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Influence of Abandoned Farmland and Protection Fencing on Agglomeration and Connectivity of Wild Boar Habitat around Orchard Fields

- Field survey in an island with citrus fruit production in the Seto Inland Sea Area -

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Abstract

Agglomeration and connectivity of wild boar habitat were measured in this paper for an island with citrus fruit production in the Seto Inland Sea Area. As a result, forests as natural habitat was separated into 44 patches by cultivated fields, while connected woodland adjacent to abandoned fields (as additional habitat) was represented by 13 patches. The maximum patch size was 12.3 ha for woodland, which increased to 41.0 ha with connected habitat. Additionally, if unfenced cultivated fields behave as corridors between habitat patches, 80% of the habitat area was connected. Fences have a function to protect fields, but also habitat. We showed the locating method of key patches and corridors with described habitat connectivity using a graph.

Key words : *Agglomeration, Connectivity, Abandoned farmland, Wild boar, Orchard field, Graph theory, Habitat management*

1. Background and Purpose

As damage to farmland and crops by wild boars in Japan becomes increasingly serious, the relationship between the composition of the rural landscape, the spatial configuration of forests, and damage to farmland is attracting more attention. Previous studies have shown that damage to farmland is more severe when the area of forests in the hinterland is large (Nomoto et al., 2010), and that the proportions of abandoned land and of forest land in each community have a positive effect on the occurrence of damage to farmland (Honda, 2007). In addition to the area of forests, studies have focused on the agglomeration of forests, the habitat of wild boars, and the occurrence of damage in the surrounding area. They showed that forest connectivity is an important factor in the formation of wild boar habitat (Harashina et al., 1999) and that damage to farmland by wild boars is more common around large green areas and less common around small, scattered green areas (Kawakami and Kamihogi, 2006).

Citrus orchards are often located on slopes in the Seto Island Sea Area (Matsuoka, 2007) and are generally in a state of “small dispersed complex plots” (Matsuoka and Ninomiya, 2005). Thus, citrus-growing areas are a mosaic of farmland and forest, and the forests that provide habitat for wild boars are also fragmented by citrus orchards, and so are considered less suitable as habitat. However, in recent years, damage by wild boars has become more serious in citrus-growing areas (e.g., Takeyama and Kuki, 2008). Previous studies have shown that citrus fruits are the main food source for wild boars in September when their nutritional status is the poorest (Kodera and Kanzaki, 2001), that mandarin oranges are the main food source for wild boars on islands (Koba et al., 2009), and that discarded citrus fruits around citrus orchards are the main food source for wild boars (Hogen, 2012). It is assumed that citrus feeding is contributing to the increase in wild boar populations. In addition, a study (Ueda and Jiang, 2004) on orchards confirmed that wild boars use abandoned orchards as feeding grounds during the fruit ripening period. Yamamoto (2001) pointed out that the abandonment of farmland may contribute to the formation of new green areas that provide habitat for wild animals.

In this study, we evaluate the effects of abandoned fields and protective fences around orchard areas on the connectivity of wild boar habitats in a citrus-growing area and examine the effectiveness of the evaluation method from the perspective of designing and planning community-wide measures to prevent damage by wild boars.

2. Research Methods

2.1 Scope of the survey

Previous studies evaluating the aggregation and continuity of biological habitats include join analysis using raster data (Yamamoto et al., 2002; Yoshikawa, 1999) and analysis using the index CON for evaluating forest continuity (Harashina et al., 1999). However, existing numerical map data maintained at the regional level cannot distinguish differences in the spatial degree of human influence (Ichinose et al., 2008), and it is difficult to detect new natural areas such as forests in rural areas due to the abandonment of agricultural land (Yamamoto, 2001). In particular, it is difficult to distinguish between farmland and wasteland (Mochizuki et al., 2007). Therefore, in many cases, studies targeting a wide area treat only green areas and forests as wildlife habitats (e.g., Harashina et al., 1999). However, wild boars not only use forests but also abandoned fields as feeding grounds and resting places during the daytime (Kodera et al., 2001; Ohashi et al., 2013). The damage to fields caused by wild boars is strongly related to the distance from abandoned fields (Nomoto et al., 2010). Therefore, it is not appropriate to evaluate habitats by focusing only on forests.

