South East Asian Studies Vol. 11, No.1, June 1973

Soil Water Regime of Rice Lands in South and Southeast Asia

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Introduction

There are some 84 million hectares of rice land, or more than 60% of the world's rice acreage in South and Southeast Asia. The natural environment, especially climate and physiography or their combined effect on water conditions, is generally believed to have favored the rice cultivation of the region.

The water conditions of rice land may be broadly grouped into three categories: rain-fed, irrigated, and water conserved. The last one is important in the relative depressions of alluvial plains and in deltas of great rivers where water accumulates from the surroundings. Thus, in water conservation areas physiographic factors overshadow climatic factors with respect to water conditions.

Irrigated areas have more or less elaborate irrigation installations, such as weirs and canals or sometimes tube wells with pumps, to secure and distribute water effectively. This applies not only to government administered irrigation systems, but also to communally operated ones, though these systems may be quite different in scale.

Even so-called rain-fed rice areas have some means of irrigation, such as small reservoirs, ditches and dikes. However, the source of water is localized and limited, and the influence of climate and such factors as gradient and catchment-rice area ratio have a direct bearing on water conditions in rain-fed rice lands. Thus, rice production here is controlled to a great extent by nature's whim.

Although the author would like to quote pertinent statistics on areas under different water conditions, no adequate statistical data are available. Table 1 shows the area of irrigated rice land and the total area of rice land in some tropical Asian countries in recent years. The irrigated areas in the table sometimes include water conservation areas but sometimes it does not. Thus, it is difficult to see whether unirrigated land areas can be equated to rain-fed rice land areas. Even so, it is safely said from the table that large areas, say more than 50% of the rice land, are still left under rain-fed conditions.

The present paper attempts to clarify the soil water regime of rice lands in South and Southeast Asia, based on the available climatic data. As the approach taken herein has

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Table 1 Areas of Irrigated Rice Land and Total Rice Land in Some Tropical Asian Countries (×1000 ha)

Country	Year	Irrigated	Total
Sri Lanka	1969	403[1)]	530[1)]
India	1964	13430[2)]	35930[2)]
Indonesia	1961	3668[1)]	6857[3)]
Philippines	1966	960[1)]	3096[1)]
Thailand	1967	2039[4)]	6759[5)]

Source: 1) *FAO Production Yearbook*, 1970.
2) *Indian Agriculture in Brief*, 8th Ed., 1967.
3) *Statistik Indonesia, 1964–1967.*
4) *RID/NEDECO Report on Feasibility of Land Consolidation*, 1968.
5) *Statistical Yearbook of Thailand*, No. 29, 1970-1971.

many obvious limitations, the applicability of the results is naturally limited. The findings in this paper would be more directly applicable to the rain-fed and irrigated rice lands than to the water conservation areas.

I Materials and Methods

There are two preceding papers by the author on the climate of South and Southeast Asia. One dealt with a climatic classification according to Thornthwaite's scheme[1)] and the other dealt with a climatic regional division by means of numerical classification[2)]. In this paper the results of these two papers are utilized.

The stations selected for this study are the same 125 stations scattered throughout South and Southeast Asia that were used for establishing climatic groupings in the numerical classification. Table 2 shows the location of the stations together with their climatic region, which is used in this paper as a frame of reference.

The method of water regime computation is basically the same as that used in Thornthwaite's scheme except for the following consideration: levies or banks are built around each rice field in order to pond water during the cropping season. Thus, the following assumptions were put forward for computing soil water regimes.

1. The soil can retain 100 mm. of water in the effective rooting depth of the soil profile, as Thornthwaite assumed.

2. The bank height is 20 cm.; a maximum of 200 mm. of water can be retained and ponded on the field and any excess is lost as run-off.

3. Percolation loss from the ponded water amounts to a maximum of 100 mm. per month, which corresponds to the permeability coefficient of ca. 4×10^{-6} cm/sec.

From the difference between actual precipitation and potential evapotranspiration, which was computed in a previous paper, the surplus or deficiency of water was computed for each month, allowing for the above assumptions. An example of the computation is given in Table 3.

