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Energy use analysis of food-forage based cropping system in semi-arid environment of India

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Energy input in agricultural sector is of prime concern in India today. Energy analysis, therefore, is necessary for efficient management of scarce resources for improved agricultural production. It would identify production practices that are economical and effective. Other benefits of energy analysis are to determine the energy invested in every step of the production process (hence identifying the steps that require least energy inputs), to provide a basis for conservation and to aid in making sound management and policy decisions (Chaudhary *et al*. 2006). Efficient cropping system with respect to biological potential along with increased efficiencies of land and water are to be evaluated for specific regions (Sunil Kumar and Faruqui 2007). Intensive forage production utilizes higher amount of inputs, energy and other resources for maximization of biomass. Presently energetic, agro-economic analysis and sustainability aspects are greatly affecting the growth and development of agriculture. Efficient cropping systems in relation with energy budgeting for effective utilization of resources have relevance in both local and national context. Food-forage system analysis on productivity, profitability and sustainability terms are important because of emerging importance of livestock sector for fulfilling the food and fodder requirement. Keeping these facts in view the present investigation was carried out.

The field experiment was carried out at the Central Research Farm (located at 25° 27^{I} N, 78° 37^{I} E, 275 m above mean sea level) of the Indian Grassland and Fodder Research Institute, Jhansi during the year 2002–2007. The site is characterized as semi-arid subtropical climate with hot summers and cold winters. The mean annual rainfall of the site was about 910 mm and potential evapo-transpiration was 1600 mm. The soil of the experimental site was sandy loam, low in organic carbon (0.41 and 0.45 %), available nitrogen (173 and 193 kg/ ha) and phosphorous (11.3 and 13.8 kg/ ha) and medium in available potassium (265 and 272 kg/ ha) in the start and at the end of experiment, respectively. The experiment was conducted in a randomized block design with four replications to estimate the input and output energy use and biomass production over five years for food – forage based sequence. The treatments consisted of six crop sequences, viz. groundnut (*Arachis hypogaea* L.) – wheat (*Triticum aestivum* L.) – greengram (*Vigna radiata* L.), sorghum (*Sorghum bicolor* (L.) Moench) (multi-cut)-berseem (*Trifolium alexendrinum*), sorghum (single cut)-wheat – greengram, groundnut – berseem-maize (*Zea mays* L.) (fodder) + cowpea [*Vigna unguiculata* (L.) Walp] (fodder), groundnut – wheat - maize (fodder) + cowpea (fodder) and NB hybrid + (cowpea – berseem). The site of experimental field was fixed during all the experimental years. The crops were raised with standard package of practices adopted for the region. The gross plot size of experiment was 10 m × 5 m for all 24 plots. The net area of the experimental field on net plot basis was 0.1026 ha. All plots were harrowed twice and tilled once with cultivator followed by leveling and bund making. Preparatory tillage operation to perennial system Napier bajra hybrid spaced at 1m × 1m row to row was given in establishment year only.

Measurement of energy use was done for manual, mechanical and other inputs with standard procedures (Umar 2003).The total manual labours recorded in each operation with working hours were converted in man – hours. Manual energy (Em) was determined with following equation:

$$EM = 1.96\ Nm\ Tm\ MJ$$

where, Nm-Number of labour spent on a farm activity; Tm-Useful time spent by a labour on a farm activity, (h).

Mechanical energy use was determined by the quantification of diesel utilized during various agricultural operations like primary tillage, sowing, threshing and post harvest operation.

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Table 1 Energy equivalent for different inputs and outputs

Particular	Units	Equivalent energy (MJ)
Input Human labour		
Adult man	Man hour	1.96
Adult woman	Woman hour	1.57
Animals : Bullock (medium)	Pair – hour	10.10
Diesel	Litre	56.31
Electricity	Kwh	11.93
Farmyard manure	Kg (dry mass)	0.3
Chemical fertilizers		
Nitrogen (N)	Kg	60.60
Phosphorous (P_2O_5)	Kg	11.1
Potash (K_2O)	Kg	6.7
Output		
Main product		
Wheat	Kg (dry mass)	14.7
Green gram	Kg (dry mass)	14.7
Groundnut	Kg (dry mass)	25.0
Fodder crops (sorghum, maize, cowpea, NB hybrid, berseem, oats)	Kg (dry mass)	18.0
By product		
Straw	Kg (dry mass)	12.5

Ef = 56.31 DMJ

where, 56.31= Unit energy, value of diesel, MJ/L; D = Amount of diesel consumed, L.

The different field operations performed for completion of each activity in the experiment was measured in terms of time taken for human, machinery and fuel consumption and expressed as energy input in mega joules (MJ) using corresponding conversion factors presented in Table 1. The inputs used for different operations in various crop sequences and outputs obtained in terms of yield were used for quantification of energy use of food – forage based system. Energy relationship for operational and non operational components was also worked out. Cut wise yield data of multi-cut forage crops was pooled to get total biomass yield. The farm production was assessed in terms of forage equivalent yield (tonnes/ha), energy output (MJ) and energy productivity (q/MJ). The data were statistically analyzed in a randomized block design.

