JARQ 35(2), 91 – 96 (2001) http://www.jircas.affrc.go.jp

# Erosion Control in Pineapple Fields on the Island of Ishigaki

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## Abstract

Two field trials were conducted to evaluate the potential of alternative management practices for the control of soil erosion in pineapple fields on the island of Ishigaki. In the first trial, the effect of cover crops on minimizing soil loss was investigated. Weeping lovegrass (*Eragrostis curvula*) and a legume plant (*Arachis pintoi*) were planted on a 1 m strip on the lower edge of plots, each measuring 11 m in length and 5 m in width with a 3° slope. In these plots as well as the control, pineapple seedlings were planted under conventional tillage. After 12 months, soil loss in the plots with *E. curvula* and *A. pintoi* was reduced to 1/107 and 1/680, respectively, of that in the control plot. Since *A. pintoi* is a creeping vine, it inhibited pineapple growth when it encroached upon the adjoining area. In another trial, pigeonpea (*Cajanus cajan*) was sown, cut down 4 months later, and deliberately left on the soil surface after which pineapple seedlings were planted under no-tillage and minimum tillage. These plots were compared with the control plot where pineapple seedlings were planted under conventional tillage. After 8 months, soil loss in the no-tillage plot was reduced to 1/14 of that in the control plot, whereas soil loss in the minimum tillage plot was almost the same as in the control. Based on these findings, a new management practice involving the use of cover crops and no-tillage planting is recommended to farmers for the prevention of soil erosion in pineapple fields.

**Discipline:** Soils, fertilizers and plant nutrition
**Additional key words:** cover crop, no-tillage, organic mulch

## Introduction

In the last 3 decades, red soil loading due to erosion in coastal marine environments has been serious in the Ryukyu Islands. In the northern part of the island of Okinawa for instance, muddy streams surge into the river mouth area, reclaiming the mangroves and dyeing coral reefs red in the process. Red soil accumulates within the reef ponds separated by reef edges from the ocean and the coral within it eventually dies out. Using LANDSAT TM data, Okamoto et al.[8] reported that a large amount of red soils which had accumulated near the estuary off Katabaru before 1984, was still present in 1988. They indicated that this mass of red soil flooding was due to public works such as road construction, land reclamation and residential development that were actively promoted from the 1970s to early 1980s. Large-scale crop cultivation, particularly sugarcane and pineapple, is also one of the major causes of soil loss in the island[5, 10, 11].

On the island of Ishigaki, which is located about 430 km southwest of the main island of Okinawa, a national project on irrigation and drainage was initiated in 1972, followed by the construction of the Maezato and Sokobaru dams until 1992. At the same time, the Prefectural Government of Okinawa carried out a project on irrigation, drainage, and farmland consolidation. During this period of large-scale engineering works, muddy streams surged into the river mouth areas of Miyara and Todoroki rivers whenever heavy rains occurred. Recently, the outflow of red soil originating from such large-scale land improvements has been somewhat reduced. However, the situation still calls for the intensification of erosion control practices, particularly in relation to farming activities[9]. The main crops on the island of Ishigaki are sugarcane, pineapple, paddy rice, and pas-

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Received 26 October 1999, accepted 14 November 2000.

ture grass. Soil erosion is serious in the pineapple and sugarcane fields, each of which accounted for about 10% and 20%, respectively, of arable land in 1995.

## Soil erosion in pineapple fields

On the island of Ishigaki, pineapple is cultivated in fields ranging from 20 to 150 m in length with a slope from 0 to 8° in gradient. The average annual rainfall is 2,100 mm, but during the rainy season (May–June) and during typhoons, heavy rains can reach up to 400 mm per day. During such rainfall events, roads serve as a drainage system of excess water exiting towards the sea. Pineapple grows well on acid soil and is therefore highly suitable for cultivation on Red soils and Yellow soils (Kunigami-Maji), which are widely distributed in Oki-

**Fig. 1. A farm road in a pineapple field**
Rill erosion was observed along the farm road.

**Fig. 3. Field experiment on cover crops**
Cover crops were planted on a 1 m strip on the lower edge of plots, each measuring 11 m in length and 5 m in width with a 3° slope.