In this study, we conducted a detailed land-use survey at a narrow area level, i.e. an agricultural community, and created a land-use map that classified agricultural land under cultivation, abandoned land, and forests.

2.2 Areas covered by the survey

The target area of this study is District A of Nakajima (Matsuyama City, Ehime Prefecture), which belongs to the Kutsuna Islands in the Seto Inland Sea, Japan. Nakajima is an island with an area of 21.1 km^2 and a population of 2,993 (as of January 1, 2013). According to an interview conducted in July 2013 at the JA Nakajima Agricultural Support Center, wild boars were previously absent from Nakajima, but in September 2000, the island's early ripening mandarin oranges were attacked for the first time. Since no small animals such as raccoons or weasels inhabit the island, it is assumed that wild boars are responsible for feeding damage to early ripening mandarin oranges. According to Matsuyama City records, the first wild boar was captured on the island between January and March 2001 (month and day not specified). Since there is only one chicken coop on the island and no pig or cattle barns, and no evidence of boar breeding, it is assumed that the wild boars crossed the sea and invaded the island. Since then, the damage has gradually increased. In 2013, damage has spread to all areas of the island. The number of wild boars captured on Nakajima in 2013 was 561 (according to Matsuyama City, including the hunting period).

District A is a citrus-growing area with a total of 46 farm households and 53 ha of cultivated land (all in orchards), and no paddy fields (Census of Agriculture and Forestry, 2005). There are no plantation forests, and all existing forests are secondary forests. The northern and western borders of the district are formed by the coastline.

According to interviews conducted in May 2012 (Takeyama, 2013), damage by wild boars was first observed in District A in 2002. The damage became more serious around 2011, and by 2012, all farmland in the district had been damaged. The damage included citrus eating damage, damage to citrus trees and branches, and digging up of stone walls and surface soil of farmland. In addition, there was serious damage to sweet potatoes grown for private use. In response to this, protective fences were installed around fields. However, the fences were destroyed or broken through one after another, and the damage did not stop. In each of the fiscal years 2010 through 2013 there were 1, 32, 55, and 55 wild boars captured, respectively. However, wild boars were still sighted during the daytime in 2013, suggesting that the boar population had not decreased.

Takeyama (2013) installed a total of 12 infrared sensor cameras in District A to investigate the presence of wild boars. The infrared sensor cameras were set to capture 10 seconds of video after detecting an animal and were scattered throughout the district using wild boar field signs as a guide. The survey period was from May 29, 2012 to January 29, 2013. All 12 sensor cameras confirmed the presence of wild boars during the entire survey period, and it was inferred that wild boars were continuously inhabiting the entire District A.

2.3 Survey methodology

Polygons were created from ortho-rectified aerial photographs (surveyed in 2000, provided by Ehime Prefecture Agricultural Land Development Division) by visually identifying the boundaries of land parcels. The target area was the entire area (113.0 ha) included in District A on the cadastral map. ArcGIS (Ver. 10) was used for mapping and analysis.

First, a land classification map (acquired in May 2012, courtesy of the Nakajima Branch Office of Matsuyama City) was superimposed on the white map to determine the land classification of each polygon. **Fig. 1** shows the area ratio by land category.

Second, a current land-use map was prepared. In this paper, from the viewpoint of focusing on land that can be used by wild boars, we divided the land use into three categories: "forests," "abandoned fields," and "cultivated fields." Cultivated fields was further divided into two categories: "fenced fields" and "unfenced fields." First, polygons with land classifications of "mountain forest," "security forest," and "precinct" were designated together as forests. Next, a field survey was conducted from October 23 to November 13, 2012 on polygons of land classified as "uplands" to identify cultivated fields and abandoned fields. Field surveys were also conducted from November 27 to December 12, 2013, to supplement these surveys and to confirm whether fences were

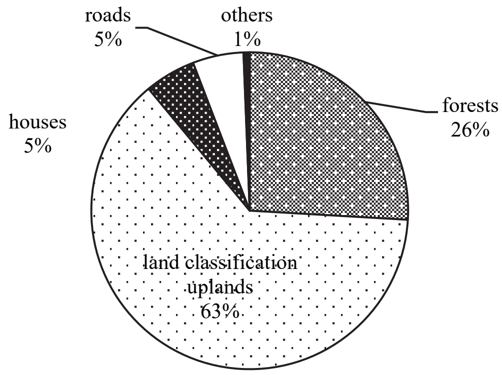


Fig. 1 Ratios of area by land category

installed around the cultivated fields, and to identify fenced and unfenced fields. Although wire mesh fences, electric fences, and net fences were fence types in the surveyed areas, these types of fences are not considered in this paper. In addition, for the areas where cultivation status could not be visually confirmed because they were surrounded by thickets, we interviewed local farmers on July 17, 2014, to determine the land-use classification.

