Indian Journal of Agronomy **49** (2) : 89–93 (June 2004)

Crop water productivity of crop sequences involving rice (*Oryza sativa*), jute (*Corchorus* species) and vegetables in deep and shallow tube-well commands of lower Gangetic plains region

S.B. GOSWAMI

All-India Co-ordinated Research Project on Water Management, Bidhan Chandra Krishi Viswavidyalaya, Gayespur, Nadia, West Bengal 741 234

Received : October 2003

ABSTRACT

Eight rice (*Oryza sativa* L.)-based crop sequences were evaluated during 1999–2000 and 2000–2001 for their land and water productivity in tube-well commands of Lower Gangetic Plains Region. On rice-equivalent yield basis autumn rice–cabbage (*Brassica oleracea* L. convar. *capitata* (L.) Alef. var. *capitata*]–summer rice (24.6 tonnes/ha) or cauliflower [*B. oleracea* convar. *botrytis* (L.) Alef. var. *botrytis* L.]–pointed gourd (*Trichosanthes dioca* Rox b.)(23.4 tonnes/ha) crop sequences recorded significantly higher land productivity (LP) than other crop sequences like winter rice–wheat (*Triticum aestivum* L. emend. Fiori & Paol.)–jute (*Corchorus* sp.) (10.3 tonnes/ha) and winter rice–summer rice (11.7 tonnes/ha). Farm-level water productivity (WP) was computed on the basis of reference crop evapotranspiration (WP_{ET}) and water supply to fields (WP_{WS}). Winter vegetables recorded higher WP_{ET} (kg/m^3) than summer-growing crop. The WP on the basis of ET was for cabbage 23.0, cauliflower 20.7, potato 18.8, tomato (*Lycopersecon esculentum* Miller nom. cons.)14.3, rice 1.6, wheat 2.1, sesame (*Sesamum indicum* L.) 0.4, jute 0.7 and pointed gourd 2.5 kg/m^3. The WP values in terms of water supply (WP_{Ws}) was 30–50% lower than potential WP_{ET}. The WP in economic term (Rs/m^3) was also high in vegetables (Rs 24.6–31.5) and its inclusion in rice-based crop sequence increased the water productivity by 2–3 times compared to other non-vegetable-based sequences. Irrigation water charge for crop production was 4–6 times higher under private owned shallow tube-well run by diesel than the government owned deep tube-well. In ST well commands water cost (WC) for cultivation was much higher in winter rice–summer rice or autumn rice–cabbage–summer rice sequences (Rs 8–13 thousand/ha) than autumn rice–tomato or other sequences. Inclusion of summer rice in the rice–rice system increased the WC for produce (Rs 57.7–71.8 q) in tubewell-irrigated ecosystem.

Key words : Crop water productivity, Rice-Jute- and vegetable- based crop sequences.

Rice is the main foodgrain crop and is extensively grown during wet and dry seasons in tube-well commands of alluvial Lower Gangetic Plains Region of West Bengal, in medium and lowland ecosystem, while vegetables, oilseeds, pulses and wheat occupy the upland and medium lands. Crop intensification has reached >250% with the area blessed with fertile soil and ample reserves of good- quality groundwaters. Inclusion of summer rice and high- yielding vegetable crops increases the groundwater tapping for irrigation. Alarming draw down of groundwater- table (3-12 m or more) during summer is a common phenomenon in most of southern part of West Bengal. Under such a situation a farm household has to choose crops and crop sequences of high water productivity (Tuong, 1999; Wichelns, 2003) particularly, when water is the binding constraints in tube-well commands. Hence an attempt was made to find out crops and crop sequences of high water productivity for the tube-well commands of this area, so that 'more crop per drop; or 'more food with less water' could be achieved in future.

