Monthly consumptive use of rice in the semiarid and humid regions of Puerto Rico[1]

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ABSTRACT

Monthly consumptive use of water (CU, mm) by rice was estimated with modified Blaney-Criddle model, Hackbart's computer program and available climatic data in the semiarid south coast (Lajas) and humid north coast (Arecibo) of Puerto Rico. Twelve planting dates and three crop lengths of 90, 105 and 120 days were considered. For 120 days and 12 planting dates, total consumptive use varied from 442 to 589 mm at Arecibo, compared with 428 to 579 mm at Lajas. Average total CU (mm) was 392 for 90 days, 458 for 105 days, 514 for 120 days at Arecibo, compared with 382 for 90 days, 447 for 105 days and 502 for 120 days at Lajas. Daily CU (mm/day) range was 4.3 to 4.4 at Arecibo, compared with 4.2 to 4.3 at Lajas.

RESUMEN

Consumo de agua del arroz en las regiones semiáridas y húmedas de Puerto Rico

Se estimó el uso consuntivo (UC) del arroz, utilizando el modelo modificado de Blaney-Criddle, el programa computarizado de Hackbart y los datos climatológicos disponibles. El estudio se llevó a cabo en la costa semiárida del sur (Lajas) y en la húmeda del norte (Arecibo), Puerto Rico. Se utilizaron 12 fechas de siembra y tres períodos en el campo: 90, 105 y 120 días. Para el período de 120 días y 12 fechas de siembra, el UC total fluctuó de 442 a 589 mm. en Arecibo y de 428 a 579 mm. en Lajas. El UC (mm./día) fluctuó de 4.3 a 4.4 en Arecibo y de 4.2 a 4.3 en Lajas. Para el período de 120 días el promedio de UC fue 514 mm. en Arecibo y 502 mm. en Lajas.

INTRODUCTION

The rice plant usually takes 3-6 months from germination to maturity, depending on the variety and location (9). The life history of rice consists of three growth stages: vegetative (germination to initiation of panicle primordia), reproductive (panicle primordia initiation to heading) and ripening (heading to maturity). A 120-day variety in the tropics spends about 60 days in the vegetative growth, 30 days in the reproductive stage, and 30 days in the ripening period (3,4,9). Direct seeded rice

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Table 1.—*Factors affecting monthly net irrigation requirements of rice in semiarid and humid regions of Puerto Rico*

	Description	Arecibo	Lajas
I.	**Geographical factors**		
	Weather station no.	66-0410	66-5097
	Location	Arecibo	Lajas
	Latitude	18°28'N	18°03'N
	Longitude	66°42'W	67°03'W
	Elevation above sea level	4.5 m	27.0 m
	Climatic zone	Humid, north coast	Semiarid
II.	**Soil factors**		
	Soil pH	5.0	6.0
	Soil type	Toa soil (Mollisol)	Fraternidad clay (Vertisols)
	Field capacity (AWC) depth	9.0 cm	9.0 cm
III.	**Management factors**		
	Root depth	60 cm	60 cm
	Allowable depletion	50%	50%
	Initial soil moisture	4.5 cm	4.5 cm
	Net irrigation application	4.5 cm	4.5 cm
	Humid area factor	0.8	0.8
	ET model, Blaney-Criddle	Yes	Yes
	Irrigation method	Flood	Flood
	Irrigation efficiency	30%	30%
	Soil moisture at end of season	4.5 cm	4.5 cm
	Irrigation for plant establishment	20 cm	20 cm
	Land preparation	Dry	Dry
	Planting	Broadcast	Broadcast
	Crop duration, days	90, 105 or 120	90, 105 0r 120
	Cut off irrigation	3 weeks before harvest	3 weeks before harvest
	Drainage water	Recycled	Recycled

normally starts tillering earlier than transplanted rice, and transplanted rice usually takes about 1 week more to mature (9). Delayed transplanting can reduce plant height, dry matter production and fertile grains per panicle (9). Lozano and Abruña (3) evaluated effects of bimonthly plantings on medium-grain rice and found highest yields for February plantings and lowest yields for October plantings at Gurabo Agricultural Substation, Puerto Rico. Crop season varied from 96 to 129 days depending on the variety and planting date (3). Vicente-Chandler et al. (8) estimated an area of 20,000 ha suited to rice production with two crops yearly in Puerto Rico and recommended irrigation of only 50 to 60% of the area at a given time.