Third, patches were created for each land-use category. When two or more polygons of the same land-use category were adjacent, they were merged into a single patch. "Adjacent" includes cases where the polygons were bounded by points and cases where they were adjacent to each other across a road less than 4 m wide (except for roads in villages). In the former case, the presence or absence of tie points was confirmed both on the lot maps and ortho aerial photographs. In the latter case, it is known that the presence of wild boars is suppressed on main roads and in villages (Honda and Sugita, 2007; Kawakami and Kamihogi, 2006). Furthermore, according to the Land Improvement Project Planning Guidelines and Rural Environment Improvement (Planning Department, Structural Improvement Bureau, Ministry of Agriculture, Forestry and Fisheries, 1997), agricultural village roads should be at least 4 m wide. According to the Building Standard Law, buildings cannot be constructed unless they are, in principle, adjacent to a road 4 m or more in width. Therefore, a road with a width of 4 m or more was designated as the main road in the district and was used as a structure to divide the wild boar habitat. The width of the road was determined from ortho aerial photographs using the distance determination tool in ArcGIS.

2.4 Analysis method

We analyzed the agglomeration and connectivity of each habitat, assuming two cases of wild boar habitat: case 1, forests only; and case 2, forests and abandoned fields (a patch comprising the combination of these two is hereafter referred to as a "habitat patch"). Specifically, we used area (ha), occupancy (p_i), number of patches (n), average patch size (ha), and maximum patch size (ha) as parameters for land-use agglomeration. Parameter RS_i (Turner et al., 2004), the relative size of the largest patch in land-use category i, is used as a parameter for land-use category connectivity:

$$RS_i = \frac{LC_i}{p_i \times A} \quad (1)$$

where, LC_i represents the maximum patch size (ha) of land-use category i and A represents the area (ha) of the entire space under consideration.

Next, as case 3, we analyzed the connectivity of wild boar habitats with the help of graph theory, assuming that forests and abandoned fields were used as habitat patches as in case 2, and that unfenced fields could be used as corridors. In graph theory, networks are abstracted by points (nodes, v_i) and lines (edges, $\overline{v_i v_j}$) and represented by a diagram (graph) composed of nodes and edges. In the fields of landscape ecology and forest ecology, this method is used to evaluate connectivity of wildlife habitats and deals with connectivity among patches by replacing patches with nodes (Ecological Society of Japan, 2011). In this paper, arbitrary points of habitat patches were replaced by nodes, and when patches were directly connected by unfenced fields, the nodes were connected by edges to create a graph. Note that the length and angle of the edges have no meaning in this paper because the nodes are arbitrary points in the patches. The connectivity was evaluated by focusing on the degree $d(v)$ *of* each node (the number of edges connected to node v).

3. Results

3.1 Case 1: forests

The measurement results showed 29.3 ha of forests (p_i = 0.26) and there were 44 patches (**Table 1**). The largest patch size was 12.3 ha (42.1% of the total forests patches), and four patches were larger than 1 ha. Forests patches tended to be scattered on a small scale on the edge of a ridge and on the fringes of the district (**Fig. 2**).

Uplands had an area of 71.3 ha (p_i = 0.63), number of patches was n = 26, and maximum patch area was 33.3 ha. The area of uplands was 2.4 times that of forests, and the connectivity was higher relative to forests. However, RS_i values were similar for forests (0.42) and uplands (0.47).

3.2 Case 2: habitat patches

The 71.3 ha of uplands was divided into abandoned fields and cultivated fields (**Table 1** and **Fig. 3**). Cultivated fields accounted for 39.2 ha (p_i = 0.35) and 55% of the total uplands. There were 39 patches of cultivated fields compared to 26 for uplands. Mean and maximum patch sizes were also lower for cultivated fields compared to uplands, resulting in lower aggregation.

