Long-term and spatial evaluation of rice crop performance of rain-fed paddy fields in a village of Northeast Thailand

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ABSTRACT **Rice production has been monitored at 8005 plots of rain-fed paddy field in a village in Northeast Thailand for the period from 1978 to 2002. Rice crop was evaluated and classified into 4 classes, i.e. "good", "poor", "crop failure" and "no planting". Distribution mapping of crop performances showed a large variability among plots, and also extreme changes among years mainly due to flood and drought. All paddy fields were classified into 8 types by cluster analysis. Lower and unstable production was observed in upper paddy fields. Areas with poor yield and no planting paddy fields have decreased in recent years owing to expanding supplementary irrigation and the direct seeding method. Supplementary irrigation is carried out by purchasing water from canals or sucking up river water using engine driving pumps at planting time or severe drought. This indicates that a gradual improvement in rice production is possible with rain-fed rice cultivation. However, large crop failure still occurs frequently especially in areas nearer to rivers.**

Key words: rain-fed rice cultivation, production, Northeast Thailand, GIS

INTRODUCTION

Rice production in Northeast Thailand has been defined as lower yields and less stable than that of Northern and Central areas in general according to the agricultural statistics and numerous observations (KKU-Ford Cropping System Project 1982, Fukui 1993). These characteristics have been understood to be the results of rain-fed cultivation under the scarce and erratic rainfall, and poor soil fertility in the region.

Miyagawa *et al.* (1985) reported the apparent relationship between rice cultivation and production, and topographical location of paddy fields of a village in Northeast Thailand, and suggested that such relationship was caused by the difference of water condition among topographical locations. Then they classified all paddy fields into 3 types such as upper, middle and lower paddy fields according to their topographical location. According to the measurement of rice yield in the farmers' rice fields in 1981 and 1983, the yield was extremely lower in the drought year than in the abundant rain year, and the decrease of yield was remarkable in the upper paddy fields (Kuroda & Miyagawa 1987). Miyagawa and Kuroda (1988a, b) showed that the water condition was the most effective factor controlling the rice growth and yield than rice varieties and soil fertility in the rain-fed rice cultivation; hence they suggested the necessity of improvement of water condition by irrigation.

It is necessary to verify the suitability of such relationship between rice production and topographical location of the paddy fields for at least several successive years under the variable amount of rainfall over the years. But a long-term study on rice production of every paddy plot is unavailable because it is difficult to carry out the actual rice yield measurement by the cutting method on thousands of paddy plots in a village every year. However, we have been monitoring the crop performances on all paddy fields of one village in Northeast Thailand since 1981. The results were mapped by GIS and the property of each paddy field with respect to rice yield was analyzed on the maps. Mapping is a more useful way to intuitively understand the yield distribution and find out the obstacles to growth of rice in relation to the distribution of landform, rivers, salt spots, roads etc.

This study aims to show the close relations between the variability of rice yield and water condition by a long-term observation in rain-fed paddy fields, and the effects of supplemental irrigation which was introduced by farmers recently. Such information could be useful future inputs to rice cultivation and improve landuse and agricultural production. Moreover this method can be effectively used in agro-production analysis in village studies for rice growing areas.

STUDY SITE AND METHODS

Don Daeng village of Khon Kaen province in Northeastern Thailand designated in Fig.1 is a typical rain-fed rice growing village. Paddy fields are located on hilly areas as well as the floodplains of Chi River, which is the main tributary of Maekhong River. A total of eight thousand and five plots (537ha) which are cultivated by farmers of Don Daeng and neighboring villages were studied. Paddy areas were classified into three topographic types; upper, middle and lower paddy fields as in Fig.2 according to the results of landform unit survey (Miyagawa *et al.*, 1985). A total of seventeen landform units were recognized within the area shown on the paddy plots map by Hattori (Hattori *et al.*, 1983), then they were summarized into three topographic types. Upper paddy fields contain the units of valley-washout, hill-top, trough-washout, trough-remnant flat, shallow trough, elevation-levee, elevation-flat and elevation-ridge. Middle paddy fields contain valley-sideslope and trough-sideslope. Lower paddy fields include valley-hollow, valley-bottom, valley-headslope, channel, trough-hollow, trough-bottom, and trough-headslope. The normal height difference from the bottom of the lower paddy field to the top of the upper paddy field was merely one meter or a maximum of 4–5 meters. However this small difference strongly affects the difference in water regimes among paddy fields. Annual precipitation was 1182mm in average for the period from 1978 to 2002 at Thapra town 4km west of the village. Most of the rainfall events were observed in the rainy season during the period from late April to the middle of October in Table 1.

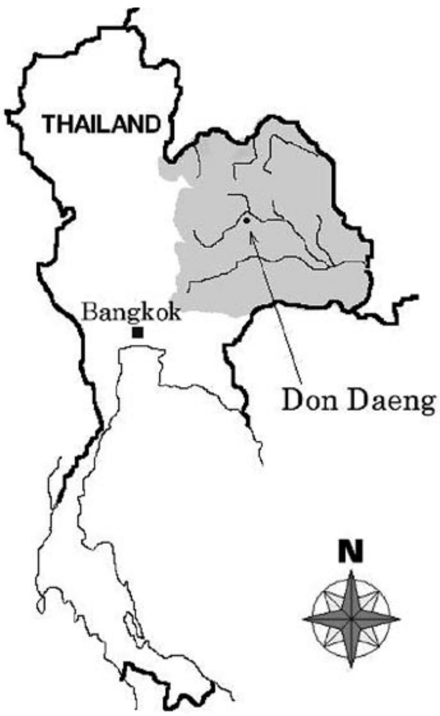

Fig. 1. Location of study site. Area colored with gray shows the Northeast Thailand.

