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# Introduction of Direct Seeding and Selection of Farmland in Rainfed Rice Fields in Small Water Sheds in Northeast Thailand

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## Abstract

Paddy rice cultivation in rainfed areas in northeast Thailand has been practiced mainly by transplanting. However, the introduction of direct seeding is increasing in rainfed paddy fields for a variety of reasons, including saving on labor. To elucidate the relationship between the introduction of direct seeding, the selection of paddy lots, and precipitation in rainfed paddy field, we surveyed two small watersheds in Nong Saeng village, Khon Kaen prefecture, central-northeast Thailand. The surveys were carried out on a lot-by-lot basis between 2002 and 2004. In 2002, despite the lagging expansion of transplanting due to low precipitation in the early rainy season, direct seeding was not introduced. On the other hand, in 2003, direct seeding began before the transplanting area was expanded after rainfall in late August. In 2004, direct seeding began in the early rainy season of June and July. As to its relationship with topography, direct seeding was not conducted in the lower paddy fields in one watershed. However, the ratios of direct seeding increased in the middle and upper paddy fields in both watersheds in 2004. There were few households that did not continue direct seeding cultivation after introduction.

**Discipline:** Watershed and regional resources management
**Additional key words:** farmland use, direct seeding, watershed

## Introduction

The direct seeding method of rice planting spread in the early 1990s in rainfed paddy fields in northeast Thailand. The ratio of direct seeding areas in northeast Thailand was about 25% in 1997, the lowest in the whole country. Dry seeding has been adopted as a method of direct seeding in rainfed paddy fields (Sumita and Ando, 2002). Until the 1980s, dry seeding had been observed only in fields vulnerable to drought or flooding, and most fields were transplanted in northeast Thailand. Economic growth transformed land-use and agriculture, and a typical example of transformation was the change in planting methods from transplanting to dry seeding (Konchan and Kono, 1996). However, it is said that dry seeding is difficult to introduce in the paddy fields without stable water ponding throughout the rainy season (Kono, 1991). Therefore, transplanting has continued in the water-starved paddy fields in the upper stream of the plateau.

Rice seedlings must be transplanted in a short period of time after rainfall in rainfed paddy fields without any irrigation facilities. However, the characteristics of precipitation in northeast Thailand include not only large fluctuations in annual precipitation but also fluctuations in when the rainy season begins and ends, and in patterns of precipitation. Therefore, farmers could not finish transplanting within the required time or they abandoned pad-

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dy rice planting in those paddy lots without suitable water use conditions for some years. In addition, it is difficult to obtain manpower for intensive transplanting after rainfall, with increasing guest labors out of farming villages. Therefore, dry direct seeding in rainfed paddy fields is increasing in the upper stream region in northeast Thailand. To elucidate the relationships among the direct seeding introduction, the selection of paddy lots, and precipitation in the upper stream region, we examined rice planting, water ponding, and the location of each paddy lot in Nong Saeng village, Khon Kaen province, central-northeast Thailand.

The introduction of direct seeding was an anomaly in Nong Saeng in 2002. However, direct seeding has flourished since 2003, and continued to be practiced in 2009. All of the direct seeding was carried out by dry seeding. We surveyed planting and ponding in each paddy lot between 2002 and 2004 to elucidate the relationship between the land use of paddy fields and water use conditions. The history of development in northeast Thailand is not long, and methods of planting and farming have changed quickly. Hence, it is unclear that direct seeding will become established in the rainfed paddy fields of northeast Thailand. This study provides the results of the survey of the introduction of direct seeding in two watersheds in Nong Saeng and the relationship between the introduction of direct seeding and farm lot conditions.

## Survey method

### 1. Survey region

The survey was carried out in the two watersheds in Nong Saeng village, Khon Kaen province, northeast Thailand. These watersheds are located in the upper part of Chi River, a tributary of Mekong River. Nong Saeng is located 30 km south of the city of Khon Kaen. It is located on a plateau about 200 m above sea level. There are many shallow valleys of the upper Chi River. The floor and both sides of the valleys are used for rice paddy fields and the ridges of the plateau are mainly used for upland fields to cultivate cash crops, such as sugarcane and cassava. Meanwhile, upland rice cropping has increased in the fallow period of sugarcane during the rainy season since around 2003.

The paddy fields are located in the survey regions stretching along the valley. They form several steps from the floor of the valley to both sides of valley. There are no rivers in the watershed and when surface runoff occurs, the runoff flows from paddy to paddy. A great number of water ponds have been constructed on the floor of the valley and along the boundaries between the paddies and the upland fields. These ponds are not connected to any water-collecting facilities outside the watersheds. Each paddy lot is a rainfed paddy dependent only on the rainfall in its own basin. Therefore, the rice paddy crop is a single crop during the rainy season, and the second crop in the dry season is comprised of vegetables for self-consumption and upland crops, such as cassava, in some parts of the lots.

### 2. Method

The surveys were carried out on a lot-by-lot basis. Planting and water ponding were surveyed in all the paddy lots in the watersheds from June 2002 to February 2005. The surveys were carried out every two weeks in 2002 and on a weekly basis after 2003 in principle. At the same time, precipitation was measured by a tipping-bucket rain gauge. In 2005, a survey of planting in the rainy season was executed once in both watersheds to examine the establishment of direct seeding.

