Problems facing and research perspectives on the agricultural environment in Okinawa, Japan

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Introduction

Agricultural conditions in Okinawa, Japan have drastically changed since its reversion to Japan in 1972 due to infrastructural improvements. The convenience and effectiveness of agricultural production have been substantially upgraded. However, the agro-ecosystem framework has become increasingly rigid and simplified. Overloading of the environment on small islands risks leading to disruption of local ecosystems and/or pollution as a result of the use of various agricultural materials and practices. This paper reports on the effects of summer drought, typhoons and invasions of pest insects, all of which lead to serious problems.

Summer drought

Okinawa consists of 160 small coral reef islands, all of which lack major rivers or lakes. It is therefore difficult to maintain a reliable supply of water. Due to the influence of Pacific high pressure areas and typhoons, precipitation fluctuates both yearly and seasonally, making it impossible to maintain a reliable water supply for agriculture. Figure 1 shows the frequency distribution of zero rainfall (less than 1 mm) lasting more than 10 days in Naha and Ishigaki City from 1771 to 2000.

Generally, crop losses occur due to droughts in which no rainfall has fallen for more than 10 days, and disasters caused by drought usually occur when the monthly amount of rainfall falls to below 30% of normal. Lack of rainfall is most frequently observed in October in Naha City, but in July in Ishigaki Island. Okinawa is in a subtropical region, so evaporation of water from soil and/or plants readily occurs due to the high intensity of solar radiation in the summer. For these reasons, damage to agricultural production caused by drought occurs more frequently on Ishigaki Island, where drought strikes in July. As a general trend, long-term meteorological disasters in Okinawa are mostly droughts caused by insufficient rain.

Industries use biological resources, significantly affecting productivity is environmental stress. Environmental stress is not controlled, and artificial control would incur huge costs. Environmental factors, for example moisture and/or nutrient element is incompatibility for crops, strong shine was becoming stress for plant. To reduce loss of crop yield caused by drought, it is essential to construct stormwater holding tanks.

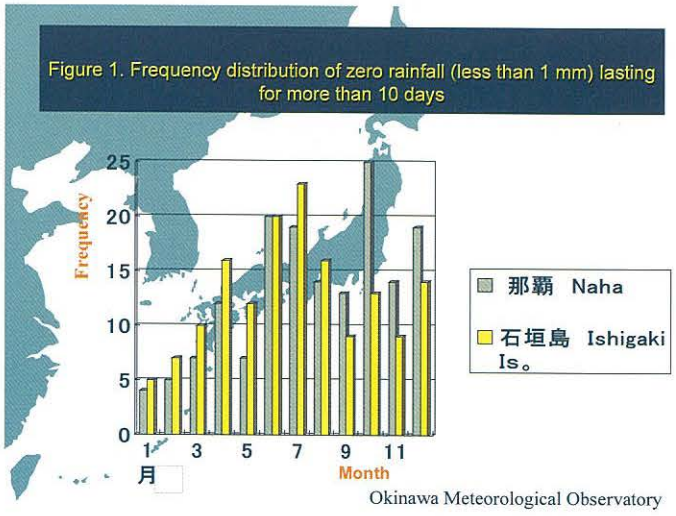

Fig. 1. Frequency distribution of zero rainfall (less than 1 mm) lasting for more than 10 days

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Typhoons

Typhoons are a common climatic hazard in Southeast Asia. The annual average number of typhoons from 1961-1990 was 27.8, of which 7.3 approached Okinawa. The frequency of approach of typhoons to Okinawa was the highest in the whole of Japan.

Figures 2 and 3 show a simulation of the effect of wind profile reduction made by windbreak forests 13 m and 6m height from base level, respectively. The wind profile reduction effect by a 13-m windbreak forest, at wind speeds of 33-35 m/s, is about 80% at Point A and 40% at Point B (Fig. 2). If a 6-m windbreak is modeled, the wind profile decreases from 33-35 m to 6 m at Point A (Fig. 3). Since greenhouses are usually about 6 m tall, damage by typhoons can be avoided in this way. For these reasons, windbreak forests can play an important role in preventing typhoon damage.