In early 1980s, rice was transplanted in the middle of rainy season as in July, August and September, but planting time was variable among the various years depending on the rainfall distribution and among plots of different water conditions. Harvesting season started from late October and ended in early December. The differences in harvesting time among paddy fields was the result of the different earliness of planted rice variety, such as early, medium and late which were traditional and photosensitive. Numerous varieties were replaced by two medium maturing varieties of RD6 (glutinous) and Khao Dawk Mali (non-glutinous) in 1990s. Small amounts of fertilizer application became popular in the 1990s. The area of direct seeded paddy field became more than the area of transplanted field in 2000s. Direct dry seeding method is usually adopted in the paddy field where supplemental irrigation for transplanting is not available or the operating farmer has insufficient labor. Some farmers who have a plenty of transplanting labor or have been suffered from sever weed damage in direct seeded field prefer transplanting method. The yield of transplanted rice is higher than that of direct seeded rice in general (Miyagawa *et al.* 1998, Tomita *et al.* 2003). Seed sowing is carried out for the period from April to July in Don Daeng.

The evaluation of rice crop performances was carried out by a skilled villager on each patch of paddy field using paddy-plot maps for the period from 1978 to 2002. At the maturing time of rice of every paddy field, crop performances were evaluated on the basis of 4 classes as good yield (good), poor yield (poor), no yield of planted paddy field (crop failure) and unplanted field (no planting). Poor yield was distinguished from good yield by the presence of damage by drought, flood and/or salinity. Then it was recorded on the maps. Map database and geographical analysis were carried out by GIS software (ArcInfo 6, ESRI).

RESULTS AND DISCUSSION

Geographical distribution of crop performances

The results of evaluation for crop performances at each plot of paddy field every year were mapped on Fig. 3. Almost all plots showed "good" in only four years: 1983, 84, 92 and 1998. "No planting" plots were shown

