How Growth and Yield of Upland Rice Vary with Topographic Conditions: A Case of Slash-and-burn Rice Farming in South Konawe Regency, Southeast Sulawesi Province, Indonesia

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Abstract Farmer interviews and a yield survey were conducted to elucidate the actual conditions of upland rice cultivation by the Tolakinese, the native people of Southeast Sulawesi Province, Indonesia. The interview results indicated that native farmers had been cultivated upland rice by slash-and-burn farming during the rainy season for personal consumption because of its good flavor, especially aroma, despite the low productivity. We categorized the topographical conditions in our survey field as either: flat, sloping, or depression. The growth and yield of upland rice varied according to these different topographic conditions. Our results of the yield survey suggest that uneven upland rice fields generate different cultivation environments and crop management strategies, which contribute to the variability in grain yields. Moreover, grain yield was highest under depression condition where more water was available, followed by flat and sloping condition. These findings suggest that soil water conditions are important in rainfed upland rice cultivation.

Key words: Indonesia, Slash-and-burn farming, Topography, Upland rice

Introduction

The world rice acreage is approximately 150 million ha, and more than 90% of the world’s rice is produced in Asia (FAO, 2015). Rice is grown in different ecosystems, mainly classified into three types according to the environmental water conditions: irrigated, rainfed lowland, and upland ecosystems, which account for approximately 75%, 19%, and 4% of the global rice production, respectively (IRRI, 2013).

Upland rice acreage in Asia which accounts for less than 9% of Asia's total rice acreage has been declining with the expansion of irrigated fields (Kush, 1997). In Latin America, including the Caribbean countries and West Africa, on the other hand, upland rice cultivation is a major part of rice production, covering approximately 46% and 47% of the total rice acreage, respectively (IRRI, 2013). In particular, in sub-Saharan Africa, where rice consumption has been increasing rapidly every year (Otsuka and Kalirajan, 2006; Somado et al., 2008; Diagne et al., 2011), upland New Rice for Africa (NERICA) varieties have been disseminated even to areas where rice had not been cultivated in order to fill the gap between supply and demand (Kijima et al., 2006).

Upland rice is generally less stable and its production is lower than that of paddy rice, because it is often grown under many environmental stresses such as low soil fertility, frequent droughts, high weed infestation, and low input use (Swamy and Kumar, 2012). In Asia, upland rice is mainly grown on mountainous and hilly, steeply sloping land (Hirose and Chairuddin, 1981; Gupta and O’Toole, 1986; Nemoto, 2008), where the topography makes the development of irrigation facilities difficult. Under such uneven upland conditions, rice production may be considerably affected by the cultivation environment (Worou et al., 2012). Little information is available about growth and yield of upland rice under actual farmers’ fields with different topographic conditions. It is important to elucidate how upland rice productivity differs with topographic conditions.

In the present study, we conducted farmer interviews and a yield survey in Southeast Sulawesi Province, Indonesia (Fig. 1), where upland rice cultivation has been maintained from historical times. Our study area is characterized by the highest proportion of slash-and-burn upland rice cultivation in Indonesia, which is important...
because upland rice cultivation in Indonesia has been declining similarly to that in other Asian countries. In addition, our survey provided useful information for new upland rice cultivation areas, such as sub-Saharan Africa. In the present study, we determined how topographic conditions influenced the growth, yield, and yield components of upland rice grown under typical farming conditions in relation to soil water conditions.

Materials and Methods

Study sites

In Indonesia, the total rice acreage increased by approximately 1.1% a year, from 11.4 million ha in 1995 to 13.2 million ha in 2010 (IRRI, 2013). However, upland rice production accounted for less than 5% of the total rice production in the 2000s (Panuju et al., 2013). On the other hand, upland rice in Southeast Sulawesi Province provided 8% of the total production and covered 12% of the total rice acreage in 2008 (Fig. 2A).

