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**Satoyama destruction and homogeneity as sources of environmental vulnerability
in Tokyo**

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Abstract

Satoyama are marginal areas located between foothills and arable land in Japan. These landscapes support a wide range of species and are regarded as indicators of biodiversity and sustainable agriculture. However, deforestation in these areas has increasingly threatened local ecosystems. This study examined the ecological and environmental effects of Satoyama degradation and urban landscape homogenisation in Tokyo and surrounding areas using a “surface-to-line” analytical framework. Landscape analysis showed reductions in forested and vegetated areas between 1976 and 2024, accompanied by increased urban development and the expansion of concrete-covered surfaces. Meteorological data indicated increasing temperatures and declining humidity in Tokyo since the 1990s. Field observations showed altered behaviour of Japanese pygmy woodpeckers following the removal of large trees. Overall, current urban-development and land-management practices contribute to increasing ecological and landscape homogeneity, potentially reducing environmental resilience. The findings suggest that development projects in Satoyama may be deviating from their original social and ecological purposes.

Keywords: Satoyama destruction, Street trees, Vulnerability to disaster, Landscape homogeneity, Deviation from purpose

38 **Introduction**

39 Global warming in Tokyo is progressing at twice the speed of the global
40 average. Urban landscapes reflect both shared community functions and diverse human
41 activities, including socialising, working, commerce, recreation, and safety. However,
42 deforestation, urbanisation, wildlife capture, pesticide and herbicide use, and the felling
43 of street trees can severely affect wildlife^[1-7]. Among the landscapes affected by these
44 pressures are Satoyama, a Japanese term for the marginal areas between foothills and
45 arable land^[8-10]. These landscapes typically consist of hilly terrain, grasslands, forests,
46 agricultural land, or hydrological environments. They support a variety of species and
47 are frequently seen as indicators of sustainable agriculture and biodiversity^[11-14].

48 However, it remains unclear why the destruction continues despite the absence
49 of an apparent necessity or purpose. Past studies tend to focus on how Satoyama or
50 nature can be utilised to generate benefits while simultaneously preserving these
51 landscapes. This raises an important question of whether Satoyama should be preserved
52 simply for its existence, rather than only when associated with a particular use.

53 Although Satoyama landscapes include human-altered farmland, these
54 landscapes continue to evolve regardless of human intentions. Under global warming,
55 the rate and grade of warming, as well as changes in water-holding capacity, vary

among landscapes. Furthermore, the destruction of Satoyama and tree felling in urbanised areas, including city centres, share common underlying factors. In both cases, land is used solely for financial purposes, with unused land often considered a waste. This study addresses the institutionalised vulnerability as a verification system with no safeguards against destruction.

This study introduces the underappreciated concepts of surface and line, namely surface continuity and cumulative linear (historical) resilience. Treating space as space, surface as surface, and time as line allows for a more objective and evidence-based comprehension of biodiversity.

Satoyama originally contained extensive rolling hills and continuous surface landscapes. These landscapes respond abruptly to climate and precipitation variability and have helped regulate temperature increases. Urbanisation has fragmented this continuity, impairing these ecological functions. The cumulative effects indicate that environmental thresholds are being exceeded.

Amid the ongoing loss of landscape continuity, there is a growing need to incorporate both surface-based and line-based validation systems into environmental regulation. The study aims to contribute to the development of such systems and the

rehabilitation of degraded landscapes. Figure 1 shows a typical Satoyama landscape in the Tokyo and Kanagawa border area.



Fig. 1 Satoyama landscape on the prefectural border area between Tokyo and Kanagawa prefecture, April 2026 (photographed by the author).

The destruction of Satoyama landscapes has important ecological and social consequences. Land in Satoyama is often sold to developers because landowners are unable to pay inheritance tax after ownership transfer. To maximise profit, developers often construct small-scale (100–150 m³) residential lots with few or no green gardens or trees. Concrete parking areas in these developments may contribute to localised

temperature increases. The decline in street trees in urbanised areas also contributed to rising urban temperatures. Satoyama landscapes have historically absorbed deterioration, but their capacity to do so may be reaching its limit. Similarly, large-scale forest parks in urbanised areas, such as in Tokyo, have helped offset environmental degradation. In this respect, Satoyama in urbanised areas and forest parks in the city centre have similar counteracting functions. Viewed as a temporal line, trees contribute to accumulated humidity, provide windbreaks, and mitigate temperature increases. The loss of these landscapes, therefore, represents the loss of historically accumulated resilience.

