information is available on effect of CA

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practices on energetics and profitability of peanut-based cropping systems in Saurashtra region of Gujarat, hence the present investigation was undertaken.

MATERIALS AND METHODS

The present field investigation was conducted for five consecutive years (2011–12 to 2015–16) at a fixed site at research farm of ICAR-Directorate of Groundnut Research, Junagadh, Gujarat (70º 26' E longitude and 21º 31' N latitude and about 60 m AMSL). The soil of the experimental site was Typic haplustepts (USDA soil classification) which is underneath by meliolitic limestone having high clay content (52–55%). The soil was alkaline in reaction (*p*H 8.12), shallow to medium in depth, medium black in colour, slightly calcareous (4–8% $CaCO_3$) and low in available nitrogen (104.2 kg/ha), medium in phosphorus (13.5 kg/ha) and potassium (289.1 kg/ha). The experiment was laid out in randomized block design with 3 replications and comprised of 14 treatment combinations [peanut (*Arachis hypogaea* L.); peanut–sesbania (*Sesbania aculeata* Willd.); peanut–green gram (*Vigna radiata* L.); peanut– conventionally-tilled wheat (*Triticum aestivum* L.) (CTW); peanut–CTW–sesbania; peanut–CTW–green gram; peanut–CTW– wheat straw incorporation (WSI); peanut–zero tilled wheat (ZTW); peanut–ZTW–sesbania; peanut–ZTW–greengram; peanut–ZTW–WSI; peanut+pigeonpea; peanut+pigeonpea-sesbania and peanut+pigeonpea–greengram].

All the treatment were applied to peanut-based cropping systems in the first cycle of present experimentation (2011-12), hence, the findings are being discussed based on effect of treatments on rest four years of experimentation i.e. 2012–13 to 2015–16. Before execution of treatments, experimental field was prepared by cultivator followed by harrowing and planking during *kharif* (second fortnight of June) 2011–12. Plot size was 5.0 m × 6.3 m having 21 rows of peanut across 5.0 m length. In peanut+pigeonpea intercropping system (3:1), after every 3rd row of peanut, a row of pigeonpea variety BDN 2 was sown. Wheat was sown during *rabi* in the same field after harvesting of peanut with seed cum fertilizer drill and zero till drill as per treatment (Table 1). Wheat straw was incorporated in the plots as per treatment after harvesting of the crop followed by irrigation for easy decomposition. The green manuring crops, viz. sesbania and greengram were sown as per treatments after pre-sowing irrigation. These green manure crops were ploughed down *in situ* at 45–50 DAS using disc plough. All the crops in rotation were cultivated as per recommended agronomic practices (Table 1).

Table 1 Standard agronomic operations performed in different crops during experimentation.

Operation	Crops				
	Peanut	Pigeonpea	Wheat	Sesbania	Greengram
Sowing time	Second fortnight of June to first week of July	Second fortnight of June to first week of July	Second fortnight of November	First to second week of March	First to second week of March
Seed rate spacing	100 kg/ha 30 cm × 10 cm	7.5 kg/ha (As intercrop) 120 cm × 10 cm	100 kg/ha 22.5 cm	50 kg/ha 20 cm ×5 cm	40 kg/ha 20 cm × 5 cm
Variety	TG 37A	BDN 2	GW 366	Local	GM 1
Fertilizer dose	25 kg N, 22 kg P and 24.9 kg K/ha (Sole crop) In intercropping, on the basis of number of rows in each plots	10 kg N, 11 kg P and 12.5 kg K/ha (In intercropping)	100 kg N, 22 kg P and 24.9 kg K/ha (half N at sowing and half in two splits at 20 and 40 DAS)	20 kg N, 17.6 kg P and 24.9 kg K/ha	20 kg N, 17.6 kg P and 24.9 kg/ ha
Source of fertilizers	Urea, Single super phosphate (SSP) and muriate of potash (MOP)	Urea, SSP and MOP	Urea, SSP and MOP	Urea, SSP and MOP	Urea, SP and MOP
Irrigation management	Depending upon the rainfall as per requirement	Depending upon the rainfall as per requirement	20, 40, 60, 80 and 100 days after sowing	12-15 days interval	12-15 days interval
Weed management	Pendimethalin @ 1.0 kg a.i./ha or Oxyfluorfen @ 0.24 kg a.i./ha as pre-emergence	Pendimethalin @ 1.0 kg a a.i./ha as pre-emergence	2,4-D (ester) @ 0.5 kg a.i./ ha as post-emergence	Nil	Nil
Plant protection measures	As per need	As per need	As per need	Nil	Nil
Harvesting	First/second fortnight of October	Second fortnight of November to First week of March	Second fortnight of February to First Fortnight of March	*In situ* ploughed down at 45-50 days after sowing	*In situ* ploughed down at 45-50 days after sowing