The planting and water ponding data were accumulated using GIS software (ILVIS). The GIS data from the paddy lots were generated from a satellite image using QuickBird (acquired in 2002). At first, planting in each lot was classified into three categories by usage: paddy rice planting, the planting of other crops, and no planting. Paddy rice planting was then classified into four categories by planting method and stage. The other crops were classified into six categories by crop species. Classifications are shown in Table 1. Water melon planting and horticulture were limited to the dry season.

Each paddy lot was classified into three categories by location in the valley (Fig. 1). A lot on the valley floor was a lower paddy field. A lot on the first and the second step from the valley floor was a middle paddy field. A lot on the third step or above was an upper paddy field. Thus, there was no upper paddy field in a transverse direction without more than three steps, according to Fig. 1.

The ponding area was limited to part of each paddy lot in some cases because the levels in each lot were un-

**Table 1. Classification of paddy field use**

| Rice planting | Other crops | No planting |
|---|---|---|
| Nursery | Sugarcane | |
| Transplanting | Cassava | |
| Direct seeding | Beans | |
| Harvesting | Corn | |
| | Water melon* | |
| | Horticulture* | |

* Only in dry season

even in the survey region. Water ponding was surveyed with ratio of ponding area in each lot with visual measurements. Ponding was classified into classes 0 to 4 (Table 2). The ponding area of the fields was calculated by multiplying each lot area as follows: Class 0 by 0, Class 1 by 0.2, Class 2 by 0.5. Class 3 by 0.8, and Class 4 by 1.

## Results and discussion

### 1. Paddy field placement and water use facilities

Satellite images of the surveyed watersheds are shown in Fig. 2. Each surveyed watershed was called NS-1 and NS-2, as shown in Fig. 2. The area of NS-1 was 155.2 ha and the area of NS-2 was 65.5 ha. The percentage of the farmland area was 67% and 89%, respectively, while the percentage of the paddy field to farmland was 22% and 31%, respectively. The number of paddy lots was 293 and 209, respectively. It was often the case that the alignment of the paddy lots at the headstream in Nong Saeng was a continuously spread-out sector pattern. NS-2 was a representative example of this alignment. We presumed that this alignment was formed to secure irrigation water for the upper step paddy lots with water distribution from the upstream lower lot to the downstream contour lots. However, this alignment has not been maintained recently because farmers have been irrigating by using an engine pump transporting water from ponds located around the lower to neighboring upper lots. As a result of the introduction of engine pumping irrigation, it is presumed that the farmers do not need to consider water distribution to downstream paddy lots. The sector pattern paddy lot alignment in NS-2 was maintained due not only to geographical condition but also proper management by only family-organized farmers. Thus, it is presumed that observation of the paddy use rule in NS-2 effectively protected alignment in the watershed. NS-1 was managed by 12 farmers, and NS-2 was managed by nine farmers.

As previously mentioned, ponds were constructed as facilities for water use. There were 31 ponds in NS-1 and 15 in NS-2 as of April 2002. One pond was constructed in each watershed between April 2002 and the end of 2004. Meanwhile, four ponds in NS-1 and one pond in NS-2 almost lost their water storage function due to sedimentation caused by eroded soil from the upper fields. Paddy rice was sometimes planted in part of the sedimented ponds.

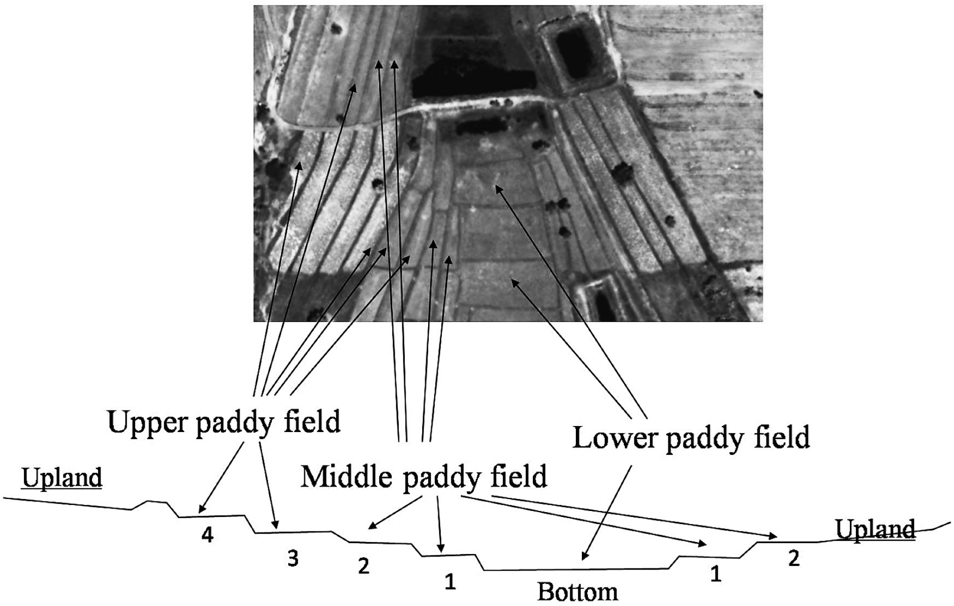


**Fig. 1. Classification of paddy fields by location**

**Table 2. Classification of paddy water ponding**

| Ponding area (%) | 0 % | 10–30 % | 40–60 % | 70–90 % | 100 % |
|---|---|---|---|---|---|
| Class | 0 | 1 | 2 | 3 | 4 |

**2. Precipitation during observation term**

The monthly precipitation throughout the observation term is shown in Table 3 with the existing data of average precipitation over 11 years (1991–2001) in Ban Haed. The distance between Ban Haed and the observation point in Nong Saeng was about 8 km.