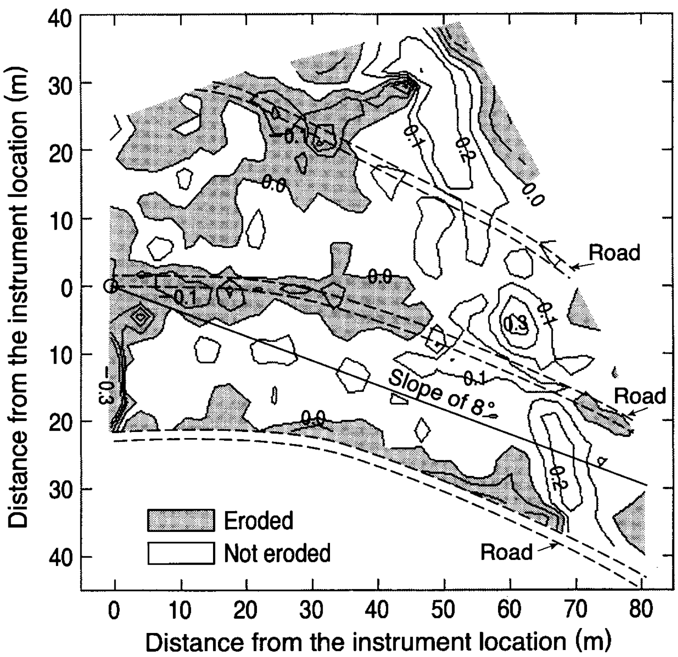


**Fig. 2. Topographical changes in a farmer's field for one year after planting of seedlings using an optical surveying instrument**
Figures in the box indicate the altitudinal difference between 1993 and 1994.
Symbol ○ shows the instrument location on the lower edge of the field.

nawa. Kunigami-Maji soil is highly dispersible, has a weak structure, and is more erosive compared to Andosols that were the typical upland soils in mainland Japan.

Ishigaki farmers usually plant pineapple seedlings in August–September, harvest the fruits in the second summer and in the autumn after 3 years, and then renew the land (summer planting). Renewal is a process whereby farmers crush old stubbles of pineapple and plow the residues into the soil followed by harrowing. In the past, they cut the topsoil off, dropped it into a valley, and then planted seedlings on the subsoil in order to avoid soil-borne diseases. Such a practice however has been discontinued and farmers now just leave the field fallow after plowing and harrowing.

The growth of the pineapple plant is very slow. For about one year, fields are not covered with enough vegetation, and hence soil erosion becomes a serious problem. Moreover, farm roads that run in the fields for the transport of fertilizers, agricultural chemicals and fruit harvests, act as a drainage system during heavy rains (Fig. 1). Although sediment runoff appears to be large along the farm roads, there are no reports on the quantitative evaluation of soil erosion under actual conditions[3, 12]. Thus, we investigated the topographical changes in a farmer's field for one year after planting of seedlings using an optical surveying instrument[2]. Results of the survey indicated that a substantial amount of soil erosion was due to the construction of farm roads in the fields (Fig. 2). Although management practices for farm roads are important, no practical method has been identified and recommended yet.

## Field experiments on the effect of cover crops and no-tillage on the control of soil erosion

In general, contour ridging and covering of the soil surface with organic mulch are recommended for the alleviation of soil erosion in pineapple fields[1, 3, 4]. In Okinawa, however, farmers grow pineapples in the fields without ridging. Moreover, very few farmers apply leaves and stalks of a tall weed such as eulalia (*Miscanthus sinensis*) on the soil surface. Organic mulching is not a popular practice with local farmers mainly because of the scarcity of organic materials and insufficient labor supply. Since farmers generally spurn management practices that are expensive, unavailable, and difficult to mechanize, we investigated an alternative management practice to minimize soil erosion, i.e. the use of vegetative cover on the lower edge of pineapple fields.