Abandoned fields represented 32.1 ha (p_i = 0.28), accounting

Table 1 Measurement results

	Area (ha)	Share p_i	Number of patches n	Average patch size (ha)	Maximum patch size (ha)	RS_i
Forests	29.3	0.26	44	0.7	12.3	0.42
Uplands	71.3	0.63	26	2.7	33.3	0.47
Cultivated field	39.2	0.35	39	1.0	14.3	0.36
Abandoned fields	32.1	0.28	81	0.4	4.2	0.13
Habitat patch (forest + abandoned fields)	61.4	0.54	50	1.2	41.0	0.67
Patches that include forest	58.6	0.52	13	4.5	41.0	0.70

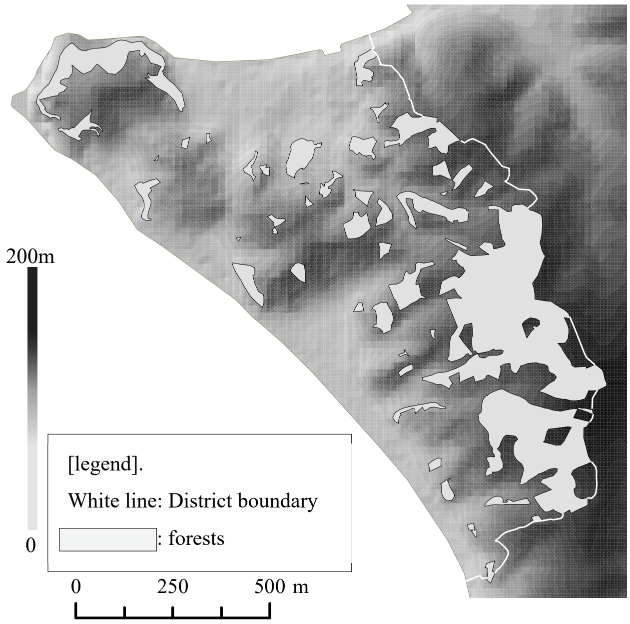
for 45% of uplands. There were 81 patches, average patch size was 0.4 ha, and maximum patch size was 4.2 ha, indicating that small patches were scattered throughout the district.

Abandoned fields were considered to have been incorporated into the wild boar habitat, and habitat patches consisting of forests (44 patches) and abandoned fields (81 patches) were considered. The analysis showed that three patches of forests and 37 patches of abandoned fields remained as patches consisting only of forests and abandoned fields, respectively, without being combined with surrounding abandoned fields and forests. The other 85 patches were merged into 10 patches of forests and abandoned fields. These patches were combined into 50 habitat patches with a total area of 61.4 ha (p_i = 0.54). Focusing on forests patches, the 44 patches before the synthesis were aggregated into 13 patches by connecting them with abandoned fields. The average size of the patches including forests was 4.5 ha and RS_i was 0.70. Aggregation and connectivity were higher in case 2 than case 1.

3.3 Case 3: traffic between habitat patches is possible via unfenced fields

Cultivated fields were classified into unfenced and fenced fields. The area of unfenced fields was 11.8 ha, accounting for 30% of the total cultivated fields. The location of the unfenced fields is shown in **Fig. 4.** These unfenced fields were considered fields where the cultivator knowingly accepted the damage done to fields and did not do anything to correct it due to the cost and other challenges associated with farmland management, in addition to iyokan and lemon orchards, which are considered less susceptible to damage.

Next, habitat patches were replaced with nodes. The number of nodes was set to 50, and a graph was created by connecting adjacent nodes via unfenced fields with edges. There were 25 nodes connected to adjacent nodes, and the remaining nodes were isolated points [$d(v_i) = 0$] that were not connected to any node. As a result, four clusters of nodes connected by edges were formed in (**Fig. 4**, excludes the isolated nodes). The number of nodes in each cluster was n = 18, 2, 3 (forests, and abandoned fields), and 2 (abandoned fields only). When restricted to patches containing



The elevation map is based on tin data (provided by Ehime Prefecture Agricultural Land Development Division).