The majority of northeast Thailand is located in the climatic zone of 1,200–1,400 mm in annual precipitation. In northeast Thailand, the transitions between the rainy season and the dry season are clear. However, the start and end of the rainy season is not clear (Wada, 1997).

Comparing the monthly precipitation of the observation point and the 11-year average precipitation at Ban Haed, characteristics of precipitation during the observation period were as follows: (Ogura *et al*., 2007)

・ A little precipitation in the early rainy season (precipitation lower than the average precipitation in Ban Haed in June and July) in 2002 and 2003.
・ Precipitation in September 2002 was higher than September precipitation records collected at Ban Head.
・ Early end of rainy season (zero precipitation after 21 September) in 2004.
・ Late end of rainy season (rainfall in November and December) in 2002.


NS-1 NS-2

**Fig. 2. Distribution of paddy fields in survey watershed**
**P** : Paddy field, **U** : Upland field, **F** : Forest, ➘ : Pond, ——— : Boundary between paddy and upland field.

**Table 3. Monthly precipitation (mm)**

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Amount |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2002 | | | | | 156* | 89 | 64 | 222 | 411 | 178 | 13 | 29 | 1,162 |
| 2003 | 0 | 72 | 125 | 11 | 74 | 80 | 101 | 157 | 361 | 17 | 0 | 0 | 998 |
| 2004 | 23 | 67 | 2 | 129 | 91 | 165 | 167 | 186 | 122 | 0 | 0 | 0 | 951 |
| 1991–2001** | 0 | 9 | 30 | 68 | 133 | 157 | 126 | 165 | 244 | 76 | 15 | 2 | 1,025 |

*: Observations started on 2nd of May.
**: Observed at Ban Haed 8 km far from observation point. It is average precipitation of 11 years (1991–2001).

・ Abnormal precipitation (rainfall in January and February) during ordinary dry season.

The precipitation in September 2002 was higher than the maximum monthly precipitation in 11 years in Ban Haed. Precipitation had never occurred in January in those 11 years. Thus, the fluctuation of precipitation in the observation term was comparatively large even in northeast Thailand, which is a region known for fluctuating precipitation.

In relation to paddy rice planting, the gentle rain of the first half of the rainy season in 2002 and 2003 influenced planting methods. In addition, irrigation using the reservoir supply was carried out to avoid a drought at the early end of the rainy season in 2004.

**3. Rice planting paddy lots each year**

The paddy rice planting lots between 2002 and 2004 are shown in Fig. 3 with the planting method and the upland crop planting lots. Figure 3 shows the situation at the end of seeding or transplanting in 2002, 2003, and 2004, so the dates of the maps are different in each year. Transplanting was practiced in the part of the lots where direct seeding was practiced in 2003 and 2004. Upland crops were cultivated in some lots after the rice was cut before the harvest in 2003 and 2004. The annual ratio of the final paddy rice planting area to the total area is shown in Table 4. Sugarcane was planted on some lots in the middle and upper paddy fields in NS-1 in 2002. Therefore, these lots were exempted from rice planting in 2003. The calculation of the ratio of the rice planting area in 2003 excludes the sugarcane planting area in Table 4.

Paddy rice planting in 2002 was done by transplanting in the survey region. However, direct seeding was introduced in 2003, and the direct seeding area increased until 2005.

The rice planting lots of both survey watersheds varied year by year as shown in Fig. 3. The ratio of the rice planting area of all paddy fields was from 78% to 98% as shown in Table 4.

By paddy location, the ratio of the rice planting area in the lower paddy fields was over 90% every year in both watersheds. On the other hand, the ratio of the rice planting area in the upper paddy fields fluctuated year by year. The ratio of the rice planting area was under 50% in NS-2 in 2002. The result of the investigation by Caldwell shows that the highest paddy lots were cultivated about once every five years (Caldwell *et al.*, 2002).

Major upland crops, such as sugarcane and cassava, were planted in the middle and upper paddy fields in both surveyed watersheds all year round. Interviews in NS-1 revealed that farmers who cultivated sugarcane in the middle and upper paddy fields selected crops for planting by the stock of surplus rice for self-consumption and the price of upland crops.

**4. Expansion of each planting method each year**

The rice nursery for transplanting was usually prepared in June in the survey region. Transplanting took place as soon as the water for puddling was secured by precipitation and storage water in the ponds. Usually puddling and transplanting took place on the same day. It was preferable that transplanting was finished by August since the varieties of rice in the survey region were RD-6 (glutinous rice) and RD-15 (non glutinous rice), which are photosensitive and need enough time for vegetative growth before heading in mid-October.