The present study was conducted in the villages of Kiaca (04°36’ S, 122°33’ E, 111 m above sea level) and Wawonggura (04°35’ N, 122°34’ E, 113 m above sea level), Palangka District, South Konawe Regency, Southeast Sulawesi Province, Indonesia. The study sites were located in the southeastern part of Sulawesi Island (Fig. 1). This province covers an area of 38,140 km² (BPS Sultra, 2014), consisting of mountainous (49%), lowland (26%) and hilly areas (25%) (Pasolin and Rianse, 2011). According to the 2014 census of Indonesia (BPS Sultra, 2014), the agricultural land in the province (2,481,713 ha) mainly consists of: 119,367 ha (4.8% of the total agricultural land) of paddy fields, including both irrigated and rainfed paddies; 240,680 ha (9.7%) of permanent upland

Fig. 1. Map of the study site in Southeast Sulawesi Province, Indonesia.
fields; 138,008 ha (5.5%) of slash-and-burn fields; 86,203 ha (3.5%) of grasslands; 621,636 ha (25.0%) of plantation fields (cashew nut, cacao, coconut, etc.); 927,363 ha (37.3%) of national forests; 348,456 ha (14.1%) of others. According to this classification, slash-and-burn upland rice fields fall within the slash-and-burn field category.

Starting in 1969, the Indonesian government used this province as one area within a larger transmigration relocation plan (Saragih and Yoshida, 2002). The main purpose of this relocation plan was to support the growing population by expanding agriculture to outlying areas, hence increasing domestic food crop production. Currently, the population of the Southeast Sulawesi Province is approximately 2.4 million (BPS Sultra, 2014). The population mainly consists of the native people of Southeast Sulawesi, the Tolakinese, and transmigrants who came 1) through the relocation plan (mainly from Java and Bali) or 2) independently from South Sulawesi (Nishimura, 1995a).

The population of the South Konawe Regency exceeds 280,000 in an area of 4514 km². The agricultural population accounts for more than 56% of the total population, which includes the population engaged in the production of rice and tuber crops (30%), horticultural crops (4%), and estates and plantations (22%) (BPS Indonesia, 2015). This regency is the second-largest rice-producing area in the province (BPS Kabupaten Konawe Selatan, 2015). In particular, the Palangga District accounts for 4.64% of the population of the South Konawe Regency and 3.94% of its area (BPS Kabupaten Konawe Selatan, 2015). The area of our study sites showed an almost equal ratio of native and transmigrant populations as of 1992 (Nishimura, 1995a).

The native people, Tolakinese, who eat rice as their staple food and sago palm as a supplementary food, have cultivated upland rice by traditional slash-and-burn farming during the rainy season for more than 200 years (Nishimura, 1995b). At our study site, upland rice is grown widely under various topographic conditions, such as sloping and flat lands throughout the mountainous region. However, transmigrants typically grow paddy rice using irrigation systems (Saragih and Yoshida, 2002). In addition, Tolakinese paddy rice cultivation, which was introduced by the Portuguese, has been influenced by the transmigrants. Saragih and Yoshida (2002) reported that the average annual growth rates of the rice acreage and production in Southeast Sulawesi Province were 5.31% and 7.65%, respectively, for paddy fields, and -1.16% and -1.68%, respectively, for upland fields from 1968 to 1997. The relocation plan remarkably changed the percentage of upland and paddy rice cultivation, especially after the 1980s. The cultivation acreage of paddy rice (23,000 ha), which was similar to that of upland rice (20,000 ha) in 1968, had increased rapidly from the 1980s onward, and was 8 times as large as the upland rice cultivation area in 2008 (Fig. 2A). Paddy rice production (45,000 t) was approximately 30% higher than that of upland rice (31,000 t) in 1968, while in 2008, paddy rice production (380,000 t) was more than 13 times higher than that of upland rice (29,000 t) (Fig. 2B). Moreover, the yield of paddy rice per unit area doubled from 2.0 t ha⁻¹ in 1968 to 4.1 t ha⁻¹ in 2008, while the yield of upland rice increased from 1.6 t ha⁻¹ in 1968 to 2.5 t ha⁻¹ in 2008 (Fig. 2C).

As mentioned above, paddy rice production and acreage in the region have increased dramatically because of the influence of the transmigrants. On the other hand, the upland rice production and acreage have exhibited a declining trend, since upland rice shows a lower yield potential than paddy rice.