A set of 4 plots, each measuring 11 m in length and 5 m in width with a slope angle of 3°, was used for the investigation of the effect of cover crops on the control of soil loss. The trial was conducted from 1993 to 1994. Weeping lovegrass (*Eragrostis curvula*) and a leguminous plant (*Arachis pintoi*) were each planted on a 1 m strip on the lower edge of the first 2 plots (from right to left in Fig. 3). The third plot served as the control while leaves and stalks of napiergrass (*Pennisetum purpureum*) were applied as organic mulch in the last plot. Pineapple seedlings were planted under conventional tillage in these 4 plots and grown according to the method recommended by the Yaeyama Extension Center.

After one year, soil loss in the plot with weeping lovegrass (0.07 kg $m^{-2}$) was only 1/107 of that in the control plot (7.48 kg $m^{-2}$)(Fig. 4). Although soil loss in the plot with *Arachis pintoi* (0.01 kg $m^{-2}$) was less than that of the plot with weeping lovegrass, it was observed that the creeping legume encroached upon the adjoining pineapple and inhibited the latter's growth. Since weeping lovegrass is a popular cover crop for roadside slopes and seed can be easily obtained, we recommend that farmers use it as a vegetative cover on the lower edges of pineapple fields. A recent report of the Okinawa Agricultural Experiment Station revealed that soil loss in the plot with cover crops and organic mulch on a 4 m strip on the lower edge of bare slopes (40 m long, 2.5 m wide, and 3° inclination) was less than 5% of that in the control plot[6].

No-tillage and minimum tillage with stubble mulch are also recommended for the alleviation of soil erosion[4, 7, 12]. Stubble mulching is a practice in which crop residues are left in the field for covering the soil surface. This practice however is also unpopular because of some serious problems related to the increase in the incidence of plant pathogens, pests and weeds. In this connection, we tested a management practice whereby residues of green manure crops were deliberately left on the soil surface and then pineapple seedlings were planted under no-tillage and minimum tillage.

Another set of 4 plots, each measuring 11 m in length and 5 m in width with a slope angle of 3°, was used for the investigation of the effect of no-tillage and minimum tillage on the control of soil loss. The field trial was conducted from 1994 to 1995. In the no-tillage plot, pigeonpea was sown and cut down about 4 months after seeding, and thereafter seedlings of pineapple were planted under no-tillage. In the minimum tillage plot, the management practice was almost the same as the no-tillage planting except that the seedlings were planted after rotary tilling. The remaining plots were used for napiergrass mulch application and the control.

After 8 months, soil loss in the no-tillage plot (0.07 kg $m^{-2}$) was only 1/14 of that in the control plot (1.01 kg $m^{-2}$)(Fig. 5). On the other hand, soil loss for the same period of time in the minimum tillage plot (0.72 kg $m^{-2}$)