MATERIALS AND METHODS

Farm-level investigation was conducted by All-India Co-ordinated Research Project of Water Management, Bidhan Chandra Krishi Viswavidyalaya at Narayanpur deep tube-well (DTW) command located in Lower Indo-Gangetic Plains (LIGP) region during 1999–2000 and 2000–2001. Eight crop sequences, viz. S_1, autumn rice–tomato; S_2, jute–cauliflower–amaranth; S_3, cauliflower–pointed gourd in upland; S_4, winter rice–potato (*Solanum tuberosum* L.)–sesame; S_5, winter rice–wheat–jute; S_6, atumn rice–cabbage–summer rice in medium land; S_7 winter rice–summer rice; and S_8, winter rice–mustard [*Brassica juncea* (L.) Czerry. &b Cosson]–summer rice in lowland situation, were evaluated for the productivity of land and water as detailed in Table 2 with their crop occupancy span in Table 1. The soils of the command were sandy loam in upland, and clay loam in lowland with bulk density 1.42–1.58 g/cm^3 and infiltration rate 8–12 mm/hr and pH 6.5 – 6.8, organic carbon 0.54–0.61%, total nitrogen 0.059–0.063, available P 7–10 kg/ha and available K 127–146 kg/ha. The rainfall was 1,644 mm and 1,862 mm with season-wise break up of summer (February–May), 114.7 and 251.7 mm; rainy (June–September), 1,373.4 and 1,159.6 mm and winter (October–January), 156.2 and 450.7 mm, respectively, in 1999–2000 and 2000–2001. Crops included in various crop sequences were raised with recommended agronomic practices. Water productivity (WP) of various crops and its sequences were worked out following Kijne (2002) and Barker *et al.* (2002). For computation of land productivity rice-equivalent yield was computed on the basis of prevailing market price after Tomar and Tiwari (1990).

RESULTS AND DISCUSSION

Crop productivity

The autumn rice–cabbage–summer rice (S_6) and cauliflower–pointed gourd (S_3) sequences gave the highest rice- equivalent yield, followed by S_1, S_2 and S_4 (Table 2). This was owing to higher tonnage and per unit value of vegetable crops like tomato, cauliflower, potato and pointed gourd. In upland and medium land situations, in-

Table 1. Crop growth stage-wise evaporation (E_0), crop coefficient (K_c) and evapotranspiration (ET) in the Lower Gangetic Plains Region of West Bengal

Stage (days)	E^1_o (mm)	K^*_c	ET^2 (mm)	Stage (days)	E^1_o (mm)	K^*_c	ET^2 (mm)
	*Autumn rice (Jun. 1W–Sep. 1W**)*				*Winter rice (Jul.2W–Nov.1W)*		
10	33	1.1	36	20	61	1.1	67
30	96	1.1	105	30	84	1.1	93
20	43	1.2	54	25	72	1.2	90
30	81	1.0	81	30	88	1.0	88
Sub-total	253		276		305		338
	Summer rice (Jan. 4W–Apr.3W)				*Jute (Mar. 3W–Jul. 2W)*		
20	47	1.1	51	20	88	0.4	40
25	72	1.1	79	30	127	0.9	114
20	73	1.2	91	30	134	1.1	148
25	122	1.0	122	30	85	0.5	43
Sub-total	314		343		434		345
	Wheat (Nov.2W–Mar.3W)				*Sesame (Feb.2W–Jun.2W)*		
20	33	0.35	15	20	47	0.4	19
40	54	0.8	44	30	124	0.8	99
30	62	1.1	68	40	172	1.0	180
30	99	0.25	25	30	140	0.2	28
Sub-total	248		152		483		326
	Potato (Nov.2W–Feb.2W)				*Mustard (Nov.1W–Feb.1W)*		
20	33	0.35	12	15	22	0.4	9
25	38	0.9	34	25	31	0.8	25
30	51	1.15	59	30	52	1.1	58
15	25	0.65	16	15	28	0.25	7
Sub-total	147		121		133		99
	Cabbage (Oct.2W–Jan 1W)				*Cauliflower (Oct.2W–Dec.4W)*		
10	33	0.35	12	10	33	0.35	12
20	39	0.8	31	20	39	0.8	31
30	34	0.95	32	20	34	0.95	32
15	22	0.85	19	10	15	0.85	12
Sub-total	125		94		121		87
	Tomato (Oct.1W–Jan.4W)				*Pointed gourd (Oct.4W–July.4W)*		
20	49	0.45	22	30	57	0.45	26
30	52	0.8	42	60	86	0.95	82
40	55	1.1	61	90	282	1.10	310
30	46	0.7	32	60	255	1.05	268
Sub-total	202		157		680		686

*K_c, Tabulated value from FAO manual; **W, week; 1 and 2, rounded off to whole mm

clusion of vegetables increased the land productivity of the crop sequences. Choudhury *et al.* (2000) reported similar finding for maize–vegetables. The lowest productivity was noted in S_5, winter rice–wheat–jute (10.3 tonnes/ha), closely followed by S_7: winter rice–summer rice sequence (11.7 tonnes/ha) and S_8: winter rice–mustard–summer rice (11.4 tonnes/ha). Inclusion of vegetables in rice-based crop sequences increased the monetary return by 2–4 times compared to other non-vegetable crop sequences. Jute–sesame and mustard gave the least yields and hence are the poorest performing crops not suitable for raising under tube-well commands with high water costs.