**Meteorological conditions**

Since there was no meteorological weather station near the study sites, the meteorological data for Kendari (04°04' S, 122°25’ E, 164 m above sea level), the provincial capital approximately 50 km away from the study sites, were used as a reference. Fig. 3 shows the monthly rainfall and air temperature in Kendari from

![Graph showing monthly rainfall and air temperature in Kendari from 2007 to 2011.](image-url)
2008 to 2011 excluding 2009. In this area, the average air temperature ranges from 24–29 °C throughout the year, with a rainy season from November to July and a dry season from August to November (Nishimura, 1995b). During the rainy season, the area receives more than 150 mm of rainfall each month, and the annual rainfall is approximately 2,000 mm. In general, upland rice cultivation requires 100–200 mm of rainfall per month during the growth period (Kaneda, 1999). The area, therefore, was considered to be as suitable for upland rice cultivation. However, recently, the distribution of rainfall has become unstable in the area, based on the lack of clear rainy and dry seasons in 2010 (Fig. 3).

Farmer interviews

An interview survey was conducted with six randomly selected native families in Kiaeaa and Wawonggura villages from the end of April to the beginning of May in 2010. The interviews were centered on the upland rice cultivation methods and planting systems adopted by the native farmers.

Yield survey

Growth and yield measurements were conducted for an upland field in Kiaeaa village with the help of a Tolakinese farmer who participated in the interview survey. The upland field adjacent to a rainfed paddy field was located in a flat-land region in a mountainous area with an area of approximately 400 m². It was the first time that upland rice had been cultivated in the field after burning. On January 4th, 2010, a pinch of rice seeds (approximately ten seeds) was sown directly into individual holes made using a “tugal” at 30 × 30–30 × 40 cm spacing. The plants were grown without the use of fertilizers or pesticides. Weeding was conducted twice during the growth period, at two- and four-weeks after sowing. Heading started from the middle of March 2010, according to our farmer interview.

A diagram of the rice field where the yield survey was conducted is shown in Fig. 4, which indicates the topographic conditions of the field and the seven plots for growth measurements and plant sampling, namely, Flat-1, Flat-2, Slope-1, Slope-2, Slope-3, Depression-1, and Depression-2. The uneven field was characterized.

![Diagram of the rice field used in our yield survey.](image-url)

Fig. 4. A diagram of the rice field used in our yield survey. Flat-1, Flat-2, Slope-1, Slope-2, Slope-3, Depression-1, and Depression-2 indicate the locations of each plot for growth measurements and plant sampling under different topographic conditions.
by three different topographic conditions: flat, sloping (with an inclination of 20–30° by visual observation), and depression. Soil water conditions varied according to the topographic conditions in the surveyed field. Therefore, growth measurements were conducted in the field under three different topographic conditions: flat, sloping, and depression. Two plots under each condition were selected for the measurements. No significant differences in the soil water conditions at the soil surface were observed between the flat and sloping areas. Depression areas lying at the bottom of a slope were approximately 2 m lower than flat areas. Furthermore, these depression areas were under swampy conditions and remained covered by approximately 1 cm of water throughout the growth period because the field was supplied with spring water. During our sampling, the rice plants grown in the depression areas were mature, whereas those grown in flat and sloping areas needed approximately 7–10 more days to reach the proper harvesting time. Therefore, we selected relatively mature plants for our growth measurements in the flat and sloping areas. Ten plants per plot were randomly selected to measure the plant length, culm length, panicle length, and the SPAD (SPAD-502, Minolta Co.) value, length and width of the flag leaf.