Table 2 List of Stations, Their Location and Climatic Region

Station		Latitude	Climatic Region
No.	Location		
1	Laokay, N. Vietnam	22°30′N	VIII
3	Langson, 〃	21°51′N	VIII
6	Hanoi, 〃	21°30′N	VIII
8	Dong Hoi, 〃	17°29′N	VI
9	Vinh, 〃	18°39′N	VIII
10	Hue, S. Vietnam	16°24′N	VI
11	Quang Tri, 〃	16°44′N	VI
12	Phanthiet 〃	10°56′N	V
13	Tourane, 〃	16° N	VI
15	Qui Nhou, 〃	13°45′N	VI
21	Saigon, 〃	10°47′N	V
23	Hatien, 〃	10°10′N	V
24	Stung Treng, Cambodia	13°31′N	V
25	Siemreap, 〃	13°22′N	V
29	Phnom Penh 〃	11°33′N	V
30	Luang Prabang, Laos	19°53′N	VII
32	Vientiane, 〃	17°57′N	VII
33	Pakse, 〃	15°07′N	V
37	Kota Bharu, W. Malaysia	6°08′N	II
40	Kuala Lumpur, 〃	3°07′N	II
42	Singapore, 〃	1°18′N	I
247	Kulim, 〃	5°23′N	II
249	Sitiawan, 〃	4°13′N	I
251	Kuantan, 〃	3°46′N	II
255	Segamat, 〃	2°30′N	I
44	Sandakan, E. Malaysia	5°50′N	II
46	Labuan, 〃	5°17′N	II
49	Bintula, 〃	3°11′N	II
50	Kuching, 〃	1°29′N	III
51	Tarakan, Indonesia	3°19′N	III
52	Balikpapan, 〃	1°17′N	I
53	Pontianak, 〃	0°01′N	II
54	Mapanget, 〃	1°32′N	III
57	Dili, 〃	8°35′S	I
60	Kupang, 〃	10°10′S	I
62	Medan, 〃	3°35′N	I
64	Padang, 〃	0°56′S	III
67	Surabaya, 〃	7°16′S	I
71	Jember, 〃	8°09′S	I
74	Semarang, 〃	7°00′S	I
77	Wedi-Birit, 〃	7°45′S	I
80	Kuyper, 〃	6°02′S	I

Station No.	Station Location	Latitude	Climatic Region
87	Buitenzorg (Bogor), Indonesia	6°35′S	III
231	Banjarmasin, 〃	3°19′S	I
232	Cirebon 〃	6°42′S	I
233	Cjilatjap, 〃	7°44′S	III
234	Subang, 〃	6°35′S	III
245	Bandung, 〃	6°55′S	III
88	Aparri, Philippines	18°22′N	VI
90	Echague, 〃	16°42′N	V
92	Tacloban, 〃	11°15′N	I
93	Cebu City, 〃	10°20′N	V
94	Manila Airport, 〃	14°31′N	IV
95	Legaspi City, 〃	13°08′N	II
96	Cuyo, 〃	10°51′N	IV
98	Iwahig, 〃	9°44′N	I
100	Dagupan City, 〃	16°03′N	IV
101	Zamboanga City, 〃	6°58′N	V
103	Davao, 〃	7°04′N	I
104	Bhamo, Burma	24°16′N	VII
106	Mandalay, 〃	21°59′N	V
107	Akyab, 〃	20°08′N	IV
108	Yamethin, 〃	20°25′N	V
109	Toungoo, 〃	18°55′N	IV
110	Victoria Point, 〃	9°58′N	IV
111	Rangoon 〃	16°46′N	IV
112	Diamond Island 〃	15°51′N	IV
113	Amherst, 〃	16°05′N	IV
115	Mergui, 〃	12°26′N	IV
118	Srimangai, Bangladesh	24°19′N	VIII
120	Jessore, 〃	23°10′N	VII
122	Cox's Bazar, 〃	21°26′N	IV
124	Bogra, 〃	24°51′N	VII
286	Lahore, Pakistan	31°33′N	IX
292	Multan, 〃	30°12′N	IX
294	Khanpur, 〃	28°39′N	IX
308	Jacobabad, 〃	28°18′N	IX
310	Hyderabad, 〃	25°23′N	IX
127	Mohanbari, Assam, India	27°29′N	VIII
128	Gauhati, 〃	26°05′N	VIII
130	Silchar, 〃	24°49′N	VIII
136	Calcutta, W. Bengal, India	22°32′N	V
138	Cuttack, Orissa, India	20°48′N	V
140	Darbhanga, Bihar, India	26°10′N	VII
145	Daltonganj, 〃	24°03′N	VII