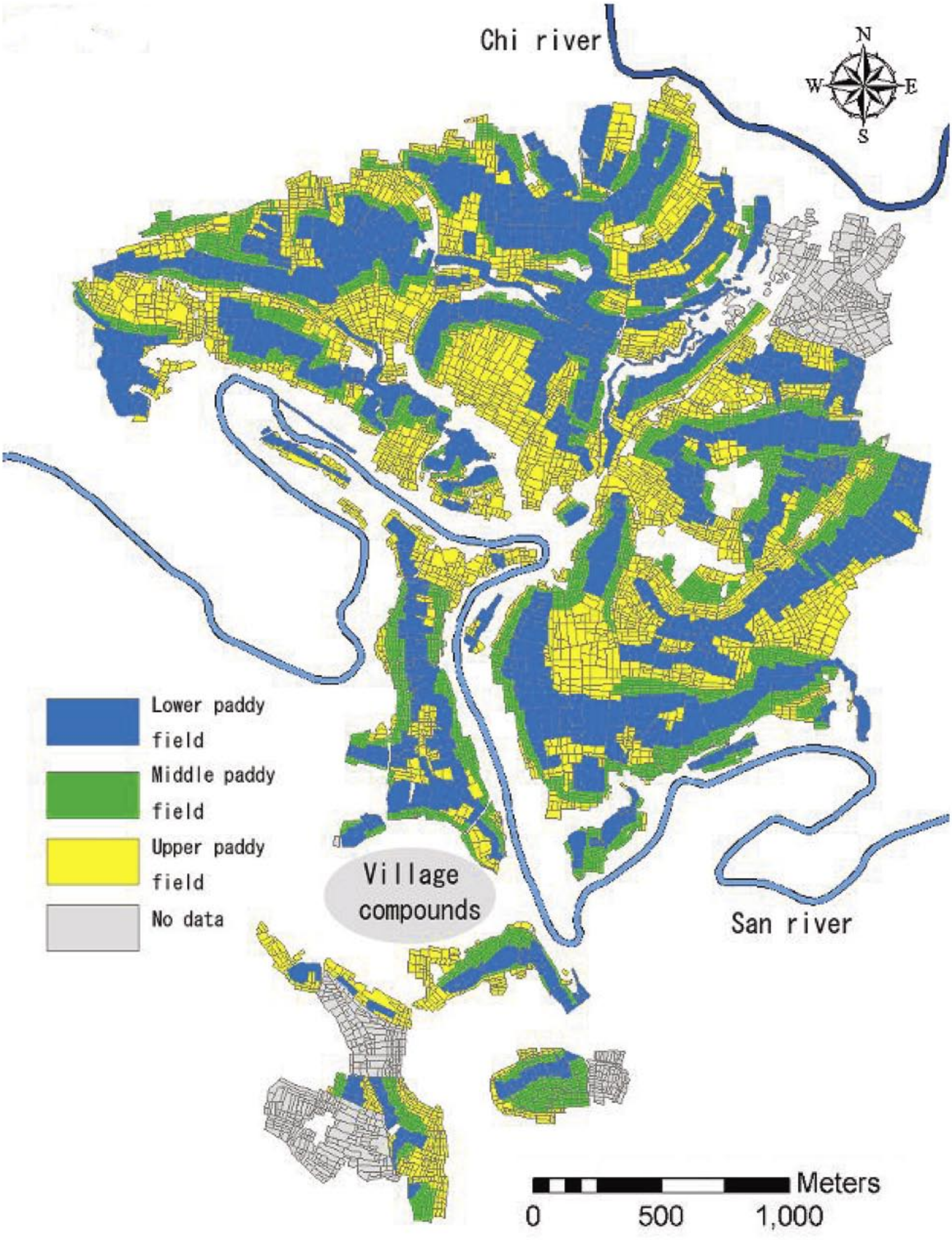

Fig. 2. Landform of paddy fields in Don Daeng village.

Table 1. Monthly rainfall (mm) at Thapra.

Year	Jan.	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total	Event
1978	36.8	1.0	12.0	89.9	171.4	189.9	324.9	147.0	534.9	47.4	3.7	0.0	1558.9	flood
1979	0.0	10.4	0.0	254.6	198.2	190.5	73.9	292.9	312.6	0.0	0.0	0.0	1333.1	drought
1980	0.0	0.0	30.2	55.4	235.5	247.6	107.8	234.7	272.9	77.2	0.2	0.0	1261.5	flood
1981	0.0	2.4	20.0	55.6	262.2	140.0	210.5	94.5	71.5	186.2	34.5	0.0	1077.4	
1982	0.0	124.3	136.9	23.8	150.9	92.5	128.3	94.3	439.3	108.8	2.5	8.4	1310.0	drought
1983	7.3	5.4	3.5	22.8	95.6	258.3	97.7	356.5	185.1	201.4	8.3	0.0	1241.9	
1984	0.9	42.4	12.8	136.4	101.3	245.0	138.8	215.5	170.0	82.1	4.9	0.0	1150.1	
1985	2.1	10.1	18.9	155.9	122.4	131.4	114.6	111.6	250.7	101.9	1.9	0.0	1021.5	drought
1986	0.0	0.0	19.6	135.6	192.4	151.1	77.5	164.3	120.8	117.2	0.0	3.1	981.6	drought
1987	0.0	86.2	16.9	56.5	145.4	133.3	106.5	230.6	159.6	97.1	42.2	0.0	1074.3	drought
1988	0.0	24.6	11.5	98.8	266.5	178.7	146.4	65.7	121.0	202.9	0.1	0.0	1116.2	
1989	0.0	0.0	36.0	48.0	168.6	148.2	157.4	100.9	126.6	227.2	0.4	0.0	1013.3	drought
1990	0.0	38.6	137.9	51.1	177.9	260.8	177.0	185.0	251.4	162.7	13.2	0.0	1455.6	
1991	0.0	0.0	6.4	9.7	217.1	30.9	99.4	482.0	265.2	76.5	0.0	14.2	1201.4	flood
1992	17.2	14.9	0.0	65.6	65.1	81.2	209.3	174.2	205.1	86.1	0.2	18.2	937.1	
1993	0.5	6.7	16.7	41.6	105.1	131.9	102.4	126.1	370.1	44.4	0.0	0.3	945.8	
1994	0.0	39.0	43.8	10.1	101.2	232.8	4.2	129.5	346.2	10.3	6.9	66.8	990.8	
1995	0.0	2.7	97.0	222.5	122.7	101.9	102.7	163.8	490.8	101.5	32.0	0.0	1437.6	flood
1996	0.0	4.3	100.7	67.5	82.5	96.9	158.7	91.9	252.1	133.8	2.4	0.0	990.8	
1997	0.0	62.0	41.2	93.7	177.2	197.8	149.6	255.5	75.1	73.4	43.9	0.8	1170.2	
1998	4.2	0.0	61.9	240.6	268.4	259.7	110.1	34.1	139.9	43.7	5.3	0.0	1167.9	
1999	0.2	31.6	1.6	182.4	285.0	254.9	207.8	320.7	307.8	100.8	0.0	0.0	1692.8	
2000	0.2	0.0	33.0	42.5	171.8	160.5	126.3	215.6	262.3	217.6	13.6	0.0	1243.4	flood
2001	13.7	1.4	61.0	37.1	75.7	89.8	79.2	151.6	434.6	194.0	38.7	33.6	1210.4	
2002	0.0	39.7	178.6	94.0	111.5	100.5	33.9	239.2	189.8	30.4	0.0	0.0	1017.6	flood
Mean	3.3	21.9	43.9	91.7	162.9	164.2	129.8	187.1	254.2	109.0	10.2	5.8	1184.0	

remarkably at upper paddy fields in 1979, 82, 85, 86, 87 and 89. This was the result of the rain shortage at the planting season. Especially, "no planting" paddy fields at upper paddy fields accompanied with "crop failure" plots at middle paddy fields and "poor" plots at the lower paddy fields were observed in 1979 and 1982. This was the result of the continuing rain shortage from the planting time to growing stage. After the long period of rain shortage, concentrated downpour in September damaged young rice in 1982. In 1986, 87 and 89, "poor" paddy fields at the middle paddy fields adjacent to the "no planting" plots at the upper paddy fields were detected. This was induced by severe drought in those years. The corresponding average rice yield of "good" and "poor" crop performances were 1.9 (n=158) and 1.4 t/ha (n=44) respectively according to the cutting survey in 1981.