Water demand and supply

Reference crop evapotranspiration (ET) computed (Table 1) for the sub-humid LIGP Region revealed that winter growing vegetable, wheat and mustard crops had low crop water demand (88–157 mm), while the summer grown crops like jute, summer rice, sesame and pointed gourd had about 2–3 times higher evaporative demand (277–685 mm). On sequence basis, inclusion of summer rice, pointed gourd and sesame during summer months increased the reference ET (714–832 mm), while rice–winter vegetable crop sequences had lower crop water demand (433–521 mm). Total crop sequence water use (Table 3) covering irrigation water application + annual effective rain called here water supply (WS) was maximum in winter rice–cabbage–summer rice sequence (2,090 mm) and the lowest noted in autumn rice–tomato crop sequence (870 mm). Growing summer rice in me-

Table 2. Crop-wise water demand and supply and productivity on absolute yield basis in tube-well commands (average of 2 years)

Crop sequence	Water demand (ET[1]) mm	Water supply (WS*) mm	Land productivity (LP)		Water productivity (WP)		
			Physical (tonnes /ha)	Economic (Rs. '000/ha)	Physical ET (kg/m³)	Physical WS (kg/m³)	Economic WS (Rs/m³)
S_1, Autumn rice–	277	150	3.2	16.0	1.0		
Tomato	157	220	22.4	67.2	14.3	10.2	30.6
Sub-total	434	370		83.2			
S_2, Jute–	344	120	2.6	15.6	0.7		
Cauliflower–	88	180	18.1	54.3	20.7	10.0	30.1
Amaranth	90	150	7.4	14.8	8.2	3.7	7.4
Sub-total	522	450		84.7			
S_3, Cauliflower–	88	180	14.8	44.4	16.9	8.2	24.6
Pointed gourd	685	640	17.4	72.4	2.5	2.7	10.9
Sub-total	773	820		116.8			
S_4, Winter rice–	337	150	4.2	21.0	1.2		
Potato–	121	180	22.7	56.0	18.8	12	31.5
Sesame	326	180	1.5	13.5	0.5	0.8	7.5
Sub-total	784	510		90.5			
S_5, Winter rice–	337	150	4.6	23.0	1.3		
Wheat–	152	200	3.2	16.0	2.1	1.6	8.0
Jute	344	120	2.1	12.6	0.6		
Sub-total	833	470		51.6			
S_6, Autumn rice–	277	150	4.8	24.0	1.4		
Cabbage–	94	240	21.5	64.5	23.0	8.9	26.9
Summer rice	344	1,200	5.8	34.8	1.7	0.5	2.9
Sub-total	715	1,590		123.3			
S_7, Winter rice–	337		4.9	24.5	1.4		
Summer rice–	344	900	6.2	37.2	1.8	0.7	4.1
Sub-total	681	900		61.7			
S_8, Winter rice–	337		4.8	24.0	1.4		
Mustard–	98	60	1.0	10.0	1.0	1.7	
Summer rice	344	850	5.6	34.7	1.6	0.7	3.9
Sub-total	779	910		68.7			

[1]Reference crop evapotranspiration, *only irrigation water

dium and lowland situation showed irrigation water use of 1,200 mm and 850 mm respectively (Table 2). There was wide gap between demand and supply of water in rice–rice or rice–cabbage–rice due to higher amount of percolation losses in rice ecosystem in sandy-loam soil of Lower Gangetic Plains Region of West Bengal.

Water productivity

Water productivity on evapotranspiration basis (WP_{ET}) of individual crops (Table 3) revealed that winter vegetable crops like cabbage, cauliflower, potato, tomato and amaranth had much higher values (8.2–23.0 kg/m^3) than the rice, mustard, sesame and jute crop. The water productivity on water supply basis (WP_{WS}) was 30–50% lower than those based on potential water needs (WP_{ET}), irrespective of crops and seasons. Economic productivity of water (WP_{WS}) was also high in vegetables (Rs 24.6–31.5 m^3) and inclusion of vegetable crops in rice-based sequence increased the economic WP_{WS} of the sequence by 2–4 times compared to winter rice–wheat–jute or winter rice–summer rice or winter rice–mustard–summer rice sequence. Hence high water-requiring crops having their sizable growth period coinciding with hot and high evaporative summer months (specially summer rice) tend to lower the system productivity, both physical and economic and thus needs to stop misuse of costly tube-well water and wasteful depletion of the under-ground aquifer.