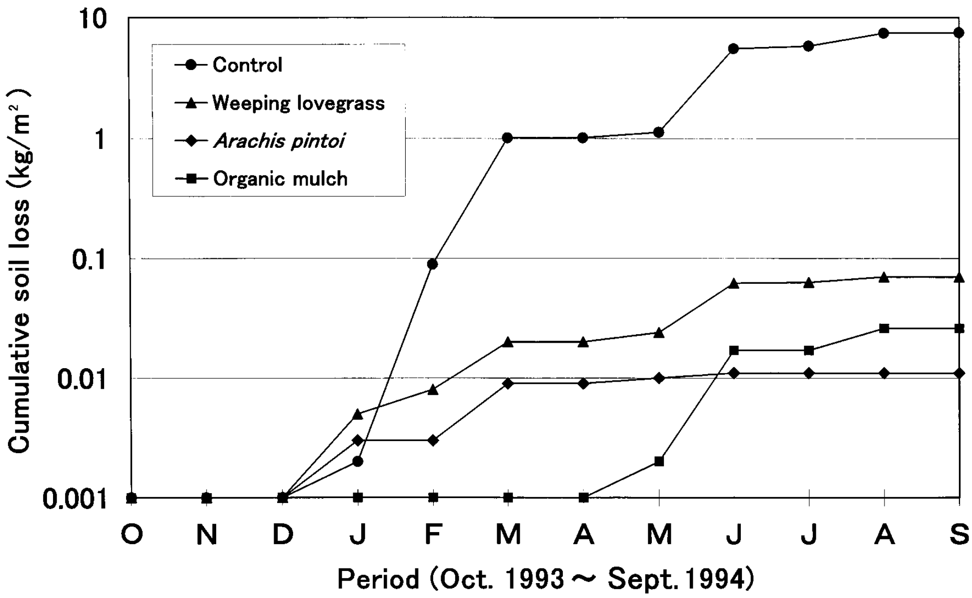


**Fig. 4. Effect of cover crops on the cumulative soil loss for one year after planting of seedlings**

was similar to that in the control plot. Since pineapple is usually planted on acidic Kunigami-Maji soil, we selected pigeonpea as a green manure crop for no-tillage planting, as it is a leguminous crop that can produce a large amount of biomass even in acid soils. Moreover, it is easy to obtain the seed of pigeonpea and to cut the plant down by using a rotary plow as a mower.

During the typhoon No. 29 in October 1994, a total amount of 228 mm rainfall was recorded at the experimental site. Data collected after this rainfall event showed that runoff in the no-tillage plot was about 1/3 of that in the minimum tillage plot. Why was runoff reduced in the no-tillage plot where pigeonpea residues were left on the soil surface? Visual observation suggests that: 1) residues on the soil surface prevented the formation of crust, and 2) residues promoted the infiltration of rainwater into soil. In this context, crust is a hard outer layer where soil particles are deposited after dispersion by the impact of raindrops. Once a crust is formed, infiltration decreases and sediment runoff increases.

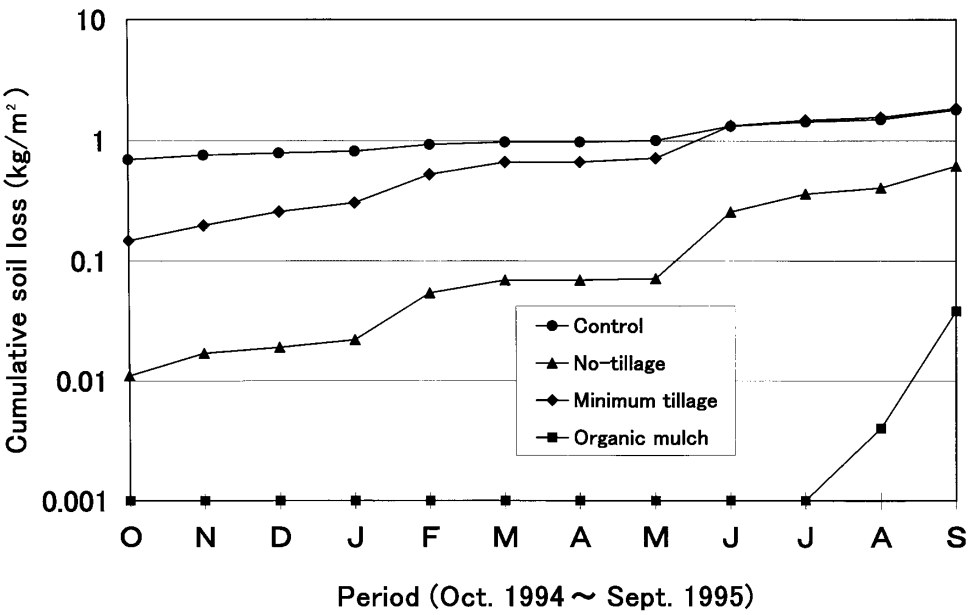


**Fig. 5. Effect of no-tillage and minimum tillage on the cumulative soil loss for one year after planting of seedlings**