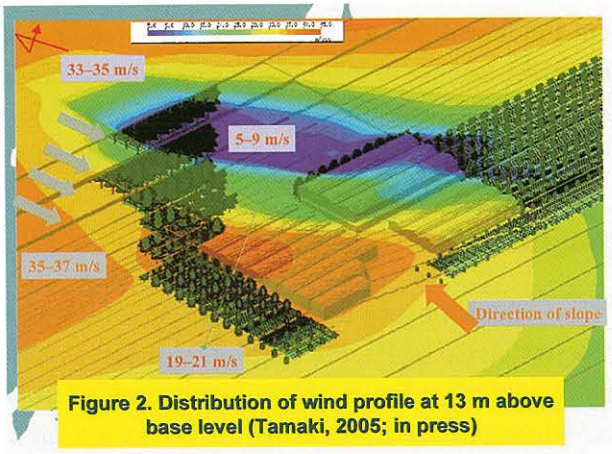


Fig. 2. Distribution of wind profile at 13 m above base level (Tamaki, 2005; in press)

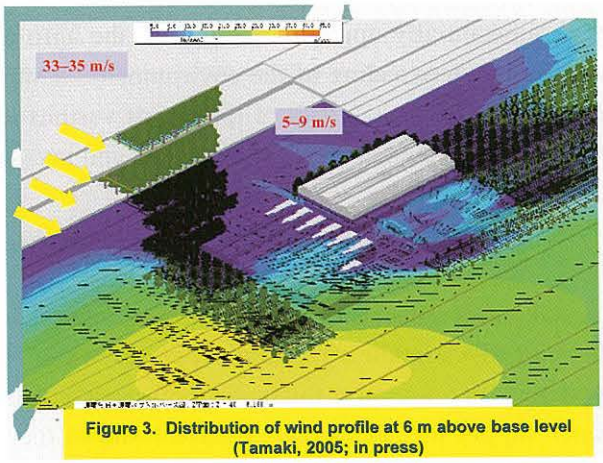


Fig. 3. Distribution of wind profile at 6 m above base level (Tamaki, 2005; in press)

Invasion of pest insects

A total of 260 insect species have been introduced into Japan since 1868. The number of exotic species becoming established has been increasing exponentially over the past 140 years (Fig. 4). Since the subtropics are a band of transition from tropical to temperate zones, Okinawa, with is in the subtropical zone, is prone to invasion by both northern and southern exotic insects. Often, little is known about the habits and life cycles of insects that invade from the south, and insect pests that invade from the north frequently carry resistance to numerous insecticides, making them difficult to control.

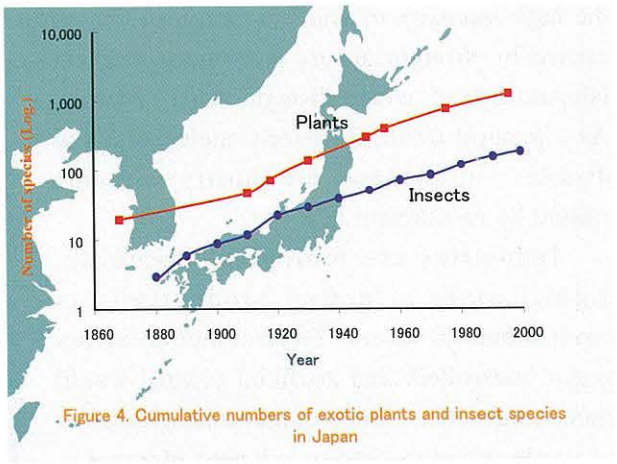


Fig. 4. Cumulative numbers of exotic plants and insect species in Japan

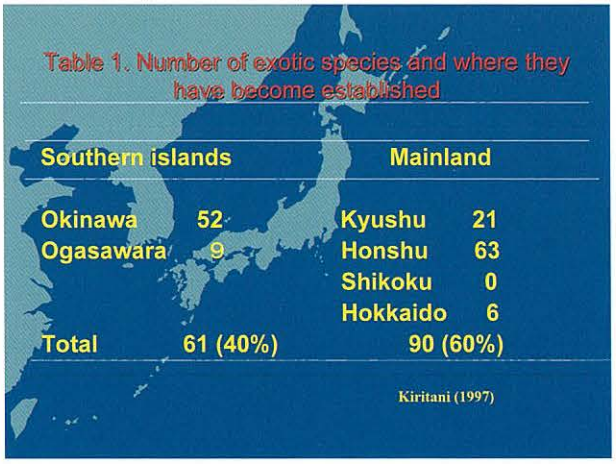
The number of invading insect species has fluctuated, but there have been several waves during the past 130 years. The first was a large-scale infestation by scale insects (Coccoidea) imported on nursery stock plants before inspection services started in 1900. The next wave was after World War II, a time of food shortages. Between 1945 and 1955, 25 species of stored grain insect pest were introduced in the large amounts of grain and feeding stuff that were imported. The third wave, in 1975 - 1990, comprised greenhouse pests. The protected cultivation of various vegetables and flowers in greenhouses created