**(1) 2002**

All paddy rice planting was executed with transplanting in both survey watersheds. The planting area increased by two steps in early to mid-July and late August to September as shown in Fig. 4. Table 3 shows low precipitation continued until late August in 2002. It has been suggested that planting stagnated between late July and mid-August due to the low precipitation. However, 118 mm of precipitation in August came after 28 August. It is presumed that transplanting continued until September due to the unsuitable distribution of precipitation for transplanting in 2002. Considering the locations, the ratio of the planting area of the lower paddy fields was 64% in NS-1 and 74% in NS-2 in mid-July. On the other hand, the ratio of the planting area in the upper paddy fields was only 12% in NS-1 and 24% in NS-2 around the same time. The increase in the planted area between mid-July and late August was only 5% in NS-1 and 3% in NS-2. The planted lots in this period of time were mainly in the lower paddy fields, whereas no lots were planted in the upper paddy fields. Figure 4 shows that the final ratio of the planted area of the lower paddy fields in 2002 was over 90% in both surveyed watersheds. However, the ratio of the planted area in the upper paddy fields was almost half of the area in both watersheds.

**(2) 2003**

Transplanting was not executed before early August in NS-1 and mid-July in NS-2. However, in NS-1, direct seeding was conducted in 18% of the lower paddy fields in mid-July, followed by an expansion in direct seeding area in both the middle and upper paddy fields until late August. After late August, the transplanting area was expanded, and transplanting was executed again in some parts of the direct seeding lots. The expansion of the transplanting area coincided with the precipitation. The ratio of the final transplanting area in NS-1 was 54% and the direct seeding area was 35%.

Transplanting started in late July in NS-2. However,

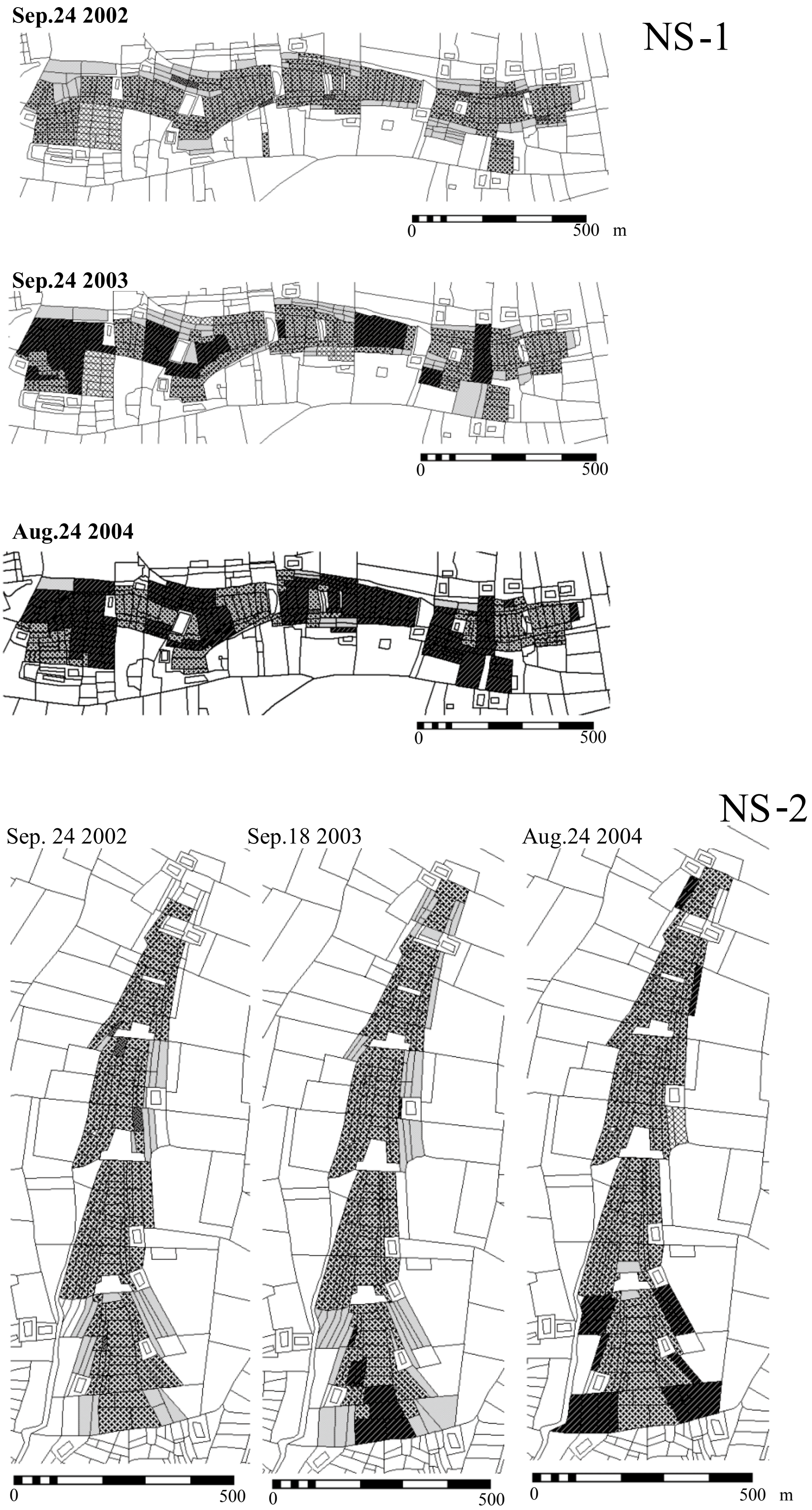


**Fig. 3. Paddy lot use in each year**

: Trans planting, : Direct seeding, : Upland crops, : Nursery, : No planting.

the timing of the expansion was late compared with 2002. Direct seeding was executed in 11% of NS-2 paddy fields mainly in August, whereas transplanting was executed in parts of the direct seeding lots. The final transplanting area was 71% and the direct seeding area was 9% in NS-2.