On the other hand "crop failure" plots were recorded at the lower paddy fields in 1978, 80, 91, 95, 2000 and 2002. In 1978 and 80, crop failure resulting from tremendous floods in most paddy fields except the southern part of paddy fields on hilly areas. Small floods have attacked the lower paddy fields of northern part in 1996 when a poorer crop yield was recorded in such area. Floodwater originated from the Chi River, so there was a higher possibility of flooding in the northern area. Also another flooding source was the San River, so lower paddy fields adjacent to village compound occasionally showed "crop failure".

It was difficult to find out the apparent relationships between monthly rainfall and crop performances in each year because the effect of rainfall is different for different rice growing stages. The variable beginning time of rainy season, variable occurrence of dry spell in rainy season and erratic daily rainfall affect the changes of transplanting time, transplanted area and growth stage of the rice (Kaida *et al.*, 1985, Miyagawa *et al.*, 1985)

The percentage of average area of each crop performance class by landform is shown in Table 2. Crop performances on lower paddy fields showed the highest percentage of "good" and the lowest percentage of "no planting" among the landforms. On the contrary, no planting area percentage of upper paddy field was higher and "crop failure" area of upper paddy field was lower than those of middle and lower paddy fields. The difference

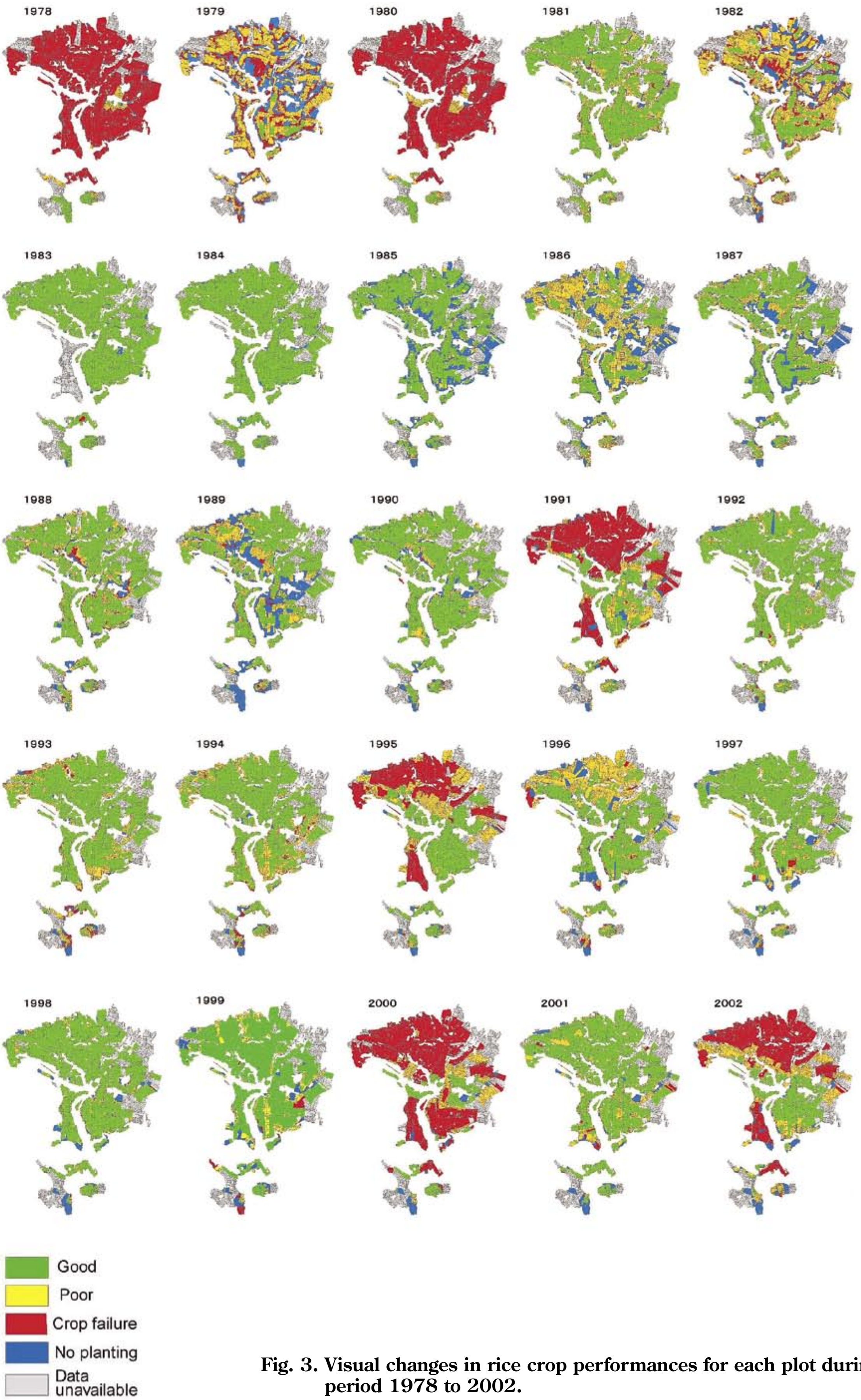

Fig. 3. Visual changes in rice crop performances for each plot during the period 1978 to 2002.