a vacant niche or ecological island which was vulnerable to invasion by exotic insects and mites. The combination of short day lengths and higher temperatures created in a greenhouse during winter favors non-diapausing insects, most of which originate in subtropical or tropical countries. The quantity of cut flowers, vegetables, and fruit imported from overseas has increased 150-fold during the past 20 years. The fauna of stored insect pests and greenhouse pests have been homogenized at the global level.

Despite the deterrent effect of plant quarantine regulations, accidentally introduced foreign species continue to be added to the fauna of Japan, and the rate of invasion by exotic insects has tended to increase exponentially. One hundred and eleven species have been recorded during the postwar period (1945-1996), with a mean of 2.13 exotic species/year. If we take into account the fact that there are 90 species present whose year of establishment is unknown, 3 species per year is a good minimum estimate of the number of species now becoming established in Japan. Of the established species, 75% are likely to be pests of some importance. Forty percent of them will find their first foothold in Japan in the southern islands, which account for only 1.2% of Japan's total land area. This disproportionately large number of immigrants to the southern islands requires special attention, not only from the viewpoint of the economic damage they cause, but to ensure the conservation of native fauna on these islands.

Table 1 shows the number of exotic species and where they have become established. Out of 151 species that have a record of naturalization, 61 species, or 40%, were first established in the southern islands and the remaining 90 species, or 60%, on the mainland. The present distribution of 260 exotic species is shown in Table 3. Twenty and 40% of them, respectively, have confined their distribution to the southern islands and the mainland. Forty percent were found to occur both in the southern islands and on the mainland. If we assume that there was no subsequent introduction directly from the place of origin to either the southern islands or the mainland, the gap between the figures in Tables 2 and 3 can be explained by secondary range extension of exotic insects between the southern islands and mainland after their first becoming established.

Table. 1. Number of exotic species and where they have become established



The oriental fruit fly, *Bactrocera dorsalis* Hendel, was combated by the male annihilation method, and the melon fly, *Bactrocera cucuribitae* Coquillet, was tackled using the sterile release method. They were eradicated in Okinawa in 1986 and 1993, respectively. In the case of the oriental fruit fly, since October 1977, sections of cotton rope or rolled cotton, saturated with pesticide and an attractant, methyl eugenol, have been placed on the ground or dropped by helicopter on forests and fields over 87% of the infested area. The control effect of the chemicals was checked using about 600 Steiner-type traps and host fruit inspection. After eradication of the oriental fruit fly was achieved, however, reoccurrence was seen in one or more parts of the affected area. Figure 5 shows the frequency of the reinvasion of the oriental fruit fly of Okinawa (the main island), Miyako, and Yaeyama in each year. Arrows indicate the host fruits found in Okinawa Prefecture. The average number of tephritid fruit flies discovered in Japan's plant quarantine is one fly

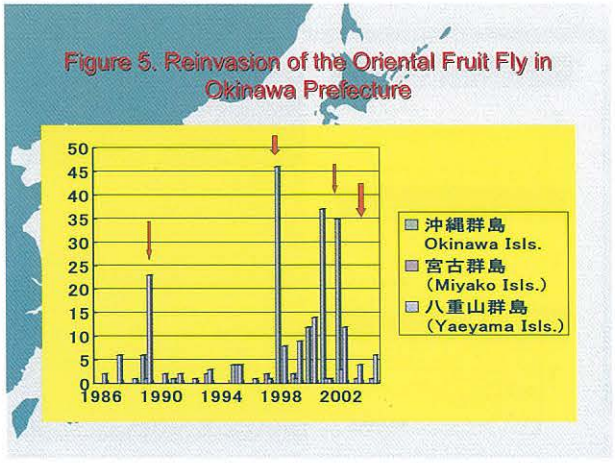


Fig. 5. Reinvasion of the Oriental Fruit Fly in Okinawa Prefecture

per day. The invasion of exotic pests is on the increase because of expanding international trade, increased tourism, and increased areas of crops grown under glass.

