Indian J. Agron. **40** (3) : 398–401 (September 1995)

Energetics and water-use efficiency of intensive cropping system

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Received: June 1994

ABSTRACT

A field experiment was conducted during 1986–88 at Coimbatore to study the energy and water-use efficiency of 6 selected, high-intensity cropping systems. Among the systems tested, fingermillet [*Eleusine coracana* (L.) Gaertn.] + onion (*Allium cepa* L.) – maize (*Zea mays* L.) + cowpea [*Vigna unguiculata* (L.) Walp.] – tomato (*Lycopersicon esculentum* Mill. nom. cons.) system required maximum energy input (54.7 MJ/ha). The total energy output (714.4 MJ/ha) and energy-use efficiency (18.1) were however highest in the sorghum [*Sorghum bicolor* (L.) Moench] + pigeonpea [*Cajanus cajan* (L.) Millsp.]– maize (*Zea mays* L.) + fodder maize system. The latter system also recorded the highest water-use efficiency of 240 kg dry matter/ha-cm, but the total quantity of water used was more in fingermillet + sunflower (*Helianthus annuus* L.)–upland cotton (*Gossypium hirsutum* L.) + onion–sorghum + cowpea system (1,989. 6 cm/ha/year).

Intensive agriculture involving high-intensity cropping systems requires larger amounts of energy and water. Increase in the cost of commercial energy supplies and dwindling fuel reserves necessitates development of highly productive cropping systems with better energy-use efficiency. The importance of energetics in cropping systems has been discussed in detail by Mahendra Pal *et al.* (1985). Irrigation water is a costly and scarce resource and availability of water for agriculture is expected to go down due to increased demand for domestic and industrial uses. Improving water-use efficiency is thus, of paramount importance for optimizing the benefits of irrigation. Therefore a study was conducted to evaluate the energy and water-use efficiencies of selected, high-intensity cropping systems, which are recommended for the region.

MATERIALS AND METHODS

The field experiment was conducted at Tamil Nadu Agricultural University, Coimbatore, during 1986–87 and 1987–88. The cropping systems studied were: S_1, sorghum [*Sorghum bicolor* (L.) Moench] + pigeonpea [*Cajanus cajan* (L.) Millsp.] (intercrop)–maize (*Zea mays* L.) + fodder maize (intercrop); S_2, fingermillet [*Eleusine coracana* (L.) Gaertn.] + sunflower (*Helianthus annuus* L.) (border crop)–cotton (*Gossypium hirsutum* L.) + onion (*Allium cepa* L.) (intercrop)–sorghum + cowpea [*Vigna unguiculata* (L.) Walp.] (intercrop); S_3, maize + cowpea (intercrop)–wheat (*Triticum aestivum* L. emend. Fiori & Paol.) + coriander (*Coriandrum sativum* L.) (intercrop) – sunflower; S_4, fingermillet + onion (border crop)–maize + soybean [*Glycine max* (L.) Merr.] (intercrops)–tomato (*Lycopersicon esculentum* Mill. nom. cons.); S_5, sorghum ratoon [the previous season-sown crop was ratooned to have the sorghum ratoon]–cauliflower [*Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *capitata* L.)]

Table 1. Energy equivalents for various inputs and outputs

Input	Unit	Equivalent energy (MJ)	Output	Unit	Equivalent energy (MJ)
Human-labour					
Adult man	Man-hour	1.96	Grains of sorghum, maize, fingermillet, wheat	Kg	14.70
Woman	Woman-hour	1.57	Grains of pulses, soybean	Kg	14.70
Animal labour					
Bullocks (medium)	Pair-hour	10.10	Groundnut and sunflower kernel	Kg	25.00
Petrol (including lubricants)	Litre	48.23	Cabbage and cauliflower heads, coriander leaves	Kg	1.20
Electricity	Kwh	11.93	Tomato fruit	Kg	0.83
			Onion bulb	Kg	1.60
Chemical fertilizer					
N	Kg	60.60	Cotton (*kapas*)	Kg	11.80
P_2O_5	Kg	10.10	Green fodder maize	Kg	18.00
			Straw, vines	Kg	12.50
Chemicals requiring dilution at the time of application	Kg	120.00	Vegetable stalk	Kg	10.00
Chemicals not requiring dilution	Kg	10.00	Other stalks	Kg	18.00

(during 1986–87)/cabbage [*Brassica oleracea* convar. *capitata* (L.) Alef. var. *capitata* (L.)] during 1987–88 –sorghum + cowpea (intercrop); S_6, soybean–maize + cowpea (intercrop)– groundnut (*Arachis hypogaea* L.).