**Table 1. Proposed calendar for the summer planting of pineapple in Yaeyama district**

| Year | First year | | | | | | | | | | | | | | Second year | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Month | N | D | J | F | M | **A** | M | J | J | A | **S** | O | N | D | J | F | M |
| Conventional management practice | Crush old stubbles------------Plow-----------Harrow | | | | | | | | | | | | | | | | |
| | | | | | | | | | | Plant seedlings | | | | | | | |
| | | | | | | | | | | | Apply diuron | | | | Apply diuron | | |
| New management practice | Crush old stubbles---Plow---Harrow | | | | | | | | | | | | | | | | |
| | | | | | | **Seed pigeonpea-----------Crush** | | | | | | | | | | | |
| | | | | | | | | | | **Apply glyphosate/glufosinate** | | | | | | | |
| | | | | | | | | | | Plant seedlings | | | | | | | |
| | | | | | | | | | | | Apply diuron | | | | Apply diuron | | |

## Management practices for the alleviation of soil erosion in pineapple fields

During the period of renewal, Ishigaki farmers often leave the pineapple fields fallow for a long period of time after plowing and harrowing. This traditional management practice exposes the bare fields to heavy rains that consequently lead to serious soil erosion through the formation of large-scale gullies. To prevent soil loss, pigeonpea can be grown as a cover crop after plowing and harrowing of old stubbles. When planted in April, pigeonpea can be cut down in August in time for the no-tillage planting of pineapple seedlings in September. Weeping lovegrass can be planted on the lower edge of the slope to provide additional soil loss protection. This management practice can be included in the proposed calendar for summer planting of pineapple in the Yaeyama district (Table 1).

In general, weed control is a serious problem in no-tillage planting compared with conventional tillage. However, the growth of weeds can be inhibited for several months by the application of glyphosate or glufosinate immediately after crushing of pigeonpea. Further weed control can be achieved by applying diuron one-month after planting of seedlings. In our field trial, however, we observed that the effect of herbicides in the no-tillage plot persisted for a longer period of time than that in the minimum tillage plot for unknown reasons. We assume that the persistence was related to the longer period of time that pigeonpea residues covered the soil surface.

In the evaluation of the potential of the management practices described in this paper, we also gathered other relevant information. For instance, we observed that the growth rate of pineapple in the no-tillage plot was initially lower than that in the control plot. This could have been due to: 1) compaction of the plow layer that prevented the elongation of roots, and 2) nitrogen starvation during the decomposition process of pigeonpea residues. In the minimum tillage planting where a substantial amount of pigeonpea residues was decomposed, the growth rate of pineapple was almost the same as that in the control plot. We thus considered that nitrogen starvation hardly occurred in either no-tillage or minimum tillage planting. The recovery of plant growth was ensured finally under a standard fertilization program until harvest.

The first fruits from the pineapple plants grown in 1994 were harvested in 1996. About one hundred pineapple fruits were picked from each of the 4 plots (no-tillage, minimum tillage, napiergrass mulch, and the control) under optimal timing. Fresh weight of the fruit (without crown of leaves) was measured and the juice was squeezed from each of about 30 pineapple fruits per plot for quality analysis. The results indicate that the

**Table 2. Effect of no-tillage planting on the yield and quality of fruits**

| Plots | Fresh weight[a)] (g) | Sugar content (Brix) | Acidity (%) |
|---|---|---|---|
| Control | 1406 ± 57[b)] | 11.5 ± 0.3[b)] | 0.78 ± 0.05[b)] |
| No-tillage | 1324 ± 46 | 12.1 ± 0.4 | 0.77 ± 0.04 |
| Minimum tillage | 1403 ± 45 | 12.2 ± 0.4 | 0.78 ± 0.04 |
| Organic mulch | 1399 ± 57 | 12.1 ± 0.4 | 0.88 ± 0.06 |

a): Without crown leaves.
b): Mean with the upper and lower 95% confidence limits.

mean fresh weight in the no-tillage plot appeared to be lower than that in the control plot, whereas the mean sugar content appeared to be higher in the former than in the latter (Table 2). Based on the analysis of variance, however, no significant differences were observed in the fresh weight and sugar content of plants grown under different management practices.

Pineapple fruits harvested in Ishigaki used to be sold to the only canning factory in the island. Unfortunately, repercussions from import liberalization forced the factory to cease operation in 1996. As a result, farmers now sell their products directly to consumers, or through a delivery system. Selling price in direct marketing is about 3 times higher than in canning factories. However, it is difficult to predict whether the farmers will be able to sustain production in a small market. Under these conditions, it is difficult to recommend management practices that require expensive materials and hard work, even if they enable to conserve the environment effectively.