Fig. 2 Spatial arrangement of forests

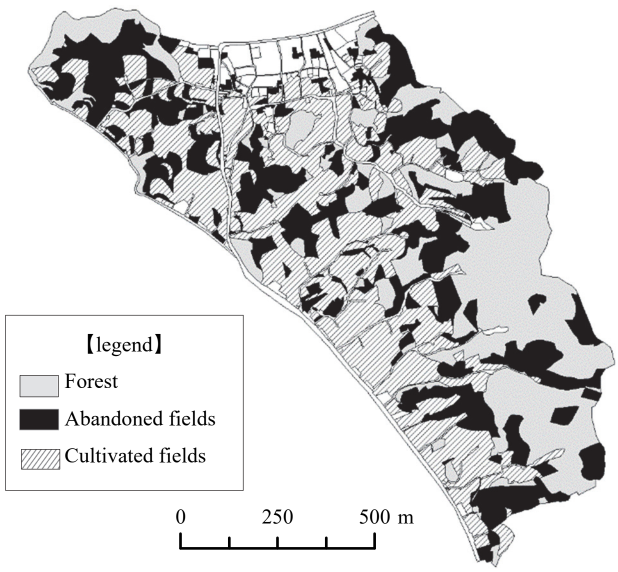


Fig. 3 Spatial layout of abandoned and cultivated fields

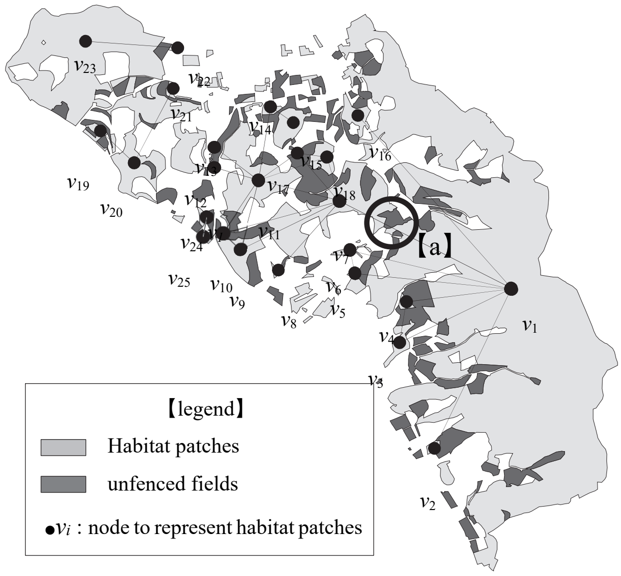


Fig. 4 Habitat patches connected by unfenced fields

forests, there were three clusters and one isolated point.

The largest cluster with 18 nodes was extracted as a subgraph G':

$$G' = \{v_1, v_2, \ldots, v_{18}\} \quad (2)$$

where the nodes in { } represent the nodes that make up G'.

The maximum order $\Delta(G')$ of G' was observed in v_{11}:

$$\Delta(G') = d(v_{11}) = 8. \quad (3)$$

In addition, $\{v_7, v_{11}, v_{17}, v_{18}\}$ and $\{v_7, v_9, v_{10}, v_{11}\}$ including v_{11} were all connected by edges. A graph in which all nodes are connected by edges is called a complete graph. The two complete graphs were connected by an edge $\overline{v_1v_7}$ to a node v_1 that represents a patch of maximum size 41.0 ha. That is, the largest area of habitat on the periphery of the district was connected to the smaller habitat network in the center of the district by the edge $\overline{v_1v_7}$ (i.e., the unfenced field in [a], circled in **Fig. 4).** The patch area connected by the subgraph G' was 49.2 ha. This corresponds to 80% of the total habitat patches.

4. Discussion

4.1 Influence of abandoned land on wild boar habitat formation

The production of unshu mandarins in Ehime Prefecture peaked in 1975 and has been declining since. Therefore, it can be inferred that the 71.3 ha of land classification uplands area in District A represents the area of fields that were cultivated around 1975. At this time, forests area was 29.3 ha, divided into 44 patches, with the largest patch size of 12.3 ha. Kawakami and Kamihogi (2006) showed that damage to farmland by wild boars was distributed mostly around large green areas (500 ha) and less frequently around scattered small green areas of less than 10 ha. Kodera et al. (2006) reported that a single wild boar's activity area was 137 ha based on a 5-day radiotelemetry survey conducted during summer. In the same survey conducted on three wild boars, the average activity area ranged from 81.4 to 132.4 ha (Kodera et al., 2010). Although the area of the wild boars' activity zones varies depending on the research period and environment, the original area and layout of forests in District A were not sufficient for wild boars to use it as their daily habitat, based on the two reports.

