Land Use and Crop Damage by Japanese Macaque on Yakushima Island, Japan

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Introduction

In Japan after WW II, natural broad-leaved forest was extensively converted to artificial coniferous forest (including *Cryptomeria japonica*) for timber production. The Japanese government promoted extensive afforestation throughout the archipelago from the mid-1950s to the mid-1980s. The expansion of farmlands has also altered forests. In particular, some types of fruit have high economic value, and orchards have expanded onto sunny slopes following the clearing of forests. Hence, Japanese forests have changed extensively within a short period.

The ecological aspects of forests have also changed extensively, which should alter the forest ecosystem services available for humans. Wild animals have caused severe crop damage recently, which may be a result of changes in the forest ecosystem. Crop damage is a long-standing source of conflict between humans and wild animals in Japan. However, damage caused by monkeys, deer, wild boars, and other animals has increased extensively since the 1970s. On Yakushima Island, we investigated the spatial elements of land use (including forest use) by humans, which are related to the occurrence of crop damage by monkeys (hereafter monkey damage).

Materials and Methods

We studied two areas on Yakushima Island, i.e., Nagata and Koshima, where there are many orchards, primarily citrus (Fig. 1). Extensive afforestation ensued on the island in the 1960s and 1970s. In 1960, farmlands occupied approximately 40% of the total area. Now, the land is used for forests, farmland, and housing. Orchards expanded from 1960 to 2000 (Fig. 2). In 1980, orchards appeared in the northeastern area where forests had expanded in 1960. Citrus orchards, which have high economic value on the island, have also expanded markedly in other areas since the 1970s.

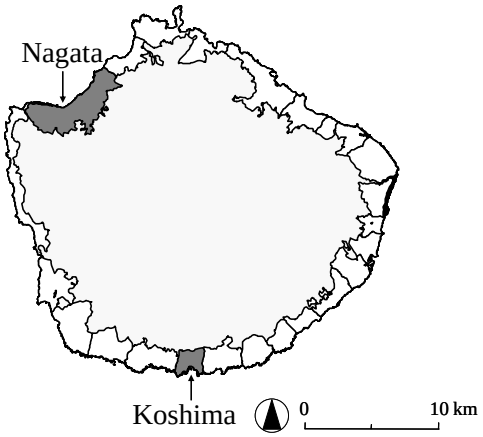

Fig. 1 Location of the study areas on Yakushima Island.

Monkey damage on the island has been severe since the 1980s in the Nagata area, and since the 1990s in the Koshima area. Previous studies investigated the distance between farmlands and forests (Hill 1997; 2000; Naughton-Treves 1998; Saj et al. 2001) and the areas adjacent to farmland (Hill 2000); such spatial elements may affect the occurrence of monkey damage. To elucidate the relationship between land use by humans and

the occurrence of monkey damage, however, the spatial elements of land use should be investigated. We performed a questionnaire survey of 11 farmers in the Nagata area and 15 farmers in the Koshima area to determine the extent of monkey damage to orchards in the two areas. The term of the survey was from 1 to 19 September 2003. We selected 12 parameters (Table 1) and used logistic regression to examine the relation between each parameter and the occurrence of monkey damage. In addition, we constructed a risk map of the probability of the occurrence of monkey damage in each area by combining the results of the model and using a geographic information system (GIS).

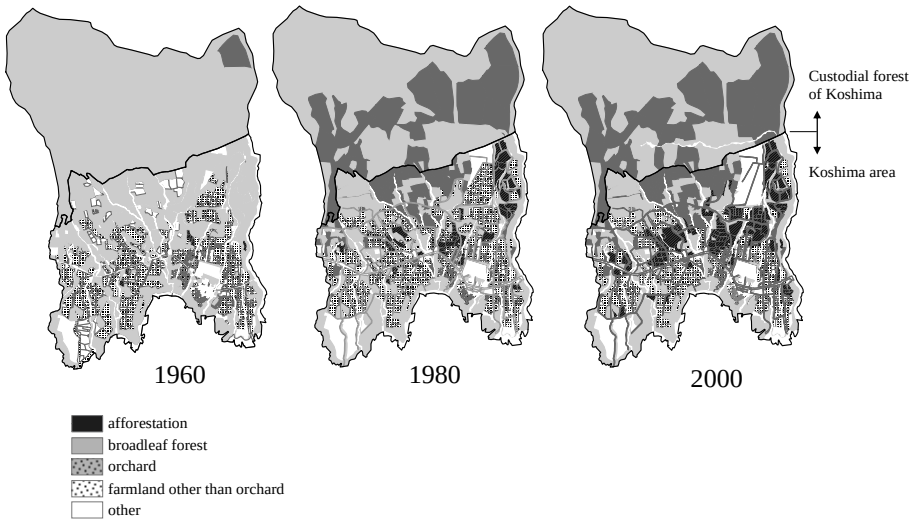

Fig. 2 Land use changes in Koshima.

Table 1 List of parameters considered.