Table 2. Average area percentage of rice crop performances in the paddy fields classified by landform for the period 1978 to 2002.

Crop performance classes	Lower paddy fields (%)	Middle paddy fields (%)	Upper paddy fields (%)	Total (%)
No planting	3.3	12.2	12.5	8.4
Crop failure	17.5	17.8	16.4	18.1
Poor	12.9	20.8	19.2	16.9
Good	66.3	49.3	51.9	56.7

was not significant statistically.

Year-to-year changes of the area of each crop

Figure 4 shows the percentage cover of each crop performance class from 1978 to 2002. The area of "no planting" exceeded the mean value remarkably were appeared in the years 1979, 1986, 1985, 1989, 1987 and 1982 in a decreasing order. The highest value, 24.3%, was recorded in 1979. The values after 1990 became lower than those of previous years. The area of "crop failure" exceeded the mean value in 1978, 1980, 2000, 1991, 2002, 1995 and 1979 in a decreasing order. In 1978, it reached a value of 91.7%. There were few years of the large "crop failure" area recorded but the covering areas were extremely broader than those of "no planting" except for 1979. On the other hand, no area under "crop failure" was recorded in 1984, 1985, 1986 and 1987. Less than 1% was recorded in 1981, 1983, 1992 and 1998. Such small values did not appear in other classes, indicating that the flooding easily attacked the rice on a large scale whenever it occurred. The "poor" areas exceeded the mean value remarkably in 1982, 1986, 1979 and 1996 in a decreasing order. Higher values than mean value were observed also in 2002, 1995, 1989, 1994 and 1981. The highest value, 47.8%, was recorded in 1982. Comparing the trend of the values of "crop failure" and "poor" with the value of "no planting", the large values of former classes still appear in recent years. The "good" areas exceeding the mean value remarkably were recorded in 1983, 1984, 1998 and 1992 in a decreasing order. The values of 2001, 1997, 1990, 1993, 1994, 1981, 1999, 1988, 1985 and 1987 were also higher than the mean value. The highest value of 98.3%, was registered in 1983, while, the lowest value of 3.5%, was recorded in 1979. In the successive 3 years of 1978, 79 and 80 the area of "good" was almost 4% owing to large values of the area of "no planting" "crop failure" and "poor."

Evaluation of productivity of each paddy field by the appearance frequency of crop performance classes

To summarize the property of each paddy field on productivity through 25 years, all paddy fields were classified into 8 production types by the cluster analysis where the samples were plots of paddy field and parameters were the appearance frequency of respective crop performance classes of the plot during 25 years. The calculation was carried out by the application of Euclidean distance and the centrobaric technique. According to the composition of the appearance rate of each crop, the property of each cluster was summarized as follows (Table 3): type1; good yield with high stability, type 2; high stability of planting and harvesting, type 3; ordinary, type 4; high possibility of poor yield, type 5; low opportunity of planting, type 6; low opportunity of planting with high possibility of poor yield, type 7; low opportunity of planting and harvesting and type 8; scarce opportunity of planting. The largest area was obtained under type 3, followed by the type 1, while the least area was obtained under type 7.

Relationship between production types and landform is shown in Table 4. In the lower paddy fields, type 1 area was more than half of total area followed by type 3 area. The area estimated for other types was very small. The percentage area of each type was similar in the middle and upper paddy fields. Area of type 3 was the largest in both paddy fields but the area percentage of latter paddy fields was slightly smaller than that of former paddy fields. The area of type 1 and type 5 were comparatively large in the upper paddy fields than in middle paddy fields.

The distribution of production types is shown in Fig. 5. Type 1 plots were located usually in the lower paddy fields except for the area close to Chi River. The type 3 plots were usually situated in the middle paddy fields and the lower paddy field near Chi River where flooding damaged the rice occasionally. Other classes were mostly situated in the upper paddy fields. The difference in the distribution among classes in the upper paddy fields might have resulted from the detailed differences in the

Table 3. Average rate of crop performances and total area classified by the cluster analysis.

Production types	Rate of crop performances (%)				Total area (%)
	No planting	Crop failure	Poor	Good	
1	3.6	13.9	12.3	70.3	36.1
2	6.4	4.8	30.0	58.8	2.2
3	8.3	20.8	20.2	50.7	45.9
4	15.4	17.8	40.4	26.4	3.7
5	25.6	12.1	12.5	49.8	5.8
6	32.3	13.6	26.8	27.2	3.8
7	38.1	30.8	10.1	20.9	0.2
8	60.5	9.5	10.3	19.6	2.4

Table 4. Distribution of production types in the paddy fields classified by landform.