However, when fields are abandoned, the remaining cultivated fields are fragmented into small patches. Connecting the abandoned fields with forests aggregated 44 forest patches into the sum total of 13 patches. In addition, connectivity (RS_i) increased significantly from 0.42 to 0.70. As a result, habitat patches increased 2.1-fold, from 29.3 to 61.4 ha, and the maximum patch size increased 3.3-fold, from 12.3 to 41.0 ha, compared to forest alone.

Abandoned fields are known to provide food for wild boars, but the results of this paper showed that the damage is not limited to only that, but also increases aggregation and connectivity between forest areas, the original habitat of wild boars and allows more individuals to live around cultivated agricultural land.

4.2 Effects of protective fences on wild boar habitat formation

Assuming that wild boars can use fields without fences as corridors, 49.2 ha or 80% of the habitat patches, were connected. Focusing only on patches containing forest areas, 12 of the 13 patches were connected, resulting in three clusters. In the central part of the district, there were areas of high connectivity between habitat patches, and these were connected to the largest patch on the district's periphery, forming a highly clustered and connected wild boar habitat in the district.

In other words, a field without a fence not only suffers damage from wild boars, but also increases the connectivity of the wild boar habitat in the entire district, allowing more individuals to inhabit the field. The counter measures taken by fences are generally regarded as "damage control" and are supposed to function to control the farmland inside the fences. However, our results indicated that installation of fences around farmland can also reduce the connectivity of wild boar habitat in District A.

4.3 Habitat management practices that reduce aggregation and connectivity

Habitat management is a method to improve the habitat of wild animals in the vicinity of farmland and to prevent damage to farmland. Studies in rice paddies have confirmed that farmland damaged by wild boars is located 400–500 m from forest edges (Honda and Sugita, 2007; Kawakami and Kamihogi, 2006;), and that individuals damaging farmland concentrate their use in a 200-

m buffer area between forest edges and the forest interior (Honda et al. 2008). Therefore, it is recommended that a buffer zone be constructed at the forest edge as a method of "habitat management" to prevent wild boars from entering agricultural lands. However, such a method is less suitable in orchard areas with low agglomeration of farmland.

Therefore, in this paper, we examine a new habitat management approach that reduces habitat connectivity throughout the district by targeting and focusing measures on sites that play an important function in the formation of habitat networks.

For example, the patch represented by node v_1 was the largest patch located on the district perimeter and considered of high importance as wild boar habitat. However, such patches are large in area, and i t is difficult to completely exclude wild boars from them. Additionally, the patch represented by v_{11} was connected to the surrounding eight patches via an unfenced field and plays a central role in the habitat network. Therefore, if environmental improvements such as mowing and trapping are intensively applied to these patches, the connectivity of the wild boar habitat can be reduced.

The habitat network centered on v_{11} was connected to the largest habitat patch in the district by an unfenced field [a] (**Fig. 4**). In this case, fencing off [a] separates the two, thus impeding the movement of wild boars.

In areas with a high proportion of farmland, such as District A, a high proportion of the surrounding wildlife depends on farmland for food (Kodera et al., 2013). Wild boars are omnivores and change the farmland they use as a feeding ground according to the harvest time of crops. In other words, an environment in which wild boars can freely move between farmlands within a district according to the harvest time of crops is important for maintaining the population. In this regard, it has been pointed out that when different types of patches are in close proximity in the same landscape, landscape complementation occurs and a large population can be maintained (Dunning et al., 1992). Therefore, reducing aggregation and connectivity of wild boar habitats in an area and inhibiting their free movement is expected to contribute to population reduction by reducing the amount of food for wild boar.

4.4 Habitat network analysis in design and planning of community-wide animal damage control measures

In this paper, we showed that it is possible to extract patches and corridors that play an important role in maintaining connectivity in a wild boar habitat network by using a graphical representation of connectivity among habitats. This method is expected to allow identification of the points in the entire rural space where priority measures should be taken and to design and plan measures that are both fast-acting and cost-effective.