The productivity of different cropping systems was computed by converting economic yield of pigeonpea and wheat into peanut pod yield based on the prevailing market/minimum support price, and expressed in terms of peanut-pod equivalent yield (PPEY) or system productivity.

Economic analysis was done based on the prevailing cost of inputs/operations and price of the produce. Gross returns were worked out based on the prices of main produce (pod/grain/seed) and by-product (haulm/straw/stalk) of the crops. Net returns and benefit cost ratio were estimated by the standard formulae. Energy budgeting was estimated based on the energy inputs under different operations/management and bio-energy output from all the cropping systems. All the inputs used in the form of machinery, labour, seed, fertilizer, irrigation, herbicides and pesticides in all cropping systems were taken into consideration using energy equivalents given by Mittal *et al*. (1985), Chaudhary *et al*. (2006) and Khosruzzaman *et al*. (2010). Different energy indices were calculated by using the standard formulae.

Experimental data were statistically analysed online on Indian NARS Statistical Computing Portal (http://stat.iasri.res.in/sscnarsportal) using General Linear Model (GLM) procedure in SAS (SAS Institute Inc.). For significant parameters, separation of treatment means and ranking of treatments was done using the Tukey's Honest Significant Difference at P=0.05.

RESULTS AND DISCUSSION

System productivity: System productivity, expressed in terms of peanut-pod equivalent yield, differed significantly among sole peanut, peanut–wheat and peanut+pigeonpea cropping systems. Peanut–ZTW–sesbania, at par to other peanut–CTW/ZTW cropping systems with or without green manuring and WSI, produced significantly higher system productivity (PPEY, 4551 kg/ha) over sole peanut and peanut+pigeonpea intercropping systems (Fig 1). The peanut followed by zero tilled wheat and sesbania cropping systems improved system productivity by 75.0% compared to sole peanut. This might be due to improvement in peanut and wheat yield under ZT and green manuring plot (data not reported) as a result of improved soil properties with conservation agriculture and green manuring. Data also showed that among the green manure crops, sesbania was found better in improving system productivity by 3.6% compared to green gram. Pooniya and Shivay (2011) also reported significantly higher system productivity of basmati rice-wheat cropping system with the incorporation of *Sesbania aculeata* before transplanting of basmati rice and was at par with use of cowpea as green manure crop. Similarly, CA-based management in zero-till direct seeded rice-wheat-mungbean also produced significantly higher system productivity (wheat equivalent yield) to the tune of 36% over conventional till rice-wheat system (Jat *et al.* 2019). Jain *et al.* (2018) also obtained higher peanut-pod equivalent yield due to conservation agriculture practices.

Profitability: The peanut–ZTW–sesbania cropping system fetched maximum net returns (₹ 125.7 × 10^3/ha) which was significantly higher over sole peanut, peanut- sesbania/green gram, peanut+pigeonpea and peanut+pigeonpea- sesbania/green gram cropping systems and was closely followed by peanut–ZTW (INR 120.6 × 10^3/ha) (Table 2). This clearly indicated that adoption of zero tillage reduced the cost of cultivation and increased yield and thereby enhanced the net returns (Dixit *et al*. 2019). Compared to conventional system (US$ 2570/ha), Jat *et al*. (2019) also obtained 42% higher net return with CA-based rice–wheat–mungbean system. Similarly, Das *et al*. (2020) obtained higher net returns in rice-pea cropping system under minimum tillage (MT)-no tillage (NT) compared to those under NT-NT and CT (conventional tillage)-NT systems. However, benefit: cost was significantly higher under peanut+pigeonpea (2.61) over sole peanut, peanut-sesbania/greengram, peanut–CTW–sesbania/greengram and peanut+pigeonpea–greengram. This may be mainly due to cultivation of two crops in a single season without any extra cost involved in raising second crop.