The experiment was conducted in randomized block design with 4 replications adopting a gross plot size of 15.9 m x 12.6 m. High-yielding varieties recommended for the region were raised adopting the standard package of practices. As the soil was very rich in exchangeable potassium content (560 kg/ha), no potassium was applied. Detailed records were maintained regarding the different inputs such as labour (human and animal), fertilizers, plant-protection chemicals and quantity of irrigation water used and the biomass yield. The energy input and output were calculated as suggested by Mittal *et al.* (1985) and the energy equivalents used are given in Table 1. Water-use efficiency was worked out in terms of dry-matter yield (kg/cm) of water used that included the irrigation water applied and effective rainfall.

RESULTS AND DISCUSSION

The total energy input in the different cropping systems ranged from 36.5 to 58 x 10^3 MJ/ha (Table 2). Among the systems, S_4 system required higher energy input whereas S_1 the minimum. In general, irrigation accounted for a major share of energy input (40–50%) followed by fertilizer nitrogen (22–35%) and human-labour (12–18%). The energy input through animal power, seeds, fertilizer phosphorus and

Table 2. Total energy (MJ x 10^3/ha) input and output of different cropping systems (mean data of 2 years)

Cropping system	Human-labour	Animal power	Seeds	N	P_2O_5	Irri-gation	Plant-protection chemicals	Total energy input	Total energy output	Energy-use efficiency
Sorghum + pigeonpea–maize + fodder maize	5.80	0.42	1.18	13.33	1.33	16.72	0.67	39.51	714.35	18.10
Fingermillet + sunflower–cotton + onion–sorghum + cowpea	8.98	0.43	0.69	13.33	1.33	24.90	1.72	51.39	512.86	9.99
Maize + cowpea–wheat + coriander–sunflower	6.63	0.52	2.80	16.11	2.05	21.86	0.45	50.43	388.44	7.72
Fingermillet + onion–maize + soybean–tomato	7.73	0.43	0.53	17.78	2.33	24.40	1.50	54.68	387.29	7.09
Sorghum (ratoon)–cauliflower/cabbage–sorghum + cowpea	6.09	0.33	0.31	17.50	1.75	22.36	1.42	49.76	361.28	7.27
Soybean–maize + cowpea–groundnut	6.39	0.43	3.73	9.44	1.61	22.36	1.27	45.24	318.49	7.04

Table 3. Biomass production, amount of water used and water-use efficiency of cropping systems

Cropping system	Biomass production (tonnes/ha)	Total quantity of water used (cm)	Water-use efficiency (kg dry matter/ha-cm)
Sorghum + pigeonpea–maize + fodder maize	36.28	151.0	240.1
Fingermillet + sunflower–cotton + onion–sorghum + cowpea	33.01	189.6	174.3
Maize + cowpea–wheat + coriander–sunflower	24.35	167.8	145.1
Fingermillet + onion–maize + soybean–tomato	27.49	181.2	151.2
Sorghum (ratoon)–cauliflower/cabbage–sorghum + cowpea	24.61	173.6	142.0
Soybean–maize + cowpea–groundnut	20.26	177.6	114.2
CD (P = 0.05)	0.84		4.8

Mean of 2 years

plant-protection chemicals was of lower magnitude and together accounted for only 10–15%. The total energy input for S_1 system was the lowest, mainly because of the lower amount of irrigation water used. Different cropping systems consumed varied quantities of irrigation water (Table 3) and the total water requirement was maximum with S_2 system and minimum in S_1 system. The S_4 needed maximum amount of energy input through fertilizer nitrogen. The energy input through human labour, irrigation and plant-protection chemicals was the highest in S_2 system. The total energy output was the highest in S_1 system, followed by S_2 and it was the lowest in S_6 system. The S_1 system produced the maximum biomass and thereby recorded the highest energy output. This, coupled with the lowest energy input requirement helped the system to achieve higher energy-use efficiency compared with the other systems.

Among the different cropping systems, the S_4 system used more water. The S_1 system which included 2 highly-efficient C_4 crops (sorghum and maize) besides a very high population of fodder maize as an intercrop in grain maize recorded the highest biomass yield, followed by S_2 system. The S_1 system which produced dry matter 240.1 kg/ha/cm water also recorded the highest water-use efficiency.

The study revealed that among the 6 high-intensity cropping systems tried, sorghum + pigeonpea–maize + fodder maize system used the lowest amount of energy input and irrigation water. In addition, it recorded the maximum energy-use efficiency and water-use efficiency. Considering the lowest input requirement with better labour, water and energy-use efficiencies, sorghum + pigeonpea–maize + fodder maize system appears more promising than the other system.

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