In addition to the presence or absence of damage to farmland, the actual farming conditions and farming intentions of individual owners influence the method of animal damage countermeasures (Kuki & Takeyama, 2008). In other words, the implementation of animal damage control measures is strongly influenced by the personal motivations of each farmland owner. In contrast, habitat network analysis using graph theory enables quantitative evaluation of the impact of animal damage countermeasures on specific farmland for the entire region, and pinpoints effective countermeasures based on scientific evidence. This is expected to provide a scientific basis for the design and planning of community-wide animal damage prevention measures and to be a planning method that supports consensus building for the implementation of animal damage prevention measures.

5. Conclusion

We evaluated the aggregation and connectivity of wild boar habitat. We found that abandoned fields connected forest areas, which are the original habitat of wild boars and increased habitat aggregation and connectivity. In addition, habitat connectivity was further enhanced when unfenced fields functioned as corridors between habitats. Fences can be expected not only to control damage to internal farmland but also to function as habitat management by breaking up and isolating habitats on a small scale, creating a landscape that makes it difficult for wild boars to inhabit the farmland area.

In addition, this paper shows that habitat network analysis using graph theory can be used to identify points where priority measures should be taken. This method is expected to enable designing and planning of community-wide animal damage countermeasures based on scientific evidence.

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Reference

Dunning, J.B., Danielson, B.J. and Pulliam, H.R. (1992): Ecological Processes That Affect Populations in Complex Landscapes, *Oikos*, **65**(1), 169-175.

Koji HARASHINA, Atsushi TSUNEKAWA, Kazuhiko TAKEUCHI and Seiki TAKATSUKI (1999): Relationships between Connectivity of Forests and Distributions of Terrestrial Mammals in Honshu, Japan, *Journal of the Japanese Institute of Landscape Architecture*, **62**(5), 569-572.

Honda, T. and Sugita, M. (2007): Environmental factors affecting damage by wild boars (*Sus scrofa*) to rice fields in Yamanashi Prefecture, central

Japan, *Mammal Study*, **32**, 173-176.

Honda, T. (2007): Factors Affecting Crop Damage by Wild Boar: The Analysis Using Census Data of Agriculture and Forestry, *Journal of the Japanese Forest Society*, **89**(4), 249-252.

Takeshi Honda, Yuichi Hayashi and Yoshikazu Sato (2008) : Habitat selection of wild boar (*Sus scrofa*) captured near the forest edge, *Mammalian Science*, **48**(1), 11-16.

Hogen, T. (2012): Bait measures around citrus orchards to reduce wild boar damage, *Fruits Japan*, **67**(10), 107-110.

Tomohiro ICHINOSE, Toshimori TAKAHASHI, Kazuhiro KATOH, Satoshi OSAWA and Sho SUGIMURA (2008) : A Biotope Type Mapping Procedure Suitable for Habitat Evaluation in Japanese Rural Areas, *Journal of Rural Planning Association*, **27**(1), 7-13.

Yoshifuru KAWAKAMI and Akiharu KAMIHOGI (2006) : A Study on the Distribution Characteristic and the Factor Affecting of the Agricultural Products Damage by the Wild Animal in the Sasayama City, *Journal of The Japanese Institute of Landscape Architecture*, **69**(5), 507-512.

Yuki Koba, Mika Sakaguchi, Rika Muraoka, Taketo Obitsu and Hajime Tanida (2009) : Food habitat of wild boars in Kami-Kamagari Island in Hiroshima, *Mammalian Science*, **49**(2), 207-215.

Yuuji Kodera and Nobuo Kanzaki (2001): Food habits and nutritional condition of Japanese wild boar in Iwami district, Shimane Prefecture, western Japan, *Wildlife Conservation Japan*, **6**(2), 109-117.

Yuuji Kodera, Nobuo Kanzaki, Yuuji Kaneko and Kunihiko Tokida (2001): Habitat selection of Japanese wild boar in lwami district, Shimane Prefecture, western Japan, *Wildlife Conservation Japan*, **6**(2), 119-129.

Yuuji Kodera, Takehiro Nagatsuma and Satoru Fujihara (2006): The influence of artificial feeding on the summer home range of wild boar (*Sus scrofa*): a preliminary study in Shimane prefecture, western Japan, *Mammalian Science*, **46**(1), 67-68.