Production types	Area (%)		
	Lower paddy fields	Middle paddy fields	Upper paddy fields
1	58.7	14.4	21.1
2	0.8	2.7	2.6
3	35.5	57.9	51.6
4	0.3	7.7	5.4
5	2.6	6.6	9.3
6	0.4	7.1	5.9
7	0.0	0.4	0.3
8	0.8	3.2	3.8

topography and the decision made by farmers. The plots of type 8 were more in the hilly areas of the central and southern parts where the planting was abandoned by salinity damage in the latter.

Changes of productivity

In Fig.4, the area ratio of "no planting" did not show values more than 20% after 1990. According to an interview granted to farmers and observation, spreading of supplementary irrigation and direct seeding have been promoted in the planting area although rain shortage occurred. The supplementary irrigation is carried out in the paddy fields close to San River or to the ponds by pumping up the water using small gasoline engine driving pumps. Other paddy fields that are close to the canals are irrigated by purchased canal water. Farmers who particularly own the fields near rivers, ponds and canals, and are able to pay the costs as well can irrigate their paddy fields at the transplanting time and/or at the occurrence severe drought. Total irrigated area is hence variable among the years. Coincidently, the ratio area of "poor" reduced after 1990.

The percentages of the number of years of "good" out of the observed years except for no record years for the period from 1978 to 1989 were compared in each plot with that for the period from 1990 to 2002. Figure 6 shows the difference between two percentages (the percentage of latter period minus that of former period). The plots in which the rate increased were found in the upper paddy fields in the Fig.6. Especially it was obvious in the area along the irrigation canal which has gradually extended since 1982, and in the area close to rivers. Supplemental irrigation was effective for improving crop performances in such areas. On the contrary, the rate reduced in the lower paddy fields located in the northern part and near to the San River. The productivity of these areas has been recently reduced by flooding as shown in Fig.3. The southernmost part of paddy fields also showed negative values because of abandoned cropping. In recent years, farmers are giving up rice cultivation in these areas and resorting to fish farming. On the whole, the frequency of "good crops" became higher in this village. Hence rice