Station		Latitude	Climatic Region
No.	Location		
146	Jamshedpur, Bihar, India	22°49′N	VII
148	Kanpur, U. P., India	26°26′N	VII
154	Raipur, M. P., India	21°14′N	VII
265	Sagar, M. P., India	23°51′N	VII
158	Masulipatnam, A. P., India	16°11′N	V
159	Hyderabad, 〃	17°27′N	VII
160	Visakhapatnam, 〃	17°43′N	V
162	Madras, Mapras, India	13°00′N	V
163	Nagapatlinam, 〃	10°46′N	V
166	Coimbatore, 〃	11°00′N	V
167	Belgaum, Mysore, India	15°51′N	VII
168	Mangalore, 〃	12°52′N	IV
169	Bellary, 〃	15°09′N	V
152	New Delhi, India	28°35′N	VII
267	Kotah, Rajasthan, India	25°11′N	VII
268	Bikaner, 〃	28°00′N	IX
270	Ahmedabad, Gujarat, India	23°04′N	VII
275	Bombay (Calaba), Maharastra, India	18°54′N	IV
276	Ratnagiri, 〃	16°59′N	IV
281	Akola, 〃	20°42′N	VII
170	Colombo, Sri Lanka	6°54′N	II
173	Hambantota, 〃	6°07′N	V
180	Anuradhapura, 〃	8°21′N	V
180	Batticaloa, 〃	7°43′N	II
188	Chiang Rai, Thailand	19°55′N	VII
190	Chiang Mai, 〃	18°47′N	VII
197	Tak, 〃	16°50′N	V
198	Loei, 〃	17°32′N	VII
202	Mukdahan, 〃	16°33′N	VII
204	Chaiyaphum, 〃	15°45′N	V
207	Surin, 〃	14°53′N	V
210	Nakhon Sawan, 〃	15°48′N	V
213	Kanchanaburi, 〃	14°01′N	V
215	Bangkok, 〃	13°44′N	V
217	Aranyaprathet, 〃	13°42′N	V
219	Chanthaburi, 〃	12°37′N	IV
222	Prachuap Khiri Khan, 〃	11°48′N	V
224	Ban Dan, 〃	9°08′N	V
226	Songkhla, 〃	7°13′N	II
230	Trang, 〃	7°30′N	V

Table 3 Computation of Soil Water Regime for Station No. 111 (Rangoon)

(in mm.)

Month	1	2	3	4	5	6	7	8	9	10	11	12	Year
Potential Evapotranspiration	92	100	145	167	176	158	162	152	147	152	138	103	1692
Rainfall	8	5	6	17	260	524	492	574	398	208	34	3	2529
Soil Moisture	0	0	0	0	84	100	100	100	100	100	100	0	—
Ponded Water	0	0	0	0	0	200	200	200	200	156	0	0	—
Percolation	0	0	0	0	0	100	100	100	100	100	52	0	552
Run-off	0	0	0	0	0	50	230	322	151	0	0	0	753
Deficiency	84	95	139	150	0	0	0	0	0	0	0	0	468

II Results and Discussions

The results are summarized in Table 4 and 5, and some examples of water regime patterns are illustrated in Fig. 1 for stations selected from each of the climatic regions established earlier.

Table 4 groups the stations according to the available water regime, based on the number of consecutive months over which soil moisture is available. It is obvious from the table that the climatic regions I, II, III, IV, VI, and VIII have more favorable water regimes than the climatic regions V, VII, and IX. This is not surprising for Region IX, which is classified either as arid or semi-arid according to Thornthwaite's method, but it is rather surprising to find that a fairly high percentage of the area within Region V and VII has a water regime so severe that it cannot support even a single short-term upland crop.