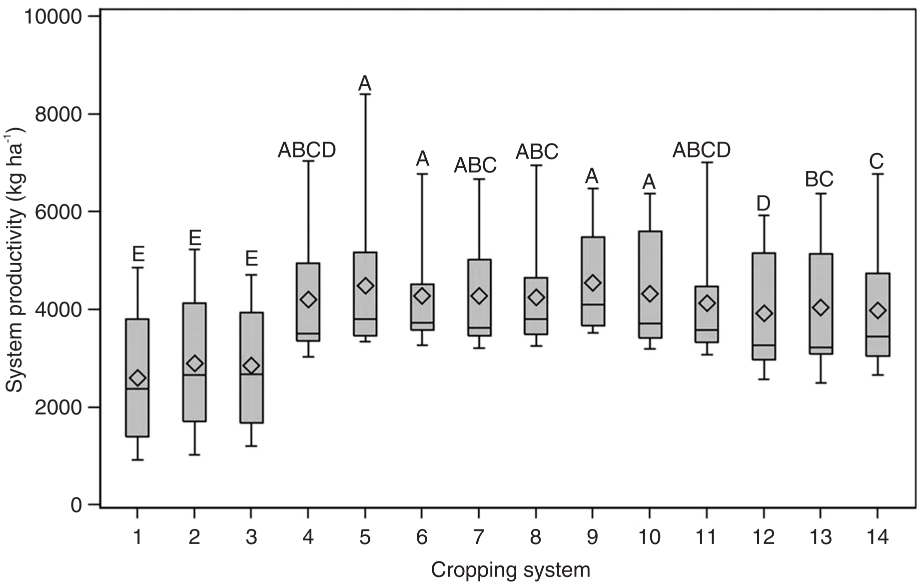

Fig 1 System productivity (Peanut-pod equivalent yield) of peanut–based cropping systems influenced with cropping systems, tillage and green manures (pooled mean of 4 years). Horizontal lines in the box show the median, the box provides the total variation for the 1st and 3rd quartile, lower and upper whiskers have minimum and maximum values, and squares in the box plot indicate the mean value. Boxplots having different letter are significantly different from each other using Tukey's Honest Significant Difference Test at P≤0.05.

Energy requirement: Energy

Table 2 Effect tillage and green manuring practices on economics and energetics of peanut–based cropping systems (mean data of 4 years)