Water cost

Irrigation water charges for cultivation varied according to the water source (Table 4). Charges were high under private owned shallow tube-well (STW), operated by diesel and were very low in deep tube-well (DTW) run by the Government. Besides, winter rice–vegetables sequences had the lower irrigation tariff rate than winter rice–summer rice sequence. Growing of summer rice increased the water cost for cultivation (Rs 8,400–13,650/ha) in the sequence by 2–4 times than the other conservative water use crop sequences and consequently the cost of crop production too increased to the tune of Rs 57.7 to 71.8/q (S_7); depending on whether source of water through electric or diesel-operated shallow or deep tube-well (Table 4) compared to as low of Rs 9.2 and 15.7 for the corresponding values in S_1.

Table 3. Land and water productivity on rice-equivalent yield (REY) basis under different crop sequences

Crop sequence	REY (tonnes/ha)	ET[1] (mm)	WS* (kg/m^3)	Physical WP (Rs/m^3)		Economics WP (Rs/m^3)	
				WP_{ET}	WP_{WS}	WP_{ET}	WP_{WS}
S_1	16.6	434	870	3.83	1.9	19.2	5.13
S_2	16.9	522	1,000	3.24	1.69	16.2	8.48
S_3	23.4	773	1,140	3.03	2.05	15.1	5.96
S_4	18.1	784	950	2.31	1.90	11.5	3.73
S_5	10.3	833	970	1.24	1.06	6.2	1.41
S_6	24.6	715	2,090	3.45	1.18	17.3	3.19
S_7	11.7	681	1,400	1.72	0.83	8.9	1.91
S_8	13.0	779	1,410	1.67	0.92	8.8	2.02
CD (P=0.05)	1.65		125.7	0.29	0.15	1.46	0.75

[1]ET, Reference crop evapotranspiration, *including effective rainfall-500 mm during crop-growing period

Table 4. Water cost (WC) for cultivation and crop production under different tube-well irrigation sources

Crop sequence	WC for cultivation (Rs/ha)			WC for the produce (Rs/q)		
	DTW_f	WTW_e	STW_d	DTW_f	STW_e	STW_d
S_1	250	1,800	3,075	1.3	9.2	15.7
S_2	240	2,025	5,625	1.4	12.0	33.2
S_3	400	2,925	5,850	1.7	12.5	25.0
S_4	215	2,925	5,400	1.2	16.1	29.8
S_5	215	2,700	4,500	2.1	26.2	47.7
S_6	915	9,075	13,650	3.7	36.9	55.5
S_7	795	6,750	8,400	6.8	57.7	71.8
S_8	820	7,050	8,600	6.3	54.2	66.1

DTW_f, Deep tube-well run by farmer; STW_e, shallow tube-well operated by electric; STW_d, STW operated by diesel oil

It may be concluded that water productivity was much higher in winter rice–vegetable (tomato, cabbage, potato, pointed gourd and cauliflower)-based sequence and inclusion of summer rice increased both the wasteful expenditure and water cost many folds in tube-well commands, irrespective of the fact whether the water source was a shallow tube-well-operated by electric power or a Government owned deep tube-well run by farmer. Ever depleting of groundwater aquifer in the LIGP Region at an alarming rate thus can be halted or position reversed by putting a legislative measures on the sinking of tubewells for the cultivation of crops like summer rice or by reducing the summer rice area through growing alternate dry crops like sunflower, sesame in heavy soils and groundnut in light soils.

REFERENCES

Barker, R., Dawe, D. and Inocencio, A. 2002. Economics of water productivity in managing water for agriculture. (In) *Water Productivity in Agriculture: Limits and Opportunities for Improvement.* Kijne, J.W. (Ed.) CABI, Wallingford, UK (*in press*).

Choudhury, J.B., Thakur, R.C., Bhargava, M. and Sood, R.D. 2000. Production potential and economics of maize–based crop sequences on farmer's field. *Indian Journal of Agronomy* **45**(2) : 232–235.

Kijne, J.W. 2002. Water productivity under saline conditions. (In) *Water Productivity in Agriculture: Limits and Opportunities for Improvement*, Kijne, J.W. (Ed). CABI, Wallingford, UK (*in press*).

Tomar, S.S. and Tiwari, A.S. 1990. Production potential and economics of different crop sequences. *Indian Journal of Agronomy* **35**(1,2) : 30–35.

Tuong, T.P. 1999. Productive water use in rice production: Opportunities and limitations. *Journal of Crop Production* **2**(2) : 241–264.

Wichelns, Dennis, 2003. Enhancing water policy discussions by including analysis of non-water inputs and farm-level constraints. *Agricultural Water Management* **62** : 93–103.