Yuuji Kodera, Takehiro Nagatsuma, Seigo Sawada, Satoru Fujihara and Hiroki Kanamori (2010): How does spreading maize on fields influence behavior of wild boars (*Sus scrofa*)?, *Mammalian Science*, **50**(2), 137-144.

Yuuji Kodera, Nobuo Kanzaki, Naoto Ishikawa and Akiko Minagawa (2013): Food habits of wild boar (*Sus scrofa*) inhabiting Iwami District, Shimane Prefecture, western Japan, *Mammalian Science*, **53**(2), 279-287.

KUKI Yasuaki and TAKEYAMA Emi (2008): Study on the Relation between Farmers' Intentions of the Measures to Decrease Agricultural Damage by Wildlife and the Characteristics of Farming Communities, *Transactions of the Japanese Society of Irrigation, Drainage and Rural Engineering*, **256**, 25-32.

Atsushi Matsuoka (2007): Fragmentation and Consolidation of Orchards Managed by Citrus Farmers -An Analysis of the Merits and Demerits of Land Fragmentation-, *Journal of Rural Problems*, **43**(1), 1-11.

Matsuoka, J. and K. Ninomiya (2005): Effectiveness and Contemporary Significance of Exchange and Segregation Projects in Arboretum, *Journal of Agricultural and Forestry Problems*, **41**(1), 166-170.

Fumiko MOCHIZUKI, Hiroyuki SHIMIZU, Takashi ARIGA and Junichiro MINAMI (2007): Grasping Method of the Pattern and Level of the Agglomeration of Land Use Using Remote-Sensing Data -Case of West Aichi-, *Journal of architecture and planning*: transactions of AIJ, **617**, 47-54.

Ecological Society of Japan (2011): *Forest Ecology*, Kyoritsu Shuppan, 118-124.

Kana Nomoto, Toshimori Takahashi, Masaaki Koganezawa and Kazunari Fukumura (2010): Relationships between crop damage by wild boar and surrounding environmental characteristics in paddy fields and non-paddy fields in Motegi, Japan, *Mammalian Science*, **50**(2), 129-135.

Planning Department, Structural Improvement Bureau, Ministry of Agriculture, Forestry and Fisheries (1997): Land Improvement Project Planning Guideline and Rural Environment Improvement, J. Agric.

Haruka OHASHI, Hiromu NOBA, Masae SAITO, Hiroshi TSUNODA, Takashi KUWABARA, Meifang YAN, Eri KATO, Shinsuke KOIKE, Yoshinobu HOSHINO, Hiroto TODA and Koichi KAJI (2013): Relationship between plant communities in abandoned field and field sign of wild boar Sus scrofa Linnaeus in southwestern Tochigi Prefecture, central Japan, *Vegetation Science,* **30**, 37-49.

TAKEYAMA Emi and KUKI Yasuaki (2008): Backgrounds and Problems of Animal Attack Control Measure Differed by Choice Behavior of the Measures —Analysis of the questionnaire to municipalities of Wakayama Prefecture—, *Transactions of the Japanese Society of Irrigation, Drainage and Rural Engineering*, **257**, 27-33.

Takeyama Emi (2013): Report of the FY 2012 research commissioned by Ehime Prefecture "Research and Study on the Actual Situation and Issues of Animal Damage Control in Dhime Prefecture", 32-65.

Turner M.G., Gardner R.H., O'Neill R.V. (2004): *Landscape Ecology*, Bunichi-Sogo Publishing, 118-124.

Hironori Ueda and Zhaowen Jiang (2004): The Use of Orchards and Abandoned Orchard by Wild Boars in Yamanashi, *Mammalian Science*, **44**(1), 25-33.

Shori YAMAMOTO (2001): Grid Data Analysis of Changes in Rural Landscape Structure in Shizukuishi Basin, Tohoku District, Japan, *Journal of Rural Planning*, **19**(4), 289-300.

Shori Yamamoto, Shuji Okushima, Noriyuki Koizumi and Takeshi Takemura (2002): Paddy Fields Locational Patterns and its Changes based on Connectivity Analysis of National Grid Database in Japan, *Journal of Rural Planning*, **21**, 163-168.

Tohru YOSHIKAWA (1999): A Method to Analyze Characteristics of Agglomeration of the Same and Different Kinds of Land Use Using Grid Data, *Journal of Architecture, Planning and Environmental Engineering* (Transactions of AIJ), **520**, 227-232.