Yoshida (9) indicated that in general 7 to 15 mm/day of irrigation depth is necessary after stand establishment to achieve the maximum

TABLE 2.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Arecibo*

Planting to last harvest	Days	Parameter		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU,	in	3.97	4.63	4.71										13.31	
to	90	ER,	in	0.84	1.02	0.95										2.82	Flood
March 31		NIR,	in	3.13	3.60	3.76										10.50	35.0
February		CU,	in		3.06	5.50	4.95									13.50	
to	89	ER,	in		1.19	0.99	1.62									3.80	
April 30		NIR,	in		1.87	4.51	3.33									9.70	32.3
March 1		CU,	in			3.98	5.76	5.77								15.50	
to	92	ER,	in			0.96	1.70	1.91								4.56	
May 31		NIR,	in			3.02	4.06	3.86								10.94	36.5
April 1		CU,	in				3.95	6.74	5.97							16.65	
to	91	ER,	in				1.24	2.01	1.66							4.92	
June 30		NIR,	in				2.70	4.72	4.31							11.73	39.1
May 1		CU,	in					4.84	7.01	5.89						17.74	
to	92	ER,	in					1.71	1.76	1.47						4.95	
July 31		NIR,	in					3.13	5.25	4.41						12.80	42.7
June 1		CU,	in						4.76	6.92	5.78					17.46	
to	92	ER,	in						1.67	1.56	1.58					4.81	
August 31		NIR,	in						3.09	5.36	4.20					12.65	42.2
July 1		CU,	in							5.03	6.82	5.40				17.25	
to	92	ER,	in							1.49	1.68	1.79				4.96	
September 30		NIR,	in							3.54	5.14	3.61				12.29	40.9
August 1		CU,	in								4.96	6.40	5.24			16.59	
to	92	ER,	in								1.46	1.89	1.83			5.18	
October 31		NIR,	in								3.50	4.51	3.41			11.41	38.0
September 1		CU,	in									4.42	6.24	4.77		15.43	
to	9	ER,	in									1.59	1.94	2.11		5.64	
November 30		NIR,	in									2.84	4.30	2.65		9.79	32.6
October 1		CU,	in										4.56	5.70	4.49	14.74	
to	92	ER,	in										1.74	2.23	2.27	6.24	
December 31		NIR,	in										2.82	3.47	2.21	8.50	28.3
November 1		CU,	in	4.39										3.93	5.33	13.66	
to	92	ER,	in	1.56										1.87	2.38	5.81	
January 31		NIR,	in	2.83										2.07	2.95	7.84	26.1
December 1		CU,	in	5.17	3.96										4.01	13.14	
to	90	ER,	in	1.63	0.99										2.11	4.73	
February 28		NIR,	in	3.54	2.97										1.90	8.41	28.0

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) * = Recommended planting date.

dry season yield depending upon crop duration, variety, management and location.

This study estimated monthly consumptive use (CU) of water by rice in the humid and semiarid regions of Puerto Rico. Arecibo in the humid north coast and Lajas in the semiarid south coast of Puerto Rico were selected to represent rice producing regions.

MATERIALS AND METHODS

Crop duration of 90, 105 and 120 days and 12 planting dates were considered in this study. Table 1 summarizes variables that affect consumptive use and irrigation requirements. Monthly consumptive use (CU) by rice was estimated with climatic data (1, 5), computer model (2) and the following relationship:

$$CUm = (K_c \times K_t \times p \times T \times H)/100 \quad /1/$$

where CUm = monthly consumptive use (inches), K_t = a climatic coefficient which is related to mean air temperature, p = monthly percentage of daylight hours in the year (7), T = mean air temperature in °F, H = humid area factor of 0.8 and K_c = crop coefficient reflecting growth stage (7). Average K_c was 0.98 for 90-day, 0.95 for 105-day and 0.96 for 120-day-old crop.

Monthly K_c (7,9) was assumed as follows:

Days	*Crop cycle, days*		
	90	*105*	*120*
0-30	0.86	0.67	0.67
31-60	1.12	1.11	1.10
61-90	0.95	1.08	1.10
91-105	—	0.95	—
91-120	—	—	0.95

Monthly CUm was then added and multiplied by 25.4 to obtain total CU in mm.

RESULTS AND DISCUSSION

Tables 2 and 7 indicate consumptive use (CUm, inches) for 12 planting dates and three crop lengths of 3, 3½ and 4 months at Arecibo and Lajas, Puerto Rico. Table 8 gives seasonal consumptive use (CU,mm) of rice for 12 planting dates and three crop seasons at these two locations.

For four-month crop and December planting, monthly CU varied from 787 to 1298 mm at Arecibo (table 4) and from 750 to 1255 mm at Lajas (table 7). CU was maximum for May planting and minimum for November planting.

For all 12 planting dates at Arecibo, seasonal CU range was 334-451 mm for 90 days, 390-524 mm for 105 days, 442-589 mm for 120 days at

TABLE 3.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Arecibo*

Planting to last harvest	Days	Parameter		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU,	in	3.47	4.60	5.28	2.45									15.81	
to	105	ER,	in	0.82	1.02	0.98	1.41									4.23	Flood
April 15		NIR,	in	2.65	3.58	4.30	1.04									11.56	38.5
February 1		CU,	in		2.67	5.47	5.53	2.76								16.43	
to	104	ER,	in		1.16	0.99	1.67	1.61								5.44	
May 15		NIR,	in		1.50	4.48	3.86	1.15								10.99	36.6
March 1		CU,	in			3.48	5.72	6.45	2.97							18.62	
to	107	ER,	in			0.93	1.69	1.98	1.41							6.01	
June 15		NIR,	in			2.55	4.03	4.46	1.56							12.60	42.0
April 1		CU,	in				3.45	6.69	6.72	2.84						19.71	
to	106	ER,	in				1.21	2.01	1.73	1.24						6.19	
July 15		NIR,	in				2.24	4.68	4.99	1.60						13.52	45.1
May 1		CU,	in					4.24	6.94	6.63	2.80					20.63	
to	107	ER,	in					1.65	1.76	1.53	1.34					6.29	
August 15		NIR,	in					2.59	5.21	5.09	1.46					14.35	47.8
June 1		CU,	in						4.17	6.88	6.53	2.71				20.29	
to	107	ER,	in						1.62	1.56	1.65	1.54				6.36	
September 15		NIR,	in						2.55	5.32	4.88	1.17				13.93	46.4
July 1		CU,	in							4.40	6.79	6.12	2.55			19.86	
to	107	ER,	in							1.44	1.67	1.86	1.58			6.55	
October 15		NIR,	in							2.96	5.11	4.26	0.98			13.31	44.4
August 1		CU,	in								4.34	6.36	5.97	2.41		19.08	
to	107	ER,	in								1.41	1.89	1.91	1.85		7.06	
November 15		NIR,	in								2.93	4.47	4.06	0.56		12.02	40.1
September 1		CU,	in									3.87	6.20	5.46	2.20	17.73	
to	106	ER,	in									1.54	1.93	2.20	2.00	7.67	
December 15		NIR,	in									2.33	4.27	3.26	0.20	10.06	33.5
October 1		CU,	in	2.14									3.99	5.66	5.11	16.89	
to	107	ER,	in	1.38									1.69	2.22	2.35	7.64	
January 15		NIR,	in	0.76									2.30	3.44	2.75	9.25	30.8
November 1		CU,	in	4.96	2.11									3.45	5.30	15.82	
to	107	ER,	in	1.61	0.89									1.82	2.38	6.70	
February 15		NIR,	in	3.35	1.22									1.63	2.92	9.12	30.4
December 1		CU,	in	5.16	4.42	2.26									3.50	15.34	
to	105	ER,	in	1.63	1.01	0.83									2.05	5.52	
March 15		NIR,	in	5.53	3.41	1.43									1.45	9.82	32.7

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) * = Recommended planting date.

TABLE 4.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Arecibo*

Planting to last harvest	Days	Parameter		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU,	in	3.09	4.54	5.39	4.95									17.96	
to	120	ER,	in	0.80	1.02	0.99	1.62									4.43	Flood
April 30		NIR,	in	2.29	3.52	4.40	3.33									13.53	45.1
February 1		CU,	in		2.36	5.38	5.64	5.77								19.16	
to	120	ER,	in		1.14	0.99	1.68	1.91								5.72	
May 31		NIR,	in		1.22	4.40	3.96	3.86								13.43	44.8
March 1		CU,	in			3.11	5.65	6.58	5.97							21.31	
to	122	ER,	in			0.91	1.69	2.00	1.66							6.26	
June 30		NIR,	in			2.20	3.96	4.59	4.31							15.05	50.2
April 1		CU,	in				3.06	6.61	6.87	5.89						22.42	
to	122	ER,	in				1.18	2.00	1.75	1.47						8.40	
July 31		NIR,	in				1.88	4.61	5.12	4.41						16.02	53.4
May 1		CU,	in					3.76	6.88	6.77	5.78					23.19	
to	123	ER,	in					1.61	1.75	1.55	1.58					6.49	
August 31		NIR,	in					2.15	5.13	5.23	4.20					16.71	55.7
June 1		CU,	in						3.73	6.79	6.67	5.40				22.59	
to	122	ER,	in						1.58	1.55	1.66	1.79				6.58	
September 30		NIR,	in						2.15	5.25	5.01	3.61				16.01	53.4
July 1		CU,	in							3.90	6.71	6.26	5.24			22.11	
to	123	ER,	in							1.40	1.67	1.88	1.83			6.77	
October 31		NIR,	in							2.50	5.04	4.38	3.41			15.33	51.1
August 1		CU,	in								3.87	6.28	6.09	4.77		21.01	
to	122	ER,	in								1.37	1.88	1.92	2.11		7.29	
November 30		NIR,	in								2.50	4.40	4.17	2.65		13.73	45.8
September 1		CU,	in									3.43	6.12	5.58	4.49	19.62	
to	122	ER,	in									1.50	1.92	2.21	2.27	7.916	
December 31		NIR,	in									1.93	4.20	3.37	2.21	11.71	39.0
October 1		CU,	in	4.39									3.54	5.59	5.22	18.73	
to	123	ER,	in	1.56									1.64	2.21	2.37	7.79	
January 31		NIR,	in	2.83									1.89	3.37	2.85	10.94	36.5
November 1		CU,	in	5.06	3.96									3.13	5.25	17.39	
to	120	ER,	in	1.62	0.99									1.79	2.37	6.77	
February 28		NIR,	in	3.44	2.97									1.34	2.88	10.62	35.4
December 1		CU,	in	5.11	4.53	4.71									3.10	17.44	
to	121	ER,	in	1.63	1.02	0.95									2.01	5.60	
March 31		NIR,	in	3.48	3.51	3.76									1.09	11.84	39.5

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) *= Recommended planting date.

TABLE 5.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Lajas*

Planting to last harvest	Days	Parameter		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU,	in	3.84	4.53	4.58										12.95	
to	90	ER,	in	0.41	0.55	0.65										1.60	Flood
March 31		NIR,	in	3.44	3.98	3.93										11.35	37.8
February		CU,	in		2.98	5.33	4.88									13.19	
to	89	ER,	in		0.61	0.68	1.25									2.55	
April 30		NIR,	in		2.37	9.65	3.63									10.64	35.5
March 1		CU,	in			3.86	5.67	5.74								15.28	
to	92	ER,	in			0.59	1.31	1.36								3.26	
May 31		NIR,	in			3.27	4.36	4.38								12.02	40.1
April 1		CU,	in				3.87	6.71	5.93							16.51	
to	91	ER,	in				0.92	1.43	0.99							3.35	
June 30		NIR,	in				2.95	5.28	4.94							13.16	43.9
May 1		CU,	in					4.81	6.99	5.74						17.55	
to	92	ER,	in					1.26	1.05	1.33						3.65	
July 31		NIR,	in					3.55	5.94	4.41						13.90	46.3
June 1		CU,	in						4.74	6.78	5.58					17.10	
to	92	ER,	in						1.11	1.41	2.13					4.65	
August 31		NIR,	in						3.64	5.37	3.44					12.44	41.5
July 1		CU,	in							4.94	6.57	5.23				16.74	
to	92	ER,	in							1.13	2.26	2.47				5.85	
September 30		NIR,	in							3.81	4.32	2.76				10.89	36.3
August 1		CU,	in								4.79	6.20	5.09			16.08	
to	92	ER,	in								1.68	2.61	2.02			6.30	
October 31		NIR,	in								3.11	3.59	3.07			9.77	32.6
September 1		CU,	in									4.28	6.07	4.63		14.98	
to	9	ER,	in									2.16	2.13	1.60		5.89	
November 30		NIR,	in									2.12	3.94	3.03		9.08	30.3
October 1		CU,	in										4.43	5.54	4.34	14.31	
to	92	ER,	in										2.14	1.68	0.99	4.81	
December 31		NIR,	in										2.29	3.85	3.35	9.49	31.6
November 1		CU,	in	4.26										3.83	5.16	13.24	
to	92	ER,	in	0.78										1.69	1.03	3.51	
January 31		NIR,	in	3.48										2.14	4.13	9.74	32.5
December 1		CU,	in	5.00	3.86										3.89	12.74	
to	90	ER,	in	0.81	0.53										1.24	2.58	
February 28		NIR,	in	4.18	3.34										2.64	10.16	33.9

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) *= Recommended planting date.

Lajas; 324-446 mm for 90 days, 378-516 mm for 105 days, 428-579 mm for 120 days. Average seasonal CU (mm/season) was 392 at Arecibo and 382 at Lajas for 90 days; 458 at Arecibo and 447 at Lajas for 105 days; and 514 at Arecibo and 502 at Lajas for 120 days. Daily consumptive use was lower at Lajas and varied from 4.2 to 4.4 mm/day. These results agree with those of Silva et al. (6) and Ravalo et al. (5) in these areas. Silva (6) indicated a consumptive use of 3.1 to 8.4 mm/day in Vega Baja, P.R. Ravalo (5) found average consumptive use of 4.77 mm/day with the Thornthwaite PET Model. Yoshida (9) has shown that the Thornthwaite method overestimates PET by 10 to 15% compared to the Blaney-Criddle model. Yoshida (9) has indicated average consumptive use of 4 mm/day for a paddy field in the Phillipines. Experiments at International Rice Research Institute (9) resulted in a daily CU of 4.4 mm/day for the dry season. Our results are within these ranges.

It is cautioned that these CU in tables 2 to 8 have not been verified with lysimeter studies. Such extensive experimental data are not available for Puerto Rico. Experimental research to determine K_c in Puerto Rico is lacking. These CU values were estimated with K_c corresponding to areas similar to Puerto Rico. The following procedure is suggested as a guide:

1. Consult an extension agent for crop duration, planting season, location, and other management practices for rice production.
2. Select crop season and planting date in tables 2 to 8 closest to recommended practices.
3. Select values of CU corresponding to data in step 2.

The following examples indicate how to utilize CU for irrigation requirements.

Example 1: Estimate total CU for a paddy crop in Lajas area. Use average K_c of 0.98 instead of 0.96 for a 4-month-old crop and consider planting on 1 December.

From tables 7 and 8, CU is 431 mm with K_c of 0.96 and 1 December planting. CU at Lajas = (431/.96) × 0.98 = 440 mm during the growing season.

This example shows how to estimate CU with a new K_c .

Example 2: Estimate monthly net irrigation requirement with the data in table 1.

Monthly effective rainfall (ERm) and net irrigation requirements (NIR) were estimated with the computer program (2) and with equations (2, 7):

$$ERm = (0.70917 \times I^{0.82416} - 0.11556) \times 10^{0.02426\ CUm} \times f \quad \text{/2/}$$

$$f = 0.531747 + 0.295164 \times D - 0.057697 \times D^2 + 0.003804 \times D^3 \quad \text{/3/}$$

$$ER = ER_{m1} + ER_{m2} + ER_{m3} + ER_{m4} \quad \text{/4/}$$

$$CU = CU_{m1} + CU_{m2} + CU_{m3} + CU_{m4} \quad \text{/5/}$$

TABLE 6.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Lajas*

Planting to last harvest	Days	Parameter	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU, in	3.35	4.50	5.12	2.41									15.38	
to	105	ER, in	0.39	0.55	0.67	1.09									2.71	Flood
April 15		NIR, in	2.96	3.95	4.44	1.32									12.67	42.2
February 1		CU, in		2.60	5.30	5.45	2.75								16.09	
to	104	ER, in		0.60	0.68	1.29	1.15								3.72	
May 15		NIR, in		2.00	4.62	4.16	1.60								12.37	41.2
March 1		CU, in			3.38	5.64	6.42	2.95							18.39	
to	107	ER, in			0.57	1.31	1.41	0.84							4.13	
June 15		NIR, in			2.81	4.33	5.01	2.11							14.26	47.5
April 1		CU, in				3.39	6.67	6.70	2.78						19.54	
to	106	ER, in				0.90	1.43	1.04	1.13						4.49	
July 15		NIR, in				2.49	5.24	5.67	1.65						15.04	50.1
May 1		CU, in					4.21	6.95	6.49	2.70					20.35	
to	107	ER, in					1.22	1.05	1.39	1.82					5.48	
August 15		NIR, in					2.99	5.90	5.10	0.88					14.88	49.6
June 1		CU, in						4.16	6.74	6.29	2.62				19.81	
to	107	ER, in						1.07	1.41	2.22	2.14				6.84	
September 15		NIR, in						3.08	5.33	4.07	0.49				12.97	43.2
July 1		CU, in							4.32	6.54	5.93	2.48			19.27	
to	107	ER, in							1.09	2.25	2.57	1.74			7.65	
October 15		NIR, in							3.23	4.29	3.36	0.74			11.62	38.7
August 1		CU, in								4.20	6.16	5.80	2.35		18.50	
to	107	ER, in								1.63	2.60	2.10	1.41		7.73	
November 15		NIR, in								2.57	3.56	3.71	0.94		10.77	35.9
September 1		CU, in									3.75	6.03	5.31	2.13	17.21	
to	106	ER, in									2.10	2.12	1.66	0.87	6.76	
December 15		NIR, in									1.65	3.90	3.64	1.25	10.45	34.8
October 1		CU, in	2.07									3.88	5.50	4.94	16.39	
to	107	ER, in	0.69									2.08	1.68	1.02	5.47	
January 15		NIR, in	1.38									1.80	3.82	3.92	10.92	36.4
November 1		CU, in	4.79	2.06									3.35	5.13	15.34	
to	107	ER, in	0.80	0.48									1.65	1.03	3.96	
February 15		NIR, in	3.99	1.59									1.71	4.10	11.38	37.9
December 1		CU, in	4.99	4.32	2.20									3.39	14.90	
to	105	ER, in	0.81	0.54	0.57									1.21	3.13	
March 15		NIR, in	4.17	3.78	1.63									2.18	11.76	39.2

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) *= Recommended planting date.

TABLE 7.—*Net irrigation requirements (inches per month) with modified Blaney-Criddle method. Crop: Rice. Location: Lajas*

Planting to last harvest	Days	Parameter	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Total	Gross irrigation
January 1		CU, in	2.99	4.44	5.22	4.88									17.53	
to	120	ER, in	0.39	0.54	0.64	1.25									2.86	Flood
April 30		NIR, in	2.60	3.90	4.54	3.63									14.67	48.9
February 1		CU, in		2.30	5.21	5.56	5.74								18.82	
to	120	ER, in		0.59	0.68	1.30	1.36								3.93	
May 31		NIR, in		1.71	4.54	4.26	4.38								14.89	49.6
March 1		CU, in			3.02	5.57	6.56	5.93							21.07	
to	122	ER, in			0.56	1.30	1.42	0.99							4.28	
June 30		NIR, in			2.46	4.26	5.14	4.94							16.80	56.0
April 1		CU, in				3.00	6.58	6.85	5.74						22.18	
to	122	ER, in				0.88	1.42	1.04	1.33						4.68	
July 31		NIR, in				2.12	5.16	5.80	4.41						17.50	58.3
May 1		CU, in					3.74	6.86	6.63	5.58					22.80	
to	123	ER, in					1.19	1.04	1.40	2.13					5.77	
August 31		NIR, in					2.55	5.81	5.23	3.44					17.03	56.8
June 1		CU, in						3.72	6.65	6.43	5.23				22.03	
to	122	ER, in						1.05	1.40	2.24	2.47				7.16	
September 30		NIR, in						2.67	5.25	4.19	2.76				14.88	49.6
July 1		CU, in							3.83	6.47	6.06	5.09			21.45	
to	123	ER, in							1.06	2.24	2.59	2.02			7.91	
October 31		NIR, in							2.77	4.22	3.48	3.07			13.54	45.1
August 1		CU, in								3.75	6.08	5.93	4.63		20.38	
to	122	ER, in								1.59	2.59	2.11	1.60		7.89	
November 30		NIR, in								2.16	3.49	3.81	3.03		12.49	41.6
September 1		CU, in									3.32	5.95	5.42	4.43	19.04	
to	122	ER, in									2.05	2.11	1.67	0.99	6.83	
December 31		NIR, in									1.27	3.84	3.75	3.35	12.21	40.7
October 1		CU, in	4.26									3.44	5.43	5.05	18.17	
to	123	ER, in	0.78									2.03	1.67	1.03	5.51	
January 31		NIR, in	3.48									1.41	3.75	4.02	12.66	42.2
November 1		CU, in	4.89	3.86									3.04	5.08	16.87	
to	120	ER, in	0.81	0.53									1.62	1.03	3.98	
February 28		NIR, in	4.08	3.34									1.42	4.05	12.88	42.9
December 1		CU, in	4.94	4.43	4.58									3.00	16.95	
to	121	ER, in	0.81	0.54	0.65									1.18	3.19	
March 31		NIR, in	4.13	3.88	3.93									1.82	13.76	45.9

CU = Consumptive use, ER = Effective rainfall, NIR = Net irrigation requirement, (CU − ER) *= Recommended planting date.

$$NIRm = CU_m - ER_m \quad /6/$$

$$NIR = CU - ER \quad /7/$$

where ER_m = monthly effective rainfall (inches); I = monthly rainfall (inches); CU_m = given by equation /1/ and tables 2 to 7; f= correction factor; D= net depth of application (inches); ER= total effective rainfall (inches) obtained by summing ER_m of first, second, third and fourth month, CU = total consumptive use (inches); NIR_m= monthly net irrigation requirement (inches); and NIR= total net irrigation requirement (inches).

Tables 2 to 7 indicate monthly effective rainfall (inches) and net irrigation requirements (inches) for twelve planting dates and three crop seasons of 90, 105 and 120 days at Arecibo and Lajas. These values are multiplied by 25.4 to obtain NIR in mm. For 4-month crop and twelve planting dates, total NIR range was 270-424 mm at Arecibo and 310-445 mm at Lajas. This is equivalent to 2.3 - 3.5 mm/day at Arecibo and 2.6 - 3.7 mm/day at Lajas.

Example 3: Estimate total gross water requirement for 12 planting dates and 3 crop lengths of 90, 105 and 120 days for example 2.

Gross water requirement (GIR,mm) was estimated with GIR = (NIR × 25.4)/0.30 where 0.30 represents an irrigation efficiency for flood irrigation system. Table 9 indicates total GIR of paddy at Arecibo and Lajas.

TABLE 8.—*Total water consumption of rice in Arecibo and Lajas, Puerto Rico*

Planting date	Seasonal consumptive use, mm[1]					
	Arecibo			Lajas		
	Crop season, months					
	3	3.5	4.0	3	3.5	4.0
January 01	338	401	456	329	392	445
February 01	343	417	487	335	409	478
March 01	394	473	541	388	467	535
April 01	423	501	569	419	496	563
May 01	451	524	589	446	516	579
June 01	443	515	574	434	503	559
July 01	438	504	562	425	489	545
August 01	421	485	534	408	470	518
September 01	392	450	498	380	437	484
October 01	374	429	476	363	416	462
November 01	347	402	442	336	390	428
December 01	334	390	443	324	378	431
Monthly average	392	458	514	382	447	502
mm/day (average)	4.4	4.4	4.3	4.2	4.3	4.2

[1]Crop season includes 2 to 4 weeks for seedling establishment, 2 to 3 weeks after last irrigation to allow harvest at recommended moisture, and period for permanent flooding.

For 4-month crop, gross water requirement (table 9) varied from 899 to 1415 mm at Arecibo compared to 1034 - 1481 mm at Lajas during all 12 planting dates, respectively. Average total water requirement was 1164 mm at Arecibo, compared to 1223 mm at Lajas. Daily water requirement was 9.4 - 9.9 mm/day at Arecibo compared to 9.9 - 10.4 mm/day at Lajas. These results agree with Silva et al. (6) and Ravalo et al. (5) in these areas. Silva et al. (6) indicated that a consumptive use of rice was 3.1 to 8.4 mm/day, and 1200 mm of total irrigation was required to produce a rice crop in Vega Baja, P.R. Ravalo and Goyal (5) found that a total water requirement of rice was 1396 mm (includes 20 cm for stand establishment) for a 122-day crop with a peak value of 12.4 mm/day in Lajas and daily water requirement ranged from 9.2 to 12.4 mm/day. Yoshida (9) has indicated 180 mm and 270 mm of monthly water requirement for wet season (June to December) and dry season (January to April) in the Philippines, respectively. He indicates that total water requirement of rice is 1200 mm with 200 mm for seedling establishment. The computed estimates are within these ranges.

TABLE 9.—*Total water requirement of rice in Arecibo and Lajas, Puerto Rico*

Planting date	Total water requirement (GIR), cm per season[1]					
	Arecibo			Lajas		
	Crop season, months[2]					
	3	3.5	4.0	3	3.5	4.0
January 01	88.9	97.8	114.6	96.0	107.2	124.2
February 01	82.0	92.9	113.8	90.2	104.6	125.9
March 01	92.7	106.7	127.5	101.9	120.7	142.2
April 01	99.3	114.6	135.6	111.5	107.3	148.1
May 01	108.5	121.4	141.5	117.6	125.9	144.3
June 01	107.2	117.9	135.6	105.4	109.7	125.9
July 01	103.9	112.8	129.8	92.2	98.3	114.6
August 01	96.5	101.9	116.3	82.8	91.2	105.7
September 01	82.8	85.1	99.1	76.9	88.4	103.4
October 01	71.9	78.2	92.7	80.3	92.5	107.2
November 01	66.3	77.2	89.9	82.6	96.3	108.9
December 01	71.1	83.1	100.3	86.1	99.6	116.6
Average	89.3	99.1	116.4	93.6	103.5	122.3
mm/day (average)	9.9	9.4	9.7	10.4	9.9	10.1

[1]Assumed an irrigation efficiency of 30% for flood irrigation.

GIR = (NIR × 2.54)/(0.30), where NIR values are from tables 2 to 7.

[2]Crop season includes 2 to 4 weeks for seedling establishment, 2 to 3 weeks after last irrigation to allow harvest at recommended moisture, and period for permanent flooding.

Example 4:

Calculate monthly NIR, total NIR, total GIR of rice for the Lajas areas of Puerto Rico. Management factors are shown in Table 1. Consider planting in December and harvesting at the end of March. Assume an irrigation efficiency of 30% for flood irrigation.

Solution: Crop season - December 1 to March 31
Location - Lajas
Crop duration - 121 days
Management factors - Table 1

For these data, table 7 gives:

	CU (in)	ER (in)	NIR (in)
December	3.00	1.18	1.82
January	4.94	0.81	4.13
February	4.43	0.59	3.88
March	4.58	0.65	3.93
Total	16.95	3.19	13.76

GIR = NIR/0.30 = 13.76/0.30 = 45.9 inches

Total water requirement = $45.9 \times 25.4 = 1166$ mm
Daily water requirement = 1166/120 = 9.7 mm/day
or 1.13 litres/ha per sec
or 97 m^3/ha per day

This example shows procedure of how to utilize information in tables 2 to 9 to obtain total or daily water requirements for paddy rice.

LITERATURE CITED

1. Climatography of the United States No. 86-45 of Puerto Rico and U.S. Virgin Islands. *In* Climatic Survey of the U.S. Supplement. United States Department of Commerce, Washington, D.C.
2. Hackbart, C. A., 1987. Conuse and User's Manual. USDA-SCS, Fort Worth, TX.
3. Lozano, J. M. and F. Abruña, 1982. Season of the year on yields of seven medium-grain varieties of rice. *J. Agric. Univ. P. R.* 66 (3): 188-93.
4. _____ and _____, 1977. Effect of planting season on yield of eight short-grain varieties of rice under irrigation. *J. Agric. Univ. P. R.* 61 (1): 6-10.
5. Ravalo, E. J. and M. R. Goyal, 1988. Water requirements of rice in Lajas Valley of Puerto Rico. Dimension CIAPR, 2 (8): 33-5.
6. Silva, S. and J. Vicente-Chandler, 1982. Water use by flooded rice in Puerto Rico. *J. Agric. Univ. P. R.* 66 (3): 181-87.
7. United States Department of Agriculture - Soil Conservation Service, 1970. Irrigation Water Requirements. Eng. Tech. Div. Release 21. U. S. Govt. Printing Office, Washington, D. C. Pages 88.
8. Vicente-Chandler, J., F. Abruña, J. Lozano, S. Silva, A. Rodríguez and C. T. Ramírez, 1977. Cultivo intensivo y perspectivas del arroz en Puerto Rico. Bol. 250, Esta. Esp. Agríc., Univ. P. R., Río Piedras, P. R.
9. Yoshida, S., 1981. Fundamentals of Rice Crop Science. The International Rice Research Institute, Manila, Philippines. Pages 65-109.