To determine the shoot fresh weight and yield components, plant sampling was carried out in the same plots as those where the growth measurements were conducted. In addition to the two plots under each topographic condition, one sloping plot was added because the plant growth was not uniform on the slopes. As a result, seven plots were used for plant sampling. For each square plot (1 m × 1 m), the number of hills per plot and the number of panicles per hill were counted, after which all the plants in the plot were cut at ground level. Shoot fresh weight was determined immediately after harvesting. Twenty panicles were randomly selected to determine the number of spikelets per panicle, percentage of filled grains, and 1000-grain weight. The percentage of filled grains was determined only for Flat-1 and Depression-1 because we considered that the value of Flat-1 could be a substitute for those of Flat-2, Slope-1, Slope-2, and Slope-3, and the value of Depression-1 for that of Depression-2, based on our visual judgment. Filled and unfilled grains were separated using fresh water and counted. To determine the 1000-grain weight, oven-dried grains in each plot were hulled after removal of the green younger spikelets, and we randomly selected one hundred intact and filled grains. The 1000-grain weight of brown rice was adjusted to 15% moisture content. The average 1000-grain weight of the plants in Slope-1 and Slope-2 was used as a substitute for those in Slope-3 because the grains in this plot were still too immature to weigh at the time of plant sampling. The brown rice yield was calculated from the yield components.

Results and Discussion

Cultivation methods

We have summarized our interview results below because all the six families reported similar information. In this area, upland rice was mainly produced using a slash-and-burn shifting agriculture system under rainfed conditions during the rainy season. The fundamental cycle of the slash-and-burn shifting agriculture system in the area was as follows: planting rice for 1–3 years after burning of an upland field, letting the field lie fallow for 1–5 years, and then burning the field to cultivate upland rice again. Farmers prepared upland fields by cutting trees in late September, started field burning at the end of the dry season in late November, and continued burning until early December. After field preparations, rice seeds were sown directly into the upland field at the beginning of the rainy season. The farmers harvested upland rice around May. Fertilizers and pesticides were not used during the growth period. Manual weed control was typically performed 2–4 times by using a sickle called “saira,” before the heading stage (Fig 5A). In this area, upland rice was intercropped with other crops and vegetables, such as corn, long bean, loofah, okra, red pepper, eggplant, and melon that were usually planted during the rice planting seasons, before or immediately after sowing of the upland rice.

The method of sowing consisted of dibbling, and the plant spacing was visually estimated. Approximately ten seeds were sown in a small hole, 1–3 cm deep, by using a long wood stick called “tugal” (length 1.5 m, diameter 3 cm). Sowing for 0.5 ha took approximately half a day with 20 people: 5 people for making holes and 15 people for sowing. The method of harvesting consisted of panicle cutting by using a small knife called “ani ani” (Figs. 5B, C, and D). Harvesting for 0.5 ha took approximately one whole day with ten people. Harvesting was based on the traditional bayon system which uses the local profit-sharing methods of Indonesia (Nishimura, 1995b; Lestari, 2014), whereby anyone participating in harvest labor is entitled to receive a share of the harvest, for example one-quarter of the harvest in this farmer’s field.

The farmers grow upland rice mainly for personal consumption because they prefer its flavor and aroma, despite the low productivity. Farmers do not typically
sell upland rice unless there is an annual surplus. In the Southeast Sulawesi Province, the market value of upland rice (10,000 rupiah/litter) is twice that of paddy rice (5,000 rupiah/litter). The farmers grow several rice varieties in a typical upland field, mainly traditional tropical japonica varieties, including both glutinous and non-glutinous varieties. Additionally, some farmers grow an improved upland variety, ‘Lampung’, which had been introduced to this area in recent years. Most farmers grow 2–5 different upland rice varieties within a field because of risk distribution. In our interviews, we were unable to clearly identify a strategy for the selection of rice varieties by the farmers, which appeared to markedly depend on the individual preference of each farmer.

The interviews indicated that the native farmers had continuously cultivated upland rice for personal consumption by slash-and-burn farming during the rainy season under rainfed conditions even after paddy rice was introduced and widely diffused around Kendari in Southeast Sulawesi Province. The farmers prefer upland rice to paddy rice because of its flavor. Compared with the survey conducted by Nishimura (1995b), the methods of upland rice cultivation around Kendari had not changed since the 1990s, except for the diffusion of the improved upland variety ‘Lampung’.

**Yield of upland rice under different topographic conditions**

In our study, the rice variety grown in the surveyed field was ‘Lampung’ with awn, which displays morphological characteristics similar to those of indica. Furthermore, our interviewed farmers indicated that ‘Lampung’ was an improved variety, which had been recently introduced to the region.
Table 1 shows the growth parameters of upland rice at harvesting time. The values of plant length, culm length, and flag leaf length were significantly higher under the depression condition than under other topographic conditions, while there was no significant difference between the sloping and flat conditions. Likewise, the values of panicle length, flag leaf width, and SPAD tended to be higher under the depression condition. The width of the flag leaf was significantly narrower under the sloping condition than that under other topographic conditions. Most growth parameters were superior under the depression condition. There were no clear differences in the growth parameters between the sloping and flat conditions.