Treatment	Net returns (× 10^3 ₹/ha)	Benefit : cost	Item-wise energy consumption (MJ/ha)					Input energy (×10^3 MJ/ha)	Output energy (× 10^3 MJ/ha)	Energy use efficiency	Net energy (× 10^3 MJ /ha)	Energy productivity (g/ha)	Specific energy* (MJ/kg)	Energy intensity (MJ/kg)	Energy intensity (MJ/INR)	Energy output efficiency (MJ/ha/day)
			Field operations	Seed	Chemical/fertilizer	Irrigation	Labour									
Sole peanut	$71.3^{D\#}$	$2.45^{DE\#}$	4191	2600	2899	4122	1498	15.3^{N}	117.3^{E}	7.66^{A}	102.0^{C}	359.6^{A}	5.90^{G}	21.3^{B}	2.47^{F}	1073.7^{A}
Peanut–sesbania	76.7^{D}	2.34^{E}	7911	3335	4762	8246	1801	26.1^{L}	133.9^{D}	5.14^{EF}	107.8^{C}	234.6^{H}	9.00^{EF}	21.9^{A}	2.40^{F}	853.9^{CDE}
Peanut–GG	75.6^{D}	2.33^{E}	7911	3188	4762	8246	1801	25.9^{M}	131.3^{DE}	5.07^{F}	105.4^{C}	231.7^{H}	9.11^{EF}	21.9^{A}	2.37^{F}	837.8^{DEF}
Peanut–CTW	114.0^{ABC}	2.41^{ABCDE}	7615	4070	10099	16491	2866	41.1^{I}	240.8^{A}	5.85^{CD}	199.6^{A}	304.3^{BC}	9.79^{CDEF}	19.2^{CD}	2.98^{BCDE}	1134.4^{A}
Peanut–CTW–sesbania	117.4^{ABC}	2.33^{CDE}	11335	4805	11962	20615	3168	51.9^{A}	248.1^{A}	4.78^{F}	196.2^{A}	245.2^{GH}	11.61^{AB}	19.5^{C}	2.81^{DE}	950.7^{B}
Peanut–CTW–GG	110.2^{ABC}	2.25^{CDE}	11335	4658	11962	20615	3168	51.7^{B}	243.6^{A}	4.71^{F}	191.9^{AB}	243.7^{GH}	12.13^{A}	19.3^{CD}	2.77^{E}	933.5^{B}
Peanut–CTW–WSI	116.0^{ABC}	2.40^{ABCDE}	8212	4070	10099	18553	2964	43.9^{E}	243.4^{A}	5.55^{DE}	199.5^{A}	288.8^{CDE}	10.24^{BCDE}	19.2^{CD}	2.96^{BCDE}	1083.1^{A}
Peanut–ZTW	120.6^{AB}	2.57^{AB}	5938	4070	10099	16492	2853	39.5^{J}	238.7^{AB}	6.05^{C}	199.2^{A}	316.3^{B}	9.30^{DEF}	19.1^{D}	3.12^{AB}	1124.6^{A}
Peanut–ZTW–sesbania	125.7^{A}	2.49^{ABC}	9658	4805	11962	20615	3156	50.2^{C}	251.2^{A}	5.00^{F}	201.0^{A}	258.8^{FG}	11.03^{ABC}	19.3^{CD}	2.99^{BCD}	962.3^{B}
Peanut–ZTW–GG	116.1^{ABC}	2.38^{ABCDE}	9658	4658	11962	20615	3156	50.0^{D}	239.8^{AB}	4.79^{F}	189.7^{AB}	247.0^{GH}	11.61^{AB}	19.4^{CD}	2.86^{CDE}	918.6^{BC}
Peanut–ZTW–WSI	113.7^{ABC}	2.45^{ABCD}	6523	4070	10099	18554	2962	42.2^{H}	239.3^{AB}	5.67^{CD}	197.1^{A}	295.6^{BCD}	10.27^{BCDE}	19.2^{D}	3.06^{ABC}	1064.9^{A}
Peanut + pigeonpea	108.7^{BC}	2.61^{A}	4073	2086	3458	20615	2703	32.9^{K}	218.4^{C}	6.63^{B}	185.5^{AB}	359.8^{A}	8.42^{F}	18.4^{E}	3.27^{A}	912.9^{BCD}
Peanut + pigeonpea–sesbania	104.7^{C}	2.38^{ABCDE}	7793	2821	5321	24738	3006	43.7^{F}	224.0^{BC}	5.13^{EF}	180.3^{B}	275.6^{DEF}	10.84^{ABCD}	18.6^{E}	2.98^{BCDE}	781.2^{EF}
Peanut + pigeonpea–GG	102.5^{C}	2.36^{BCDE}	7793	2674	5321	24738	3006	43.5^{G}	219.7^{C}	5.05^{F}	176.1^{B}	316.3^{B}	10.98^{ABC}	18.7^{E}	190.7^{AB}	766.0^{F}

GG, Greengram; CTW, conventionally tilled wheat; WSI, wheat straw incorporation; ZTW, zero tilled wheat. #Means within the same column followed by superscripted different uppercase letter(s) are statistically different using Tukey's Honest Significant Difference Test at $P \le 0.05$. *Calculated on the basis of System productivity (Peanut-pod equivalent yield.

use pattern in different peanut–based cropping systems was computed for different farm inputs/resources (Table 2 and Fig 2). Across the cropping systems, irrigation (in the form of electricity consumption) accounted for maximum energy inputs (26.9–62.6%) followed by field operations in the form of diesel (12.4–30.5%) and chemical/fertilizers (10.5–25.6%) (Fig 2). The total energy requirement varied from 15.3 × 10^3 MJ/ha in sole peanut to 51.9 × 10^3 MJ/ha in peanut–CTW–sesbania cropping systems. This might be ascribed to utilization of more energy in raising of three crops in rotation using conventional tillage. Singh *et al*. (2008) also documented higher energy input in CT soybean-wheat cropping system as compared to zero or minimum tillage. Therefore, sustainable crop intensification should be followed considering the energy requirements of crops and farm activities (Tuti *et al*. 2012). Green manuring with sesbania and green gram increased the renewable energy input by 41.23 and 40.91%, respectively. Choudhary *et al*. (2017) and Parihar *et al.* (2017) also reported use of higher renewable energy through crop residue. Skipping the tillage operation for growing next crop (wheat) helped in reducing the non-renewable energy requirement in peanut–ZTW cropping system by 1.68 × 10^3 MJ/ha than peanut–CTW. Reduction in the operations for tillage and labour for weeding etc. are responsible for lower energy requirement under zero-tilled wheat over conventional tillage. Many previous workers also indicated higher energy saving due to no-till in agricultural production systems over CT (Singh *et al.* 2016, Dixit *et al*. 2019, Das *et al.* 2020). Further, irrespective of green manure and WSI, the energy requirement of peanut+pigeonpea intercropping system was 16.7% lower than peanut–wheat cropping system owing to lower requirement of fertilizers in legume crops, reduced number of field operations as crops grown together and lesser requirement of seed and labour.