Viewed as a surface, both Satoyama and forest parks are declining simultaneously. Developments are reviewed on a project-by-project basis, and environmental assessments are conducted separately. As a result, overall green space may decline across a region even if each criterion is met for all individual projects. Consequently, the landscape loses its resilience as both a surface and a line, suggesting deficiencies in regulations and their enforcement.

Urban green areas and tall roadside trees serve identical roles as Satoyama. The relaxation of building restrictions and landscape regulations ahead of the 2020 Tokyo Olympics increased pressure on Tokyo's large trees. One prominent example is the

large-scale redevelopment of the forest surrounding the Meiji-Jingu Shrine. The redevelopment plans facilitated approval for large-scale development, leading to the construction of high-rise buildings^[15]. Over 1,000 trees over 100 years old were removed to allow the construction of commercial facilities, resulting in substantial impacts on wildlife habitat availability in the forest core^[16]. Citizens filed a lawsuit to stop logging; however, the Tokyo District Court rejected the request on May 12, 2026^[17].

A major concern is the neglect and/or underestimation of scientific data by businesses and public authorities. Many development projects proceed with limited checking and modifications. This structure fosters separation between surfaces and lines. Developers' ultimate interest is to maximise land use with minimal restrictions. Existing regulations are enforced in a manner tailored to developers' interests, without any built-in checks and balances. In addition, when an administration promotes development, regulations are often not properly enforced. As a result, green spaces are often not treated as public assets in regulatory frameworks.

Critics of similar redevelopment projects in areas such as Shibuya, Tokyo, argued that such developments reduce urban diversity by eliminating small alleys, green spaces, tiny shops, and parks that allowed people to stay without spending money.

Large buildings also emit heat, with some studies estimating local temperature increases of 2–3 °C due to exhaust heat from air-conditioning systems^[18].

These trends may increase urban vulnerability to environmental disasters and can alter human behaviour. With the deforestation of urban and Satoyama areas, wild species are no longer a part of people’s daily lives. Although biodiversity conservation is frequently emphasised in urban policy discourse, redevelopment practices prioritise human-centred objectives. Furthermore, “cookie-cutter” style residential environments with limited vegetation and dependence on electricity-based infrastructure are vulnerable during disasters or power outages. In addition, environmentally framed redevelopment initiatives, including “smart houses,” have increased in Satoyama areas.

However, these projects also require the destruction of large forests, fields, and farmlands, and still rely on thermal power for electricity. Accordingly, using a "surface-to-line" analytical paradigm, this study investigated the ecological and environmental implications of Satoyama deterioration and urban landscape homogenisation in Tokyo and nearby areas. Our findings suggest that Satoyama's development initiatives may be deviating from their initial ecological and social goals.

Methods

137 *Surface-to-line method*

138 This study used a surface-to-line method to analyse historical land-use change
139 determined using aerial photographs and environmental data. Data were collected from
140 the Japan Meteorological Agency, fieldwork, peer-reviewed studies, and reports
141 produced by civic groups.

142 First, the surface component involved using aerial photographs and historical
143 records to evaluate spatial changes in land cover, vegetation, and urban development
144 over time. The analysis focused on how changes in the landscape contribute to the
145 homogeneity of both urban and arable land. In addition, the study considered changes in
146 animal behaviour to indicate non-homogeneity and diversity. The study areas are semi-
147 urbanised areas between Tokyo and Kanagawa prefecture. This area was once a green
148 corridor connected to the city centre, with diverse production systems, varied
149 topography, and seasonally changing flora. which allows for comparisons to be made
150 with the city centre. The homes of citizens commuting to the city centre are connected
151 