Table 2 shows the yield and yield components of upland rice sampled from the areas under different topographic conditions. In areas under the flat condition, the number of hills was slightly higher than that in the areas under sloping or depression conditions. The number of hills ranged from 9 to 12 m⁻², which was similar to the estimates based on the information about spacing obtained through the farmer interview (8.3–11.1 hills m⁻², calculated from a spacing of 30 × 30–30 × 40 cm). The values were similar even though the spacing for sowing was adjusted by visual estimation, indicating farmers’ skill in accurately planting rice seeds.

The values of the shoot fresh weight m⁻² ranged from 0.8 kg m⁻² in Slope-3 to 3.6 kg m⁻² in Depression-2, and were highest under depression condition, followed by flat and sloping conditions (Table 2). Shoot fresh weight m⁻² values were approximately 76% and 220% higher under depression condition than under flat and sloping conditions, respectively. In addition, the number of hills m⁻² under depression condition was about 17% lower than that under flat condition and 11% higher than that under sloping condition. Thus, the variation in shoot fresh weight m⁻² was much larger than the variation in the number of hills m⁻², indicating that the biomass yield

![Table 1. Growth parameters of the upland rice variety ‘Lampung’ at harvesting grown in a slash-and-burn field under different topographic conditions in Southeast Sulawesi Province, Indonesia.](image_url)

<table>
<thead>
<tr>
<th>Topographical condition</th>
<th>Plot</th>
<th>Number of hills (m⁻²)</th>
<th>Shoot fresh weight (kg m⁻²)</th>
<th>Panicle number (per hill) (m⁻²)</th>
<th>Spikelet number (per panicle) (m⁻²)</th>
<th>Percentage of filled grain (%)</th>
<th>1000-grain weight (g)</th>
<th>Brown rice yield (g m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat condition</td>
<td>Flat-1</td>
<td>12</td>
<td>1.54</td>
<td>10.5</td>
<td>126.0</td>
<td>114.8 c</td>
<td>14,465</td>
<td>74.3</td>
</tr>
<tr>
<td></td>
<td>Flat-2</td>
<td>12</td>
<td>2.06</td>
<td>7.4</td>
<td>88.8</td>
<td>176.1 bc</td>
<td>15,638</td>
<td>(74.3) ²</td>
</tr>
<tr>
<td>Sloping condition</td>
<td>Slope-1</td>
<td>9</td>
<td>1.12</td>
<td>8.8</td>
<td>79.2</td>
<td>144.4 bc</td>
<td>11,436</td>
<td>(74.3) ²</td>
</tr>
<tr>
<td></td>
<td>Slope-2</td>
<td>9</td>
<td>1.04</td>
<td>8.0</td>
<td>72.0</td>
<td>150.3 bc</td>
<td>10,822</td>
<td>(74.3) ²</td>
</tr>
<tr>
<td></td>
<td>Slope-3</td>
<td>9</td>
<td>0.80</td>
<td>8.3</td>
<td>74.7</td>
<td>124.9 c</td>
<td>9,530</td>
<td>(74.3) ²</td>
</tr>
</tbody>
</table>

Means followed by the same letter indicate the absence of significance at P < 0.05.

1) The inclination angle of the slope was visually estimated at 20–30°.

Table 2. Yield and yield components of the upland rice variety ‘Lampung’ grown in a slash-and-burn field under different topographic conditions in Southeast Sulawesi Province, Indonesia.