There was little precipitation between April and July in 2003. Little precipitation in the early rainy season was thought to be one cause of delay to transplanting. The delay for the second consecutive year was estimated to be a factor in the introduction of direct seeding.

**(3) 2004**

In NS-1, planting by direct seeding started in late May, and 61% of the paddy fields were planted by direct seeding in early July. Meanwhile, transplanting started in mid-June, and 39% of paddy fields were cultivated by transplanting in early August. Thus, all paddy fields were planted by this time. Direct seeding generally proceeded in the upper paddy fields, while transplanting proceeded in the lower paddy fields. In NS-2, 15% of the paddy fields were cultivated by direct seeding and by transplanting between early June and mid-July. After late July, planting was executed only by transplanting and was almost finished by early August. Direct seeding proceeded in the upper paddy fields and transplanting proceeded in the middle paddy fields. The entire area in the lower paddy fields was planted by transplanting.

Precipitation between June and August in 2004 was higher than the average in Ban Haed over the past 10 years, so it was estimated that the precipitation did not affect rice planting.

The ratio of the direct seeding area in 2005 was 65% in NS-1 and 49% in NS-2. On the other hand, the transplanting area was 17% and 28%, respectively. Thus, the direct seeding area was expanding.

**Table 4. Ratios of rice planting area**

| Area | Location | 2002 | 2003 | 2004 |
|---|---|---|---|---|
| NS-1 | Whole | 78% | 89% | 97% |
| | Lower paddy field | 93% | 98% | 100% |
| | Middle paddy field | 78% | 87% | 97% |
| | Upper paddy field | 60% | 79% | 94% |
| NS-2 | Whole | 79% | 81% | 98% |
| | Lower paddy field | 98% | 100% | 96% |
| | Middle paddy field | 88% | 88% | 100% |
| | Upper paddy field | 49% | 55% | 98% |

## 5. Relationship between introduction of direct seeding and location of paddy lots

Figure 5 shows the annual variation in the ratio of direct seeding and transplanting area in each location. The ratio was calculated by dividing the final transplanting or direct seeding planting area by the entire paddy field area, including unused and upland crop planting fields.

In NS-1, the transplanting area continuously decreased, while the direct seeding area continuously increased from 2002 to 2004 in the lower, middle, and upper paddy fields in spite of the increase or decrease in the total area of rice planting. Meanwhile, in NS-2, the direct seeding area increased continuously in the middle and upper paddy fields, but direct seeding was not executed in the lower paddy fields in 2004. Moreover, the ratio of the transplanting area of the upper and middle paddy fields in 2004 was higher than the ratio in 2003. That was attributed to the fact that in 2004 transplanting was executed in time due to comparatively high precipitation in the early rainy season. Figure 3 shows that the fields that introduced direct seeding in 2003 were mainly lower paddy fields comparatively far from the ponds, and the upper and middle paddy fields around this direct seeding farm were not cultivated in 2003. In 2004, direct seeding was introduced mainly in these upper and middle paddy fields that were not cultivated in 2003.

## 6. Introduction of direct seeding in each farm household

The ratios of the direct seeding area to the whole paddy fields including the non-planting area in each household's paddy lots during the term of the survey are shown in Table 5. Twelve households in NS-1 were assigned numbers from 101 to 112 beginning downstream, and nine in NS-2 were assigned numbers from 201 to 209.

There were few households in the both watersheds that did not continue direct seeding after introduction, as shown in Table 5. Interviews with some farmers in the surveyed watersheds in 2005 revealed that it was during transplanting in 2003, when there was little precipitation, that direct seeding was introduced for the first time. The reason for continuing and increasing direct seeding was due to difficulties in securing transplanting labor. Despite suitable conditions for transplanting, the reason why direct seeding was introduced in NS-1 was presumably also labor shortages.

## 7. Water ponding in paddy lots

Ponding in almost all paddy fields in the rainfed regions in northeast Thailand was only for a limited period of time during the rainy season. Figure 6 shows the variation of the ratio of water ponding area in each farmland location in 2002 where all planting lots were transplanted. The ratio of ponding area passed 80% only once on September 3 during the observation days with continuous rain in both watersheds. The ponding ratio rapidly decreased after that.

Table 6 shows the maximum ratio of ponding area in both watersheds by location and year. The ratio of ponding areas in the lower paddy fields in both watersheds