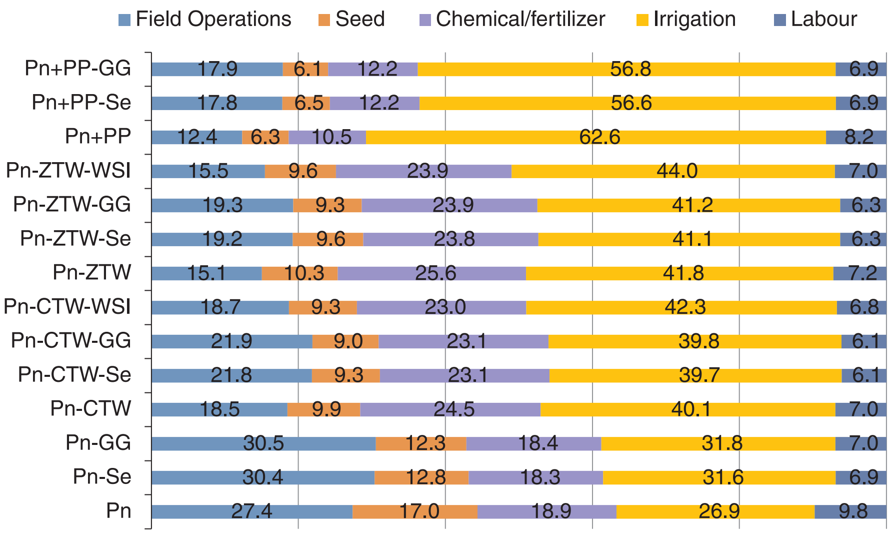

Fig 2 Energy utilization pattern (%) of different peanut–based cropping systems (pooled mean of 4 years). Pn, sole peanut; PP, pigeonpea; GG, green gram; Se, sesbania; CTW, conventionally tilled wheat; ZTW, zero tilled wheat; WSI, wheat straw incorporation.

Energetics: Energy output in terms of bio-energy equivalents was maximum in peanut–ZTW–sesbania (251.2 × 10^3 MJ/ha) and was closely followed by peanut–CTW–sesbania (248.1 × 10^3 MJ/ha) cropping system (Table 2). This may be ascribed to higher yields in these cropping system compared to other cropping systems. Further, peanut–ZTW–sesbania cropping system also recorded higher net energy (201.0 × 10^3 MJ/ha) owing to more output energy. However, sole peanut registered maximum energy use efficiency (7.66) and energy productivity (359.6 g/MJ) due to growing of a single crop in rotation and least energy input compared to other cropping systems. For assessing the energy input and combinations of energy efficient crops in a sequence, net energy and energy efficiency are main energy parameters which should be used for planning and designing of cropping systems (Yadav *et al*. 2005). As compared to other cropping systems, peanut–CTW–green gram cropping system registered maximum value of specific energy (12.13 MJ/kg) while the lowest value (5.90 MJ/kg) was in sole peanut. In physical terms, as compared to other systems, the energy intensity was higher under peanut–sesbania/green gram cropping systems (21.9 MJ/kg) whereas, in economic terms, it was found higher in peanut+pigeonpea system (3.27 MJ/INR). The energy output efficiency was maximum under peanut–CTW cropping system (1134.4 MJ/ha/day) and it showed declining trend with inclusion of green manure crop in rotation, i.e. sole peanut, peanut–CTW/ZTW and peanut+pigeonpea due to increase in duration of cropping system.

On the basis of present experimentation, it could be concluded that intensification of sole peanut through inclusion of zero tilled wheat and green manuring with sesbania or green gram may be advocated to the farmers of Saurashtra region of Gujarat being productive, economical and energy efficient cropping system.

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