Sustainable agriculture

Kiritani (2004) pointed out the relationship between IBM (Integrated Biodiversity Management) and IPM (Integrated Pest Management) by plotting conservation and preservation along a time axis. In IPM, the density of the pest population is kept below the level where it causes economic injury; whereas, in the case of conservation and preservation, the density of indigenous species is maintained above their extinction limit.

In the past, most studies on the paddy ecosystem have focused on productivity and its stability in terms of rice yields. Arthropods in paddy ecosystems can be classified into three main groups according to their ecological requirements. They are (1) resident species adapted to continuous cropping of rice in the same field; (2) migratory species that have adapted to exploit rice as an annual crop; and (3) aquatic species originating in wetland still-water habitats. Concerning groups (1) and (2), IPM programs, whose primary objective is to maximize farming profits, have been implemented with various degrees of success. Although IPM is becoming widespread, insects that have no direct economic impact on rice production have been mostly ignored, in spite of playing important roles in the rice ecosystem. Consequently, some aquatic insects are in danger of extinction and thus require conservation.

The concept of IBM is not limited to the paddy ecosystem, but is also applicable to all types of agricultural systems. Crops range from those that require intense IPM intervention with little consideration paid to species conservation, e.g., greenhouse crops, to those for which both a high level of pest control and biodiversity preservation can be attained, e.g. a complex home garden or back yard in the tropics.

Creation of agricultural environments in small subtropical islands

Due to agricultural development, agricultural ecosystems have been changing from primitive but diverse agro-ecosystems to monocultural forms. To improve the agricultural environment, it is essential to change from simple systems to complex agroecosystems that possess biodiversity. For the creation of ideal agro-ecosystems, stormwater retention tanks should be constructed and windbreak tree planting started to create shelter belts. Stormwater retention tanks and shelter belts are not only able to preserve natural enemies and conserve small-island ecosystems but also reduce crop damage caused by drought and shield against damage caused by typhoons and monsoons. Both systems would permit the sustainable use of resources in agriculture (Fig. 7).

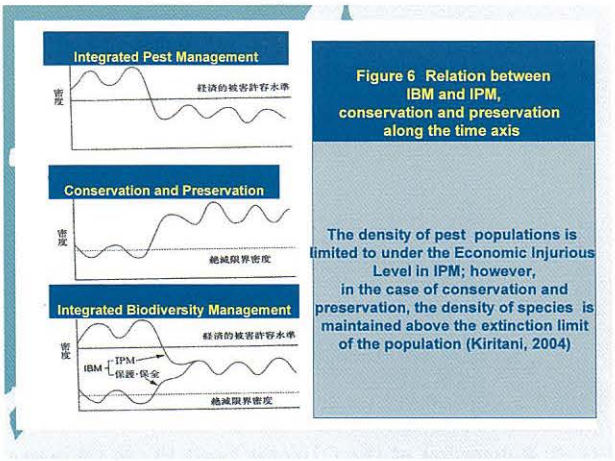


Fig. 6. Relation between IBM and IPM, conservation and preservation along the time axis

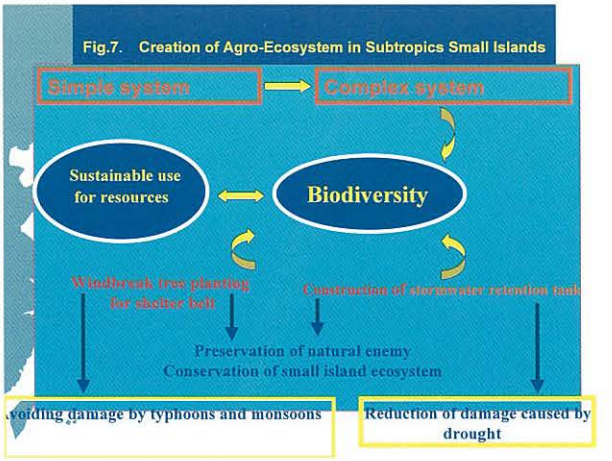


Fig. 7. Creation of Agro-Ecosystem in Subtropics Small Islands

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