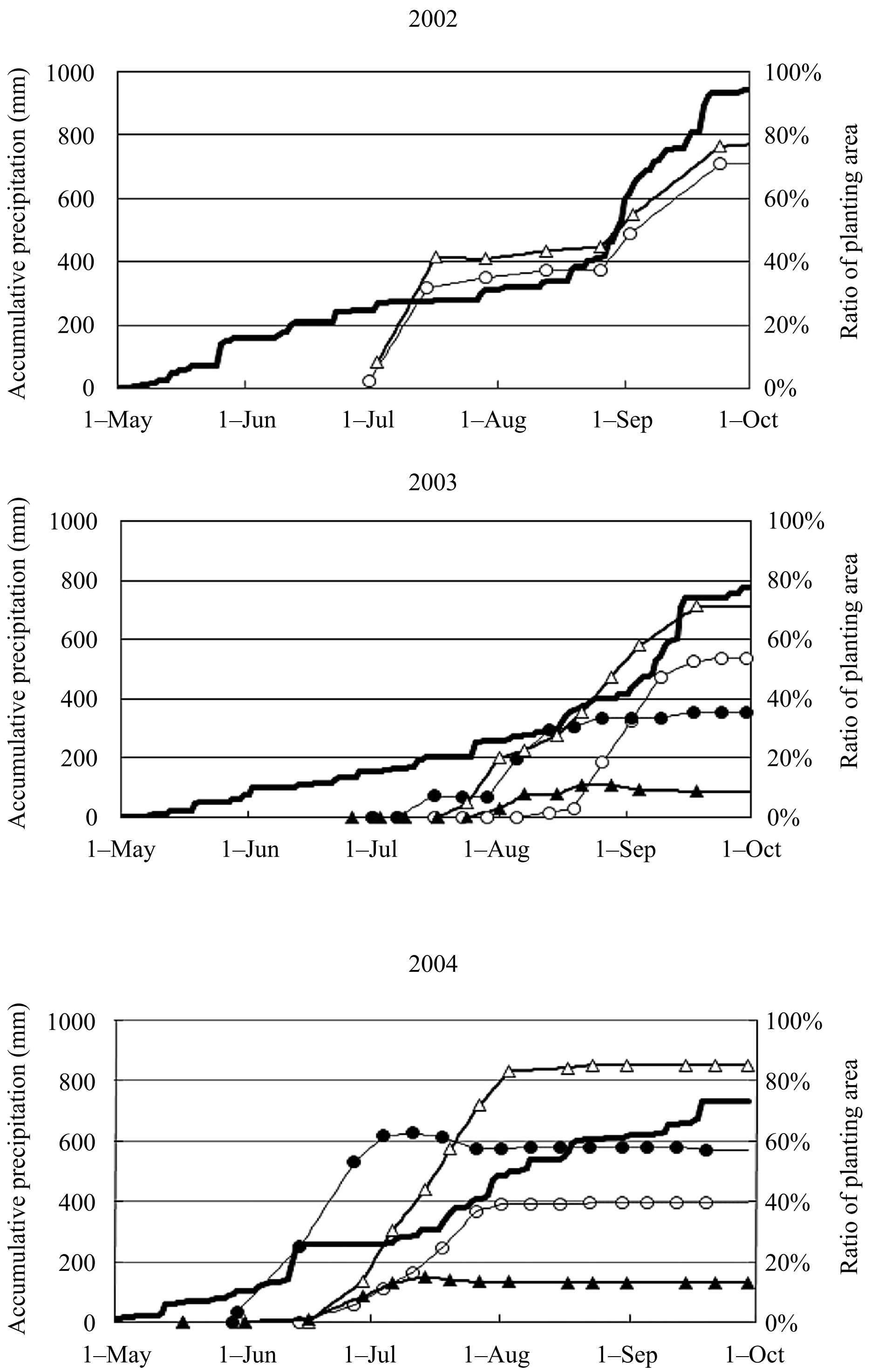


**Fig. 4. Introduction of direct seeding in each year**

——— : Accumulate Precipitation,

—○— : NS-1 Transplanting, —●— : NS-1 Direct seeding, —△— : NS-2 Transplanting, —▲— : NS-2 Direct seeding.

was over 85% at a maximum from 2002 to 2004. On the other hand, the ponding areas in the upper paddy fields were under 60% at a maximum except in 2003. The maximum ratio of ponding areas was observed on September 3, 2002, in both watersheds. In 2003, the maximum ratio of ponding areas was observed on September 9 in NS-1 and September 18 in NS-2. In these two years, ponding in the upper and lower paddies were observed on the same day. In 2004, the observed day was different. Observation was conducted in NS-1 on September 21 in the upper paddy fields, on August 3 in middle paddy fields, on August 24 in the lower paddy fields, and in all paddy fields on September 21. The upper and middle paddy fields in NS-2 were observed on August 25, and the lower paddy fields, and all paddy fields on June 18.

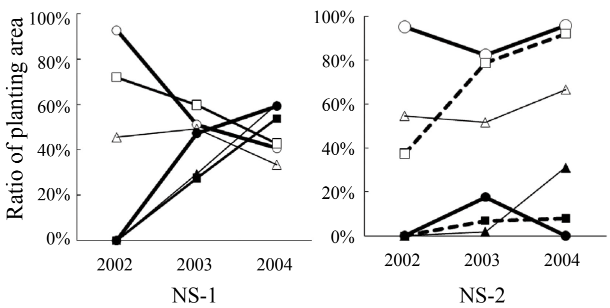


**Fig. 5. Relationship between the ratio of annual transplanting and direct seeding areas and the location of paddy fields**

—○— : Transplanting Lower paddy field,
—●— : Direct seeding Lower paddy field,
- □ - : Transplanting Middle paddy field,
- ■ - : Direct seeding Middle paddy field,
—△— : Transplanting Upper paddy field,
—▲— : Direct seeding Upper paddy field.

The results of the water ponding survey show that stable ponding is difficult in paddy lots located even in lower paddy fields in the surveyed watershed. The introduction of direct seeding is difficult in well-drained paddy fields without deep ponding in the rainy season (Kouno 1991). We investigated the relationship between paddy water ponding in 2002 and planting in 2003 in each paddy lot. The water ponding situation in 2002 was ascertained from the sum of the ponding area class observed three times between September and early October. As a result of the investigation, the term of the water ponding in the unused paddy lots in 2003 was clearly shorter compared to cultivated rice paddies However, there was little difference in ponding between the direct seeding lots and the transplanting lots. This tendency was common in both watersheds. Accordingly, the water ponding condition in each paddy lot under transplanting was not considered to have affected the selection of lot for the introduction of direct seeding for the following year.

Figure 7 shows the relationship between the average area of water ponding after planting and the planting

**Table 5. Ratio of direct seeding area in each farm household**

NS-1

| Household | 101 | 102 | 103 | 104 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2003 | 67% | 53% | | 39% | | 3% | 74% | 13% | 39% | | | |
| 2004 | 50% | 94% | | 56% | | 65% | 100% | 65% | 41% | 100% | | 43% |

NS-2

| Household | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 |
|---|---|---|---|---|---|---|---|---|---|
| 2003 | 57% | 22% | 2% | | | 1% | | | |
| 2004 | 36% | 13% | 47% | | | | 8% | | 11% |

**Table 6. Maximum ponding area by year**

| Watershed | NS-1 | | | | NS-2 | | | |
|---|---|---|---|---|---|---|---|---|
| Location | Whole | Lower paddy field | Middle paddy field | Upper paddy field | Whole | Lower paddy field | Middle paddy field | Upper paddy field |
| 2002 | 86% | 100% | 85% | 68% | 85% | 100% | 88% | 70% |
| 2003 | 73% | 92% | 68% | 56% | 62% | 87% | 53% | 45% |
| 2004 | 65% | 85% | 64% | 50% | 72% | 94% | 70% | 57% |

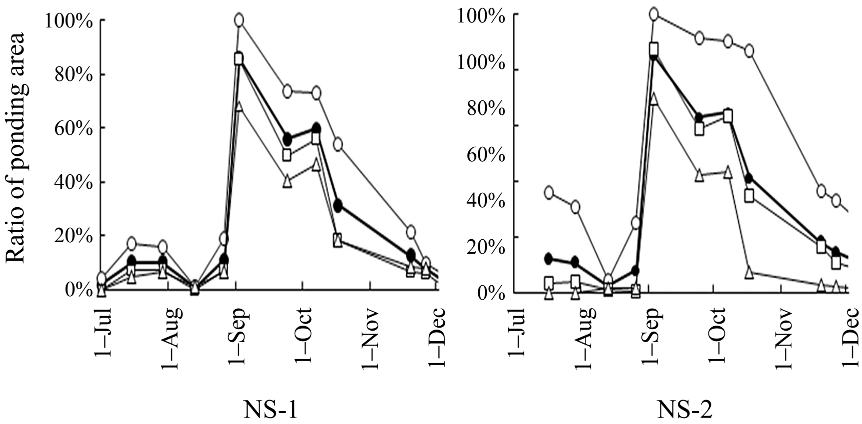


**Fig. 6. Variation of ponding area by location in 2002**
—●— : Whole, —○— : Lower paddy field, —□— : Middle paddy field, —△— : Upper paddy field.