	Name of parameter
dependent parameter	
economic damage to crops caused by Macaque	*Damage*（damage=1, no damage=0）
independent parameter	
distance between forest and orchard (*m*)	*Forest*
distance between housing and orchard (*m*)	*Housing*
distance between road (wide) and orchard (*m*)	*Road* 1
distance between road (middle-wide) and orchard (*m*)	*Road* 2
distance between road (narrow) and orchard (*m*)	*Road* 3
distance between river (wide) and orchard (*m*)	*River* 1
distance between river (middle-wide) and orchard (*m*)	*River* 2
distance between river (narrow) and orchard (*m*)	*River* 3
speceis of fruit tree planted in orchard	*Fspecies* (TANKAN; *Citrus tankan*, HAYATA=1, PONNKAN; *Citrus reticulata*, Blanco=2, TANKAN and PONNKAN=3)
age of fruit tree planted in orchard	*Fage*
whether there is electric fence or not arround orchard	*Fence*（fence=1, no fence=0）
type of forest nearest orchard	*ForestType*（broadleaved forest=1, Japanese cedar forest=2）

Results

The multivariate logistic regression analysis produced probabilities for the occurrence of monkey damage, which are the dependent parameters included in the model. The model was:

$$log\{p(x)/(1 - p(x)) = -1.172 - 0.034Forest + 0.004Road1 + B \quad (1)$$

Nagata: $B = 2.507$

Koshima: $B = 0$

where the primary factors selected were *Forest*, *Road*1, and *B*. The parameter *B* indicates differences in monkey damage between the areas and was significant (p = 0.000); the perceived monkey damage was greater in the Nagata area. Parameters regarding the quality of the orchard showed no significant differences.

We calculated the probability function of monkey damage as $p(x)$. We then constructed two risk maps of monkey damage using the function and GIS (Fig. 3). More than 90% of orchards in the Nagata area and approximately 30% of orchards in the Koshima area might suffer monkey damage, with a risk > 50%.

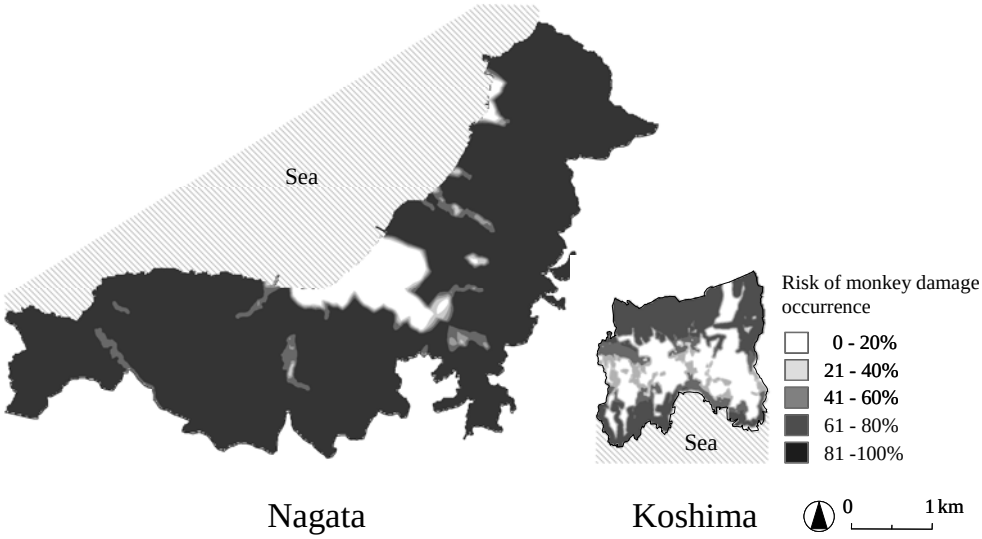

Fig. 3 Maps indicating the risk of crop damage caused by Japanese macaque.

Discussion

The model indicated that the distance between forests and farmlands (i.e., the parameter *Forest*) was negatively correlated with the occurrence of monkey damage. This result supports those of previous studies that suggest similar patterns of occurrence for monkey damage on Yakushima Island (Hill 1997; 2000; Naughton-Treves 1998; Saj et al. 2001). Monkeys are arboreal animals and forest is a space of safety for them. Therefore, when the distance between forests and farmlands is greater, the risk of raiding farmlands might be higher for monkeys. The model also indicated that the distance between roads and farmlands (i.e., the parameter *Road*1) was positively correlated with the occurrence of monkey damage. This road parameter accounts for wide roads,

which are prefectural main roads with much traffic. Therefore, monkeys might avoid these roads. These spatial elements of land use, rather than variables related to orchard characteristics, are important in predicting the occurrence of monkey damage on the island.

The distance between forests and farmlands could change with the alteration of forests and large-scale timber extraction. At the study sites, the extent of changes in land use was small, although the forest physiognomy has changed extensively in the last 40 years. Orchards have expanded since the 1970s by the clearing of forest areas. Newer orchards are more likely to be closer to forests and thus are more likely to suffer from monkey damage. We used only the current spatial elements in these analyses. Therefore, it is not possible to predict how previous changes in forest use affected the occurrence of monkey damage. We can only suggest that new farmlands located on newly cleared land would be more likely to suffer damage from monkeys.

Compared to the Koshima area, monkey damage was high in the Nagata area, where the population density of Japanese macaque was higher and the damage began earlier in the season. In other words, farmlands more likely suffer monkey damage in the Nagata area than in the Koshima area, even when the parameters *Forest* and *Road*1 are the same. The parameter *B* may imply variation in the density of monkeys, their habituation to humans, and their habitats. The forest ecosystem would affect the parameter *B* and cause differences in the extent of monkey damage.

References

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