<table>
<thead>
<tr>
<th>Topographical condition</th>
<th>Plot</th>
<th>Number of hills (m⁻²)</th>
<th>Shoot fresh weight (kg m⁻²)</th>
<th>Panicle number (per hill) (m⁻²)</th>
<th>Spikelet number (per panicle) (m⁻²)</th>
<th>Percentage of filled grain (%)</th>
<th>1000-grain weight (g)</th>
<th>Brown rice yield (g m⁻²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flat condition</td>
<td>Flat-1</td>
<td>9</td>
<td>2.72</td>
<td>9.4</td>
<td>84.6</td>
<td>200.8 ab</td>
<td>16,988</td>
<td>69.8</td>
</tr>
<tr>
<td></td>
<td>Flat-2</td>
<td>11</td>
<td>3.60</td>
<td>7.9</td>
<td>86.9</td>
<td>250.0 a</td>
<td>21,725</td>
<td>(69.3) ²</td>
</tr>
</tbody>
</table>

Means followed by the same letter indicate the absence of significance at P < 0.05.

Parentheses indicate an estimated value.

1) The value for Flat-1 was used as a substitute.
2) The value for Depression-1 was used as a substitute.
3) The values of brown rice were adjusted to 15% moisture content.
4) The value for Flat-1 was used as a substitute.
5) The average values of Slope-1 and Slope-2 were used as substitutes.
in each hill was remarkably affected by topographic conditions.

The number of panicles per hill and m² tended to be lower under the sloping condition and higher under the flat condition compared to the depression condition (Table 2). We also recorded the highest spikelet number per panicle and m² under the depression condition. Furthermore, the numbers of spikelets per panicle under flat and sloping conditions were similar, whereas the number of spikelets m² under the flat condition was higher than under the sloping condition. The value of the 1000-grain weight was higher under the depression condition than under other topographic conditions. On the other hand, the percentage of filled grains was lower under the depression condition than under the other topographic conditions. Among the yield components, the number of spikelets m² was most affected by the topographic conditions.

The brown rice yield was positively and significantly correlated with the number of spikelets m² (Fig. 6). Furthermore, the number of spikelets m² did not show any correlation with the number of panicles m² but was correlated with the number of spikelets per panicle under all the three topographic conditions (Fig. 7). Our results supported those obtained in previous study conducted by Adachi et al. (2010), who reported that the grain yield was strongly correlated with the number of spikelets m² as well as the number of spikelets per panicle in a rainfed paddy field in Laos. Miyagawa and Kuroda (1988) also reported that the rice yield varied according to the variation in the number of spikelets per panicle in rainfed lowland areas in Northeast Thailand. In our study, the higher yield under the depression condition, with better soil water conditions, was also mainly attributed to the increase in the number of spikelets per panicle (Table 2). In addition, the higher number of spikelets per panicle was attributed to the more vigorous plant growth observed under the depression condition (Table 1). However, under flat and sloping conditions, the number of spikelets m² seemed to be affected by the number of panicles m² rather than the number of spikelets per panicle. Furthermore, an increased number of hills m² under the flat condition contributed to the higher number of panicles m² (Table 2). The similarity of the growth parameters under sloping and flat conditions implies that the higher number of panicles observed under the flat condition was not related to these growth parameters (Table 1). There findings indicate that the higher plant density under the flat condition likely contributed to the increase in the number of spikelets.

Fig. 6. Relationship between grain yield and the number of spikelets m² in upland rice variety ‘Lampung’ grown in a slash-and-burn field under different topographic conditions in Southeast Sulawesi Province, Indonesia. *** Significant at 0.1% level.

Fig. 7. Relationships between spikelet number per square meter and (A) spikelet number per panicle or (B) panicle number per square meter in the upland rice variety ‘Lampung’ grown in a slash-and-burn field under different topographic conditions in Southeast Sulawesi Province, Indonesia.
* Significant at 5% level.
 n.s. not significant.
m⁻², which resulted in a higher yield. Saito et al. (2009) also reported that the higher plant density in upland rice fields likely contributed to higher yields in a survey conducted in upland rice fields in Laos. Although these results were not statistically significant due to fewer sampling plots, the authors estimate that the different topographic conditions contributed to variations in the plant density. Worou et al. (2012) suggested that upland fields with spatial heterogeneity were likely to influence crop management implementation and soil water environment. In our study, the number of spikelets m⁻² could best forecast grain yield under uneven field conditions, which was influenced by both the soil water environment and crop management.