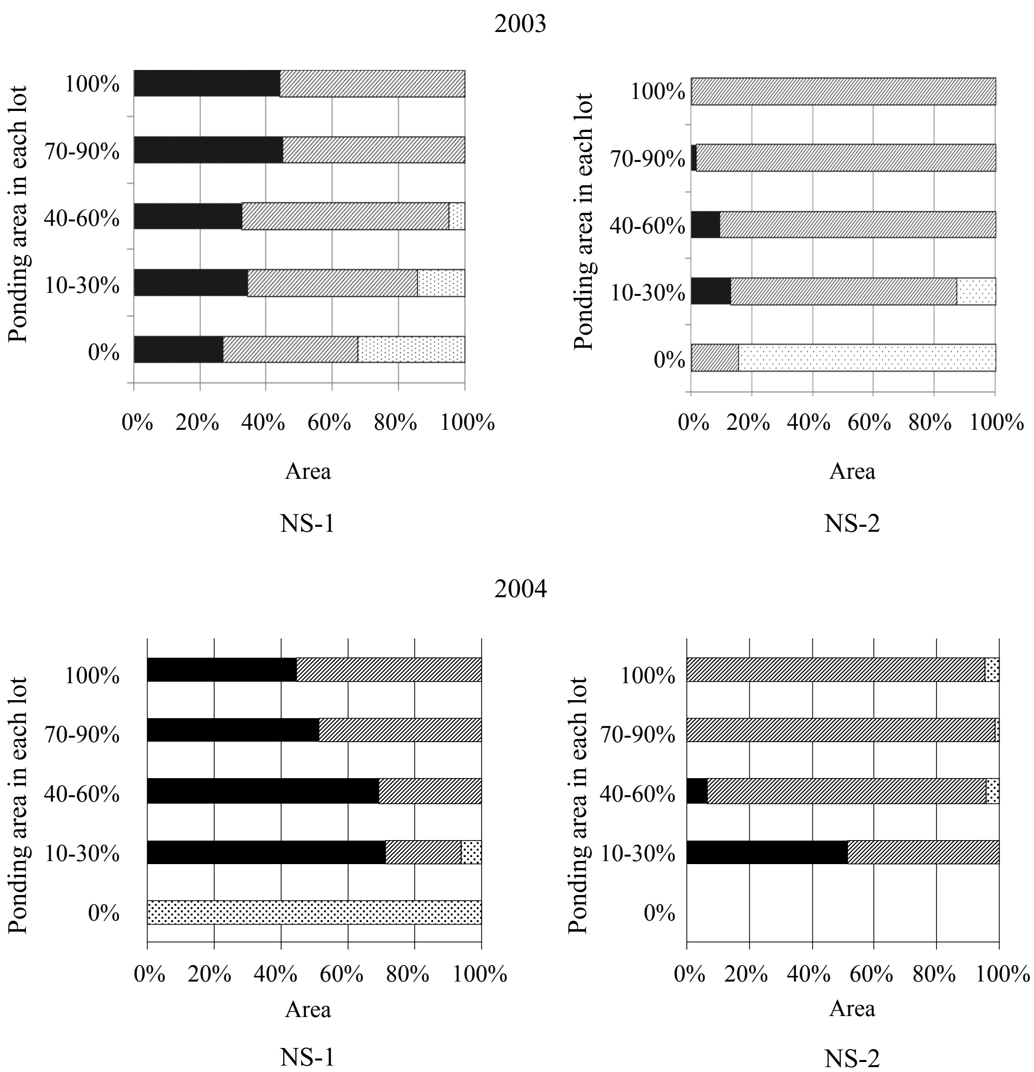


**Fig. 7. Relationship between the introduction of direct seeding and the ratio of the ponding area Ponding area shows the average area in observation terms (2003: 17, Sept – Oct, 2004: Aug. – Sept.)**
■ : Direct seeding, ▨ : Trans planting, ▩ : No planting.

method. Figure 7 shows that the paddy lots with a high ratio of average ponding area in each watershed were planted by transplanting except NS-1 in 2003. Thus, it is presumed that water management was a high priority for transplanted lots in 2004 because the relationship between lots where direct seeding was introduced in 2003 and 2004 with the water ponding area in 2002 remains unclear. Moreover, the days of maximum ponding were different in 2004 depending on the location.

## Conclusion

To elucidate the direct seeding introduction process and paddy lot selection in the rainfed region, we surveyed the two watersheds in Nong Saeng village, Khon Kaen province, northeast Thailand. The survey focused on the relationships among fields where direct seeding had been introduced, precipitation, paddy lot location, water use conditions, and land cultivators. The survey was conducted from 2002 to 2004.

The ratios of the average paddy rice planting areas were from 78% to 98% each year. In terms of paddy location, over 90% of the lower paddy fields were planted each year. On the other hand, the ratio of planted area in the upper paddy fields fluctuated year by year in both watersheds, and the ratio in one watershed dropped to below 50% in 2002.

Transplanting was the only planting method in both watersheds in 2002. Transplanting had continued until September, which is later than the appropriate planting period under unsuitable precipitation conditions for transplanting. The final ratio of the planted area of the lower paddy fields was over 90%. However, only half of the upper paddy fields were planted. In 2003, direct seeding by dry seeding was introduced, antedating the expansion of transplanting until late August. However, the transplanting area was finally expanded to over half the area in both watersheds after precipitation in late August. In 2004, direct seeding was executed in one watershed from the early rainy season, and finally expanded to over half the area. The ratio of the direct seeding area increased in the middle and upper paddy fields in both watersheds. From the point of view of the farmers, there were few households that did not continue direct seeding.

The direct seeding area expanded in both watersheds in 2005. We confirmed continuous direct seeding in the survey region in 2009. Previously, the upper paddy fields were not cultivated every year, and upland crops were introduced in the upper paddy fields instead of paddy rice. The introduction of direct seeding may change the way that land is used during the rainy season. It is necessary to elucidate the stable introduction of direct seeding in order to establish suitable farmland use in the rainfed region of northeast Thailand.

## Acknowledgments

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## Reference

1. Caldwell, J. S. *et al.* (2002) Farmer Perceptions of Water Availability, Soil Erosion, and Yield Relationships in Rainfed Paddy and Upland Fields on Two Transects in a Watershed in Nong Saeng village, Khon Kaen Province, Thailand, *JIRCAS J.* **10**, 31–40.
2. Konchan, S. & Kono, Y. (1996) Spread of Direct Seeded Lowland Rice in Northeast Thailand: farmers' Adaptation to Economic Growth, Southeast Asia Studies **33** (4), 523–546.
3. Kono, Y. (1991) Current Situation and Future Development of Rainfed Agriculture in Northeast Thailand, Rainfed Committee Field Investigation Report – Thailand by Japan Agricultural Land Development Agency, Tokyo, Japan, 35–74 [In Japanese].
4. Ogura, C. *et al.* (2004) The Characteristic of Precipitation in Nong Saeng village, Khon Kaen province, Northeast Thailand, JARQ **41** (4) 325–332.
5. Sumita, A. & Ando, M. (2002) Economy of Direct Seeding of Rice in Northeast Thailand and its Future Direction, Japanese Journal of farm Management **40**(1), 160–163 [In Japanese].
6. Wada, S. (1997) Actual situation and control policy of soil erosion in Northeast Thailand, Agricultural Technical Corporation Manual for Global Environmental Protection – Sustainable Crop Productive Technologies in Deteriorated Farmlands in Asia by Japan Agricultural Development and Extension Association, Tokyo, Japan, 95–115 [In Japanese].