Energy analysis of food-forage system (Table 2) indicated that groundnut based food–forage production system was highly efficient. The energy ratio (17.5) was highest with (groundnut – wheat- maize (fodder) + cowpea (fodder). Forage based system (sorghum (multi-cut) - berseem) was second highest in terms of energy ratio (14.8). Energy efficiency was least (9.2) with NB hybrid + berseem which may be attributed to higher energy input as compared to output. Energy output was highest (57220 MJ) with groundnut- berseem - maize (fodder) + cowpea (fodder) closely followed by groundnut-wheat-maize (fodder) + cowpea (fodder). The magnitude of increase of best treatment in this regard was 57.7 and 51.2 percent over sorghum (single cut) – wheat-green-gram and groundnut – wheat – greengram, respectively. Energy output was in the order of groundnut – berseem- maize (fodder) + cowpea (fodder)> groundnut – wheat - maize (fodder) + cowpea (fodder) > sorghum (multi-cut) - berseem > groundnut – wheat – green-gram > NB hybrid + (cowpea – berseem) > sorghum (single cut)- wheat – green gram. Enhancement in energy output is mainly attributed to higher forage equivalent yield of food-forage crops in each sequence. At this location, sorghum (single cut) did not perform well as compared to other crops like sorghum (multi-cut) and groundnut. The succeeding crops (wheat) yield was also poor due to less winter period. This resulted into lesser energy output of most adopted sequence (groundnut- wheat - greengram). The summer crop of greengram also showed higher input than output energy. This is clearly visible that the crop sequence with green-gram during summer used more energy input and produced less output energy. Groundnut – wheat - maize (fodder) +

Table 2 Energy relationship in food- forage based cropping system (Mean of 5 years)

Crop sequence	Forage equivalent yield on dry matter basis (q/ha /year)	Energy input (MJ/ ha)		Total	Energy output (MJ/ha)	Energy ratio	Energy Prodictivity (1/MJ)	Energy coefficient (MJ/ha)
		Operational	Non-operational					
Groundnut – wheat – greengram	210.35	19623	17420	35643	378540	10.6	169.56	35643
Sorghum (multi-cut) – berseem	262.89	14868	19638	32032	473040	14.8	121.93	32032
Sorghum (single cut) – wheat – greengram	201.60	19123	16058	35181	362880	10.3	174.55	35181
Groundnut - berseem – maize (fodder) + cowpea (fodder)	317.90	14519	18237	32756	572220	17.5	103.00	32756
Groundnut - wheat – maize (fodder) + cowpea (fodder)	285.45	21567	18225	39792	513720	12.9	139.47	39792
NB hybrid (perennial) + (cowpea – berseem)	209.77	24222	16856	41078	377460	9.2	195.92	41078
CD(P = 0.05)	7.40							

cowpea (fodder) sequence realized 35.7% higher energy output than food-forage based groundnut – wheat – greengram. The corresponding figure for sorghum (single-cut) – wheat – greengram was 41.6%. The trend of energy output may be mainly attributed to proportion of input to that of forage equivalent yield (FEY) on dry matter basis. The ratio of operational and non-operational was also highest with these systems. Groundnut – wheat – greengram sequence registered 35.2 and 32.0% increase in operational energy over the best treatments, i.e. groundnut –berseem - maize (fodder) + cowpea (fodder) and sorghum (multi-cut) - berseem, respectively. However, highest operational energy was recorded with NB hybrid + (cowpea – berseem) probably due to perennial and multi-cut nature of both the crops in the system. The highest performing crop sequences like groundnut – berseem - maize (fodder) + cowpea(fodder), sorghum (multi-cut)- berseem and groundnut – wheat - maize (fodder) + cowpea (fodder) used less energy for production of a unit of biomass. Lal *et al.* (2003) also reported that forage based sequence sorghum (single cut) - berseem + cowpea and sorghum (multi- cut) – berseem + oats used less energy than sorghum- wheat – fallow. Among the systems, on dry matter basis, forage equivalent yield (FEY) was highest (317.9 q/ha/year) with groundnut – berseem-maize (fodder) + cowpea(fodder) followed by groundnut – wheat - maize (fodder) + cowpea (fodder) and sorghum (multi-cut)- berseem (FEY of 285.4 and 262.8 q/ha/year, respectively). With regard to energy productivity, highest performing crop sequences like groundnut – berseem - maize (fodder) + cowpea(fodder), sorghum (multi-cut)- berseem and groundnut – wheat - maize (fodder) + cowpea (fodder) used less energy for production of a unit of biomass. Energy coefficient of different food-forage based cropping system was variable. Among the six production systems, NB hybrid + (cowpea - berseem) recorded highest energy use (41078 MJ/ha) due to perennial grass and multi-cut berseem as intercrop.

SUMMARY

Thus it is evident that food-forage based systems were more energy efficient and remunerative than food-grain based production system in semi-arid environment. The total input energy utilization was highest in NB hybrid (perennial) + (cowpea – berseem) [41078 MJ/ ha], followed by groundnut (*Arachis hypogaea* L.) – wheat (*Triticum aestivum* L.) – maize (*Zea mays* L.) (fodder) + cowpea [*Vigna unguiculata* (L.) Walp] (fodder) [39792 MJ/ ha] and groundnut – wheat – greengram (*Vigna radiata* L.) (35643 MJ/ ha). Among the systems, lowest energy use was recorded in sorghum (multi-cut) – berseem (*Trifolium alexindrinum*) crop sequence (32032 MJ/ha). Groundnut – berseem – maize (fodder) + cowpea (fodder) was highly energy efficient as evident with highest energy output (572 220 MJ/ ha) and energy ratio (17.5). Energy ratio followed the similar trend to that of energy output. Energy productivity was higher with NB hybrid (perennial) + (cowpea – berseem) [195.92 q/MJ] followed by sorghum (single cut) – wheat – greengram (174.55 q/ MJ).

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