Table 4 shows the number of stations in each climatic region falling into various categories of ponded water regimes. In the preparation of this table, a water regime that has

Table 4 Grouping of Sample Stations according to Climatic Region and Available Water Regime

Climatic Region	Available Water Regime lasting consecutively for				Sum
	⩽3 months	4–6 months	7–9 months	⩾10 months	
I	1	2	5	9	17
II	0	1	1	10	12
III	0	0	0	8	8
IV	0	3	11	1	15
V	10	11	11	0	32
VI	0	0	6	0	6
VII	4	5	11	1	21
VIII	0	0	2	6	8
IX	6	0	0	0	6
Sum	21	22	47	35	125

Table 5 Grouping of Sample Stations according to Climatic Region and Ponded Water Regime

Climatic Region	Ponded Water Regime lasting consecutively for				Sum
	⩽2 months	3 months	4–6 months	⩾7 months	
I	6	3	7	1	17
II	0	2	3	7	12
III	0	0	0	8	8
IV	0	0	12	3	15
V	25	4	3	0	32
VI	0	0	5	1	6
VII	12	4	5	0	21
VIII	1	1	4	2	8
IX	6	0	0	0	6
Sum	50	14	39	22	125

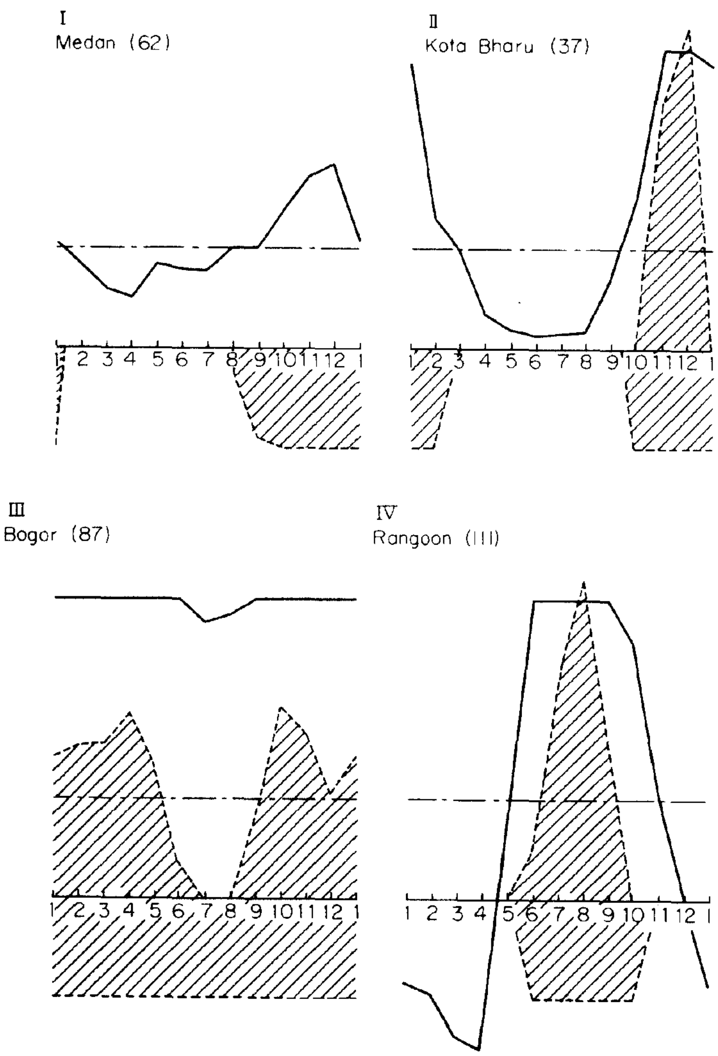
less than or equal to 2 consecutive months of ponded water is thought to be prohibitive for rice cultivation. A regime having three consecutive months of ponded water is regarded as marginal. Four to six months of ponded water may be sufficient for growing one crop of rice. Ponded water regimes lasting over 6 months would have some problems in drainage.

Based on the results given in Table 4 and 5, the following remarks may be made on each climatic region. Regions I, II, III, IV, VI, and VIII are generally suited for rice cultivation even under rain-fed conditions. Region I, Straight-Sunda Region, is peculiar in that it has areas where surplus of water is available for a considerable length of time but only a short period of ponded water regime or none at all prevails on the field. This type of water regime seems to be common in the southern half of the west coast of West Malaysia, and is better suited for multiple cropping of upland crops. Furthermore, within Region I a subregion can be demarcated to separate the northern coast and the eastern half of the island of Java and area farther east therefrom, where a distinct dry season lasts at least for 4 months. But even here one crop of rice is cultivable depending solely upon rain water.