## Conclusion

The advantages of the new management practice that we propose to pineapple farmers in the Yaeyama district are summarized as follows: 1) minimizing losses of surface soil and fertilizers, 2) preventing pineapple seedlings from being buried into the soil, and 3) enhancing the effect of herbicides on the suppression of weeds. The relatively small sediment accumulation over the soil surface enables to prevent pineapple seedlings from being buried, particularly in low-lying areas even after continuous heavy rains. It is generally recognized that pineapple growth is markedly inhibited when the center of the seedling is buried in soil. Hence, there is a considerable advantage in being able to prevent large sediment runoff within the pineapple field.

On the other hand, the disadvantages of the new management practice are as follows: 1) additional inputs in buying seeds (pigeonpea and weeping lovegrass) and herbicides (glyphosate and/or glufosinate), and 2) additional labor in seeding pigeonpea and applying herbicides. While farmers are expected to bear the cost of seeds and herbicides, the city government of Ishigaki shares the cost of buying seeds of pigeonpea.

The new management practices proposed here do not require expensive materials and hard work. Although additional effort on the part of the farmers is needed, the advantages outweigh the disadvantages and contribute to effective environmental conservation.

## References

1) Asoegwu, S. N. (1991): Effect of vegetative cover, mulching and planting time on some soil physical properties and soil loss in pineapple plots. *Agric. Mech. Asia Afr. Lat. Am.*, **22** (2), 39–43.
2) Banzai, K. et al. (1995): Measurement of soil erosion in reclaimed land with optical land surveying. *Soil Phys. Cond. Plant Growth, Jpn.*, **71**, 53–56 [In Japanese].
3) El-Swaify, S. A. & Cooley, K. R. (1980): Soil losses from sugarcane and pineapple lands in Hawaii. *In* Assessment of Erosion. eds. De Boodt, M. & Gabriels, D., John Wiley & Sons, Chichester, 327–340.
4) Hu, S. C. & Lee, S. W. (1995): Erosion control practices for steep upland fields in Taiwan. *Food Fert. Technol. Cent. Ext. Bull.*, **401**, 1–12.
5) Kadomura, H. & Yamamoto, H. (1978): Man-induced erosion; the rate of erosion and an example from Okinawa Island, southern Japan. *J. Geogr.*, **87** (1), 1–15 [In Japanese].
6) Kina, K. et al. (1997): Effective techniques to prevent the soil erosion in the fields of Red soils and Yellow soils area in Okinawa Prefecture. *Kyushu Agric. Res.*, **59**, 65 [In Japanese].
7) McPhee, P.J., Hartmann, M. O. & Kieck, N. F. (1983): Soil erodibility and crop management factors of soils under pineapple production. *Am. Soc. Agric. Eng.*, Paper No. 83–2073, 1–17.
8) Okamoto, K. et al. (1992): Evaluation of the distribution of red soil outflow in the coral reefs off the northern part of Okinawa Island by using of the LANDSAT TM data. *J. Geogr.*, **101** (2), 107–116 [In Japanese].
9) Okinawa Pref. Govern. Dept. Environ. Health (1995): Survey Report in the 1994 fiscal year on red soil outflow in Miyara River basin, 43–58 [In Japanese].
10) Onaga, K. (1986): Practical studies on soil erosion in the northern parts of Okinawa. *Sci. Bull. Coll. Agric. Ryukyu Univ.*, **33**, 111–209 [In Japanese].
11) Yoshinaga, Y. & Onaga, K. (1993): Suspended soil from reclaimed farmland of Kunigami-Maji area in Okinawa. *Trans. JSIDRE*, **168**, 105–110 [In Japanese].
12) Valentin, C. & Roose, E. J. (1981): Soil and water conservation problems in pineapple plantations of south Ivory Coast. *In* Soil Conservation – Problems and Prospects. ed. Morgan, R.P.C., John Wiley & Sons, Chichester, 239–246.