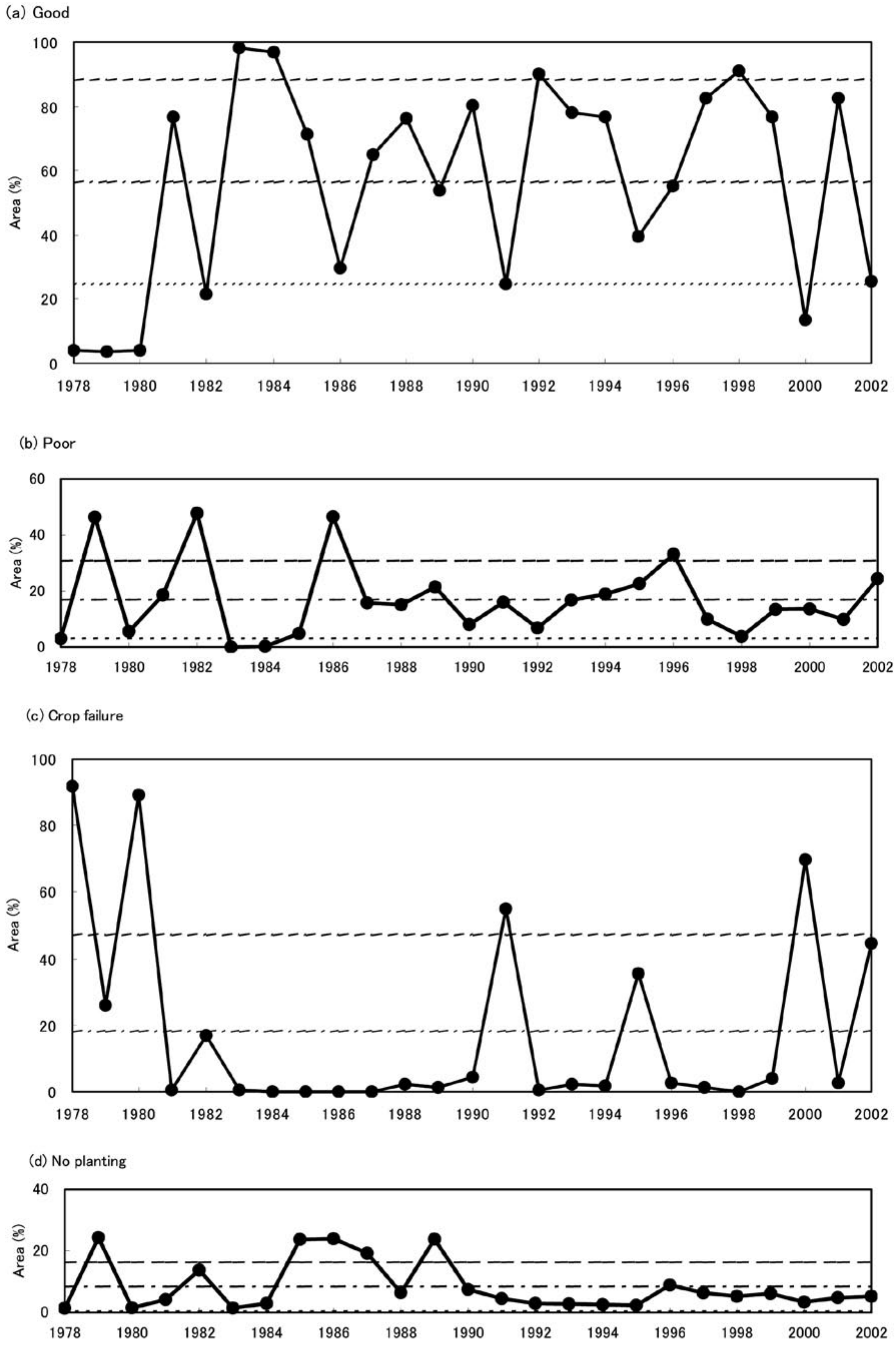

Fig. 4. Percentage changes in the land area covered by each class of crop performances. — — — —, —·—·—· and --------- show mean+ σ , mean and mean- σ of 25 years, respectively.

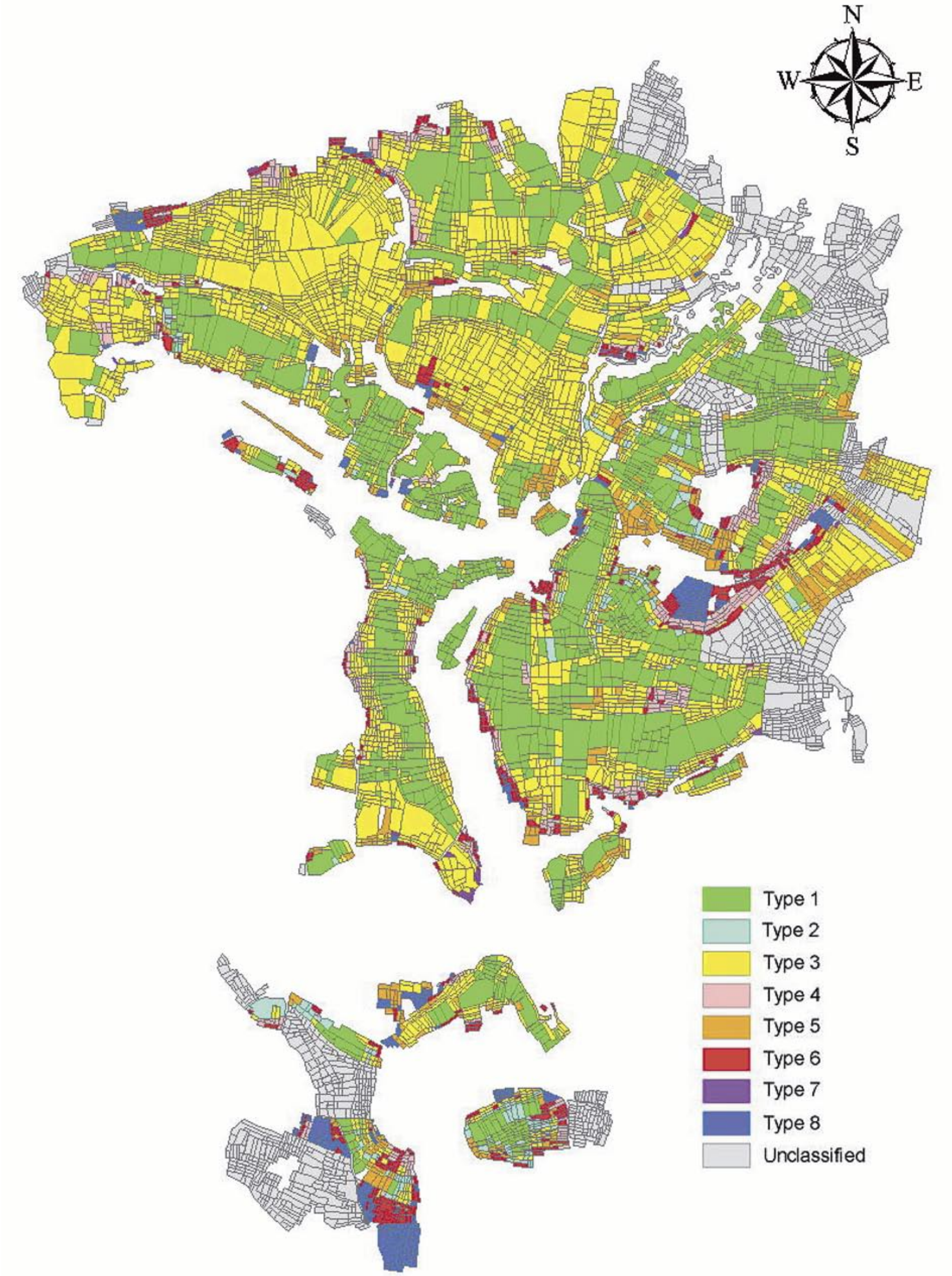

Fig. 5. Distribution of production types of individual paddy field of Don Daeng village.