Even for lowland rice, panicle-weight type varieties are considered to be superior to the panicle-number type varieties in terms of productivity under low soil fertility (Yamamoto, 2008). There findings support the opinion of Atlin et al. (2006), who suggested that high-yielding upland indica varieties with drought tolerance could play an important role in the increase of the rainfall rice productivity in Asia. According to the BPS Sultra (2008) published by the Southeast Sulawesi State Government, the average grain yield of upland rice in the province was 2.5 t ha⁻¹. The average grain yield around Kendari in the early 1990s was approximately 1.5 t ha⁻¹ (Nishimura, 1995b). In our study, the brown rice yield was 1.6–3.6 t ha⁻¹, which can be estimated at 2.0–4.5 t ha⁻¹ in grain yield, based on the husking ratio of 70–80% (Table 2). The higher grain yield recorded in our study than that in previous studies was ascribed to the fact that our yield data corresponded to the high-yielding improved variety ‘Lampung’, whereas those reported in the previous studies represented the traditional varieties. Although the upland rice yield can be 3–4 t ha⁻¹ under appropriate conditions, it is difficult to meet these conditions in rainfed upland agriculture (Kaneda, 1999). Gupta and O’Toole (1986) reported that some upland rice varieties and lines recorded high yields of 3.7–6.2 t ha⁻¹ during an on-station cultivation experiment carried out in an upland field at the International Institute of Tropical Agriculture (IITA).

Under a steeply sloping condition, land productivity is more likely to be affected by the topography than land-use history (Hayashi et al., 1993). In our study, the brown rice yield varied with the topographic conditions, and was lowest under the sloping condition, where the inclination angle was visually estimated at 20–30°, while the yield under the depression condition was higher than that under the flat condition (Table 2). Moreover, the growth and development of upland rice varied under the sloping condition, e.g., growth was delayed in Slope-3. Our results agreed with the findings of Husson et al. (2001), who reported that upland rice yield tended to decrease with an increase in the inclination of slopes, and drastic yield decrease occurred above 25–30°. We suspect that the lower yields under the sloping condition were mainly due to water runoff and nutrient leaching caused by soil erosion from heavy rains. Widawsky and O’Toole (1996) have estimated that factors related to water conditions account for approximately 25% of yield losses in upland rice under rainfed conditions. Higher land productivity under the depression condition, where the brown rice yield was 1.8 times higher than that under the the sloping condition (Table 2), was attributed to better soil water and soil nutrients supplied from the sloping areas through water runoff. The results of our study indicate that the rice yield in rainfed upland areas was significantly affected by the topographic conditions.

In the present study, the yield survey was carried out in a field, which included some plots where plants were not yet mature for harvesting, such as Slope-3, although for plant sampling, areas where plants had not matured were avoided as much as possible. Moreover, the percentage of filled grains in the plots at the proper harvesting time was used as a substitute for that in for the plots with less mature plants, and the 1000-grain weight was measured after removal of the green younger spikelets because of time constraints. Even after considering these issues, our results indicated that rainfed rice productivity was higher under the depression condition than under flat and sloping conditions.

**Conclusion**

The survey revealed that the native farmers continue to grow upland rice using the traditional slash-and-burn shifting cultivation system in the Southeast Sulawesi Province, Indonesia, although paddy cultivation methods had been introduced. In our study, the yield survey was carried out in an uneven field under typical farming practice conditions. We suggest that the uneven field led to different cultivation environments and crop management practices, which resulted in the differences in plant growth and subsequent rice yields. The highest yield was obtained under the depression condition, which was mainly attributed to the fact that the soil water environment was maintained at sufficient levels for rice cultivation. Moreover, upland rice yield was markedly affected by the soil water conditions, which confirms that the soil water environment can best forecast upland rice
productivity under typical farming conditions.

Our results imply that an uneven field with a depression where rainwater can accumulate could be advantageous, in terms of rice productivity as well as yield stability, over a field consisting only of sloping and flat lands, especially in the event of drought. Our findings may contribute to stable and improved rice productivity in upland rice farming. The relationship between the actual soil moisture variability and upland rice productivity under uneven field conditions, which was not clarified in the present study, will be the focus of subsequent work.

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References