Region II, Malay-Northern Borneo Region, seems to be good for one crop of rice during the rainy season and one crop of upland crop for the rest of the year. In some areas cultivation of the second crop may be somewhat risky without providing supplementary irrigation.

Region III, Oceanic Sumatra-West Java Region, has plenty of rain throughout the year and double cropping of rice should present no difficulties even without a large scale irrigation plan. In this region upland crop cultivation may face drainage problems rather than irrigation problems.

The greater part of Region IV, Southwest-Facing Coastal Region, experiences a distinct dry period lasting for more than 4 months. One crop of rice can be safely cultivated, but a second crop is not cultivable unless some form of irrigation facility is provided.



Fgi. 1 Pattern of Soil Water Regime for Stations representative of Each of the Nine Climatic Regions

Region VI, Middle Vietnam Region, is similar to the above mentioned Region IV, in its soil water regime, but the dry period is not as severe as that in Region IV.

Region VIII, Tongking-Assam Region, has a favorable water regime for one crop of rice and one upland crop thereafter. Here low temperatures during the winter months pose some difficulties for the cultivation of certain crops.

In contrast to the above regions, Regions V, VII, and IX are generally not suited for rice cultivation due to their unfavorable soil water regimes. Twenty-nine out of 32 stations in Region V, Southern Indochina-Southern India Region, 16 out of 21 in Region VII, Central India-Northern Indochina Region, and all of the 6 stations in Region IX, Lower Indus Region, are either prohibitive or marginal for rice cultivation under rain-fed conditions.