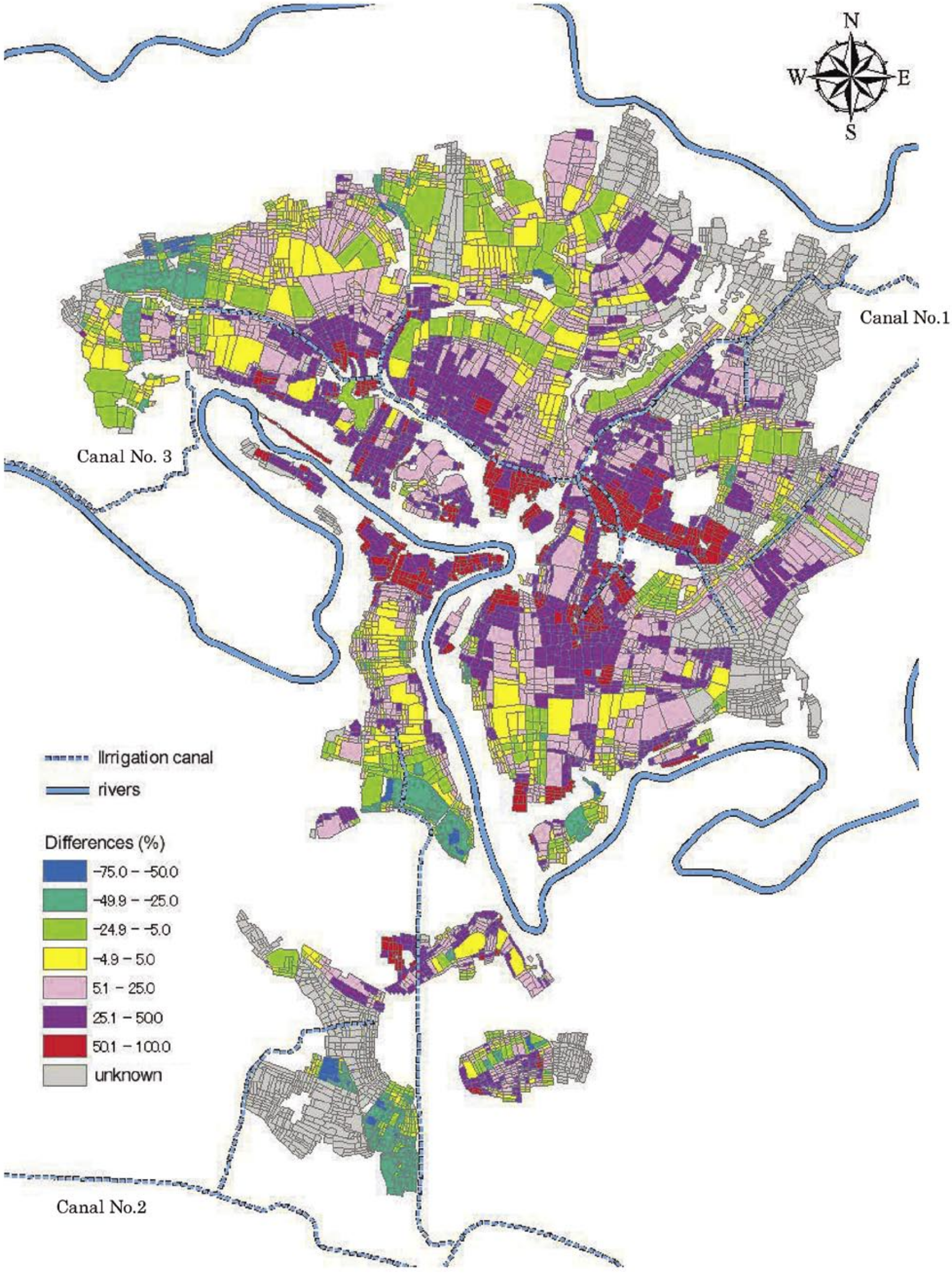

Fig. 6. Differences of good crop observed rate between the years from 1978 to 1989 and the years from 1990 to 2002. Irrigation canals of No. 1, 2 and 3 were completed in 1984, 2003 and 2005, respectively.

yield per harvested area has been increasing gradually owing to chemical inputs and improved rice variety, in addition to supplemental irrigation and direct seeding, as reported previously (Miyagawa 2004).

In general, drought by small rainfall in the early stage of the rainy season reduced planted area while that in the late stage of the season increase poor yield area of rain-fed paddy fields. The direct seeding method can secure the planted area, and supplemental irrigation using canal water can prompt transplanting area and prevent crop failure at the drought. Flooding by excess rainfall can damage the rice in lower paddy fields. The extent of the damage due to injury is usually larger than that of drought in terms of area. It is difficult to find out a means of avoiding flooding damage. Such properties of rain fed rice cultivation were recognized also in this study through long term observation.

This study could lead to the possibility of an appropriate land utilization scheme by the mapping of rice production. It will be useful in the formulation of local policy in rainfed rice growing villages of Northeastern Thailand. Also, the recent tendency in rice production of the sample village shows the possibility of a reasonable improvement in the rice productivity through small scale technical innovations.

ACKNOWLEDGEMENTS We are grateful to Mr. Ma Phanna in Don Daeng village for his persistent cooperation since the beginning of this study. A part of the research was supported by a Grant-in Aids for Scientific Research (No.14252001) from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

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Received 26th July 2005
Accepted 2nd Dec. 2005