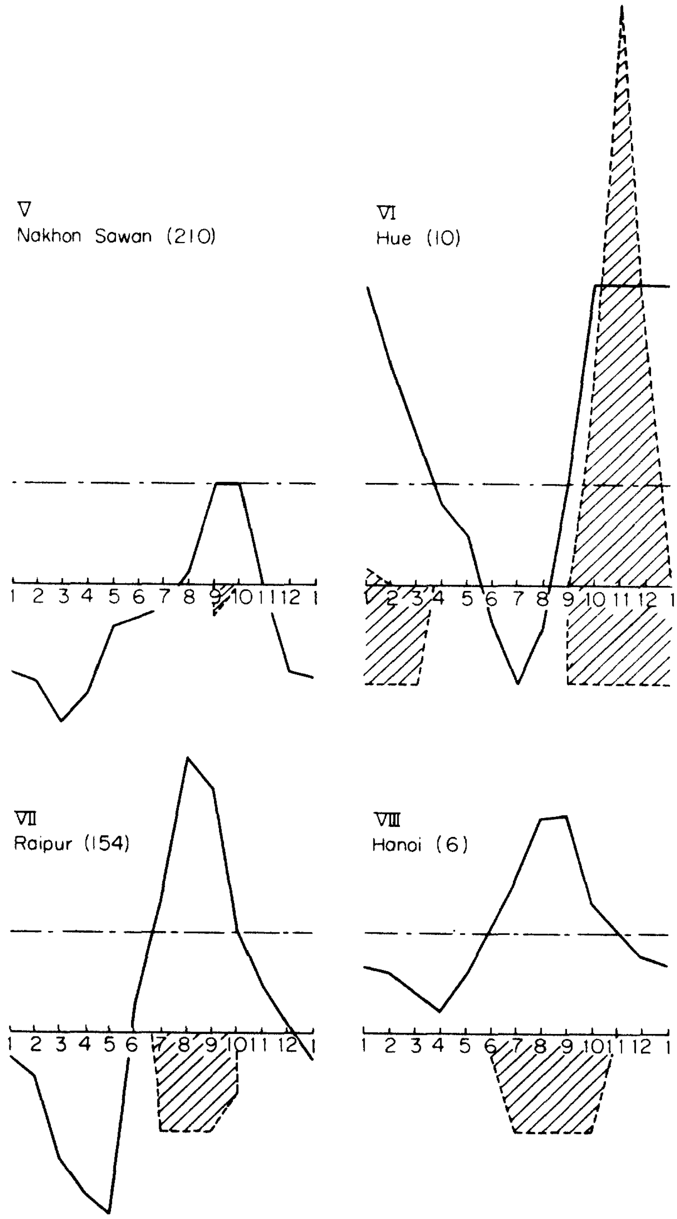


Fig. 1 continued

Important rice areas occurring in these regions are either completely irrigated, as in Region IX, or located in water conservation areas, mostly at the mouth of great rivers where the land is naturally inundated for 3–4 months during the cropping season due to physiographic conditions. However, the greater part of the rice lands in Cambodia, Thailand, and India, countries which belong to Region V and VII, are neither completely irrigated, nor located within water conservation areas, thus being in a very unstable condition with respect to water supply. A considerable year-to-year fluctuation of the planted area for rice and/or large damaged areas occurring in these countries every year can be cited as evidence of this in-

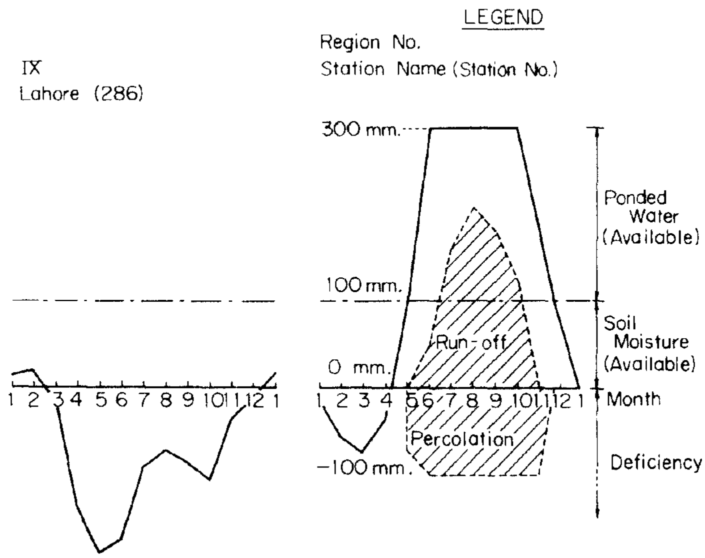


Fig. 1 continued

stability, caused by unfavorable soil water regimes.

The above computations and discussions have been based on a long term average of meteorological data. It is, however, well known that the monsoon tropical climate is quite unstable, and the timing and the amount of rainfall can fluctuate very drastically from year to year. Thus, the soil water regime as illustrated in Fig. 1 should be looked at as being one of the more frequent patterns that are possible at the site.

The validity of the assumptions we have made must also be checked. The first assumption of 100 mm. of water retention by the soil has often been questioned. The amount of water retention varies with texture, content of organic matter, and structure of the soil. In view of the wide variability in these soil properties even within one climatic region, the assumption of 100 mm. of water retention appears to be the best alternative.

Percolation loss is set at 100 mm. per month, assuming a difficult-to-permeate subsoil layer with the permeability coefficient of 4×10^{-6} cm./sec. If permeability is better than this, the percolation loss becomes larger, and the water regime tends to be more unfavorable except in cases of excessive rainfall, such as in Region III. In most rain-fed rice lands the percolation loss is generally larger than assumed.

III Summary

Patterns of soil water regimes of rice lands in different climatic regions of South and Southeast Asia were clarified by computing monthly surpluses or deficiencies of water at 125 selected stations in a manner similar to Thornthwaite's method. Basic assumptions adopted were relevant to the rice field condition, as follows: 1) 100 mm. of water retained

by the effective depth of the soil, 2) 20 cm. of bank height to pond a maximum of 200 mm. of water, and 3) 100 mm. per month of percolation loss from the ponded water.

The results revealed that the greater part of the rice lands in Pakistan, India, Thailand, and Cambodia are either prohibitive or marginal for rice cultivation unless the land is artificially irrigated or naturally inundated due to physiographic conditions. Most of the rest of the area are generally suited for cultivating at least one crop of rice even without elaborate irrigation facilities. The water regime study suggests the possibility of more intensive land use for certain areas.

Acknowledgement

The author is greatly indebted to Drs. Y. Takaya and Y. Kaida, Center for Southeast Asian Studies, and to Mr. H. Fukui, Faculty of Agriculture, for their invaluable discussions and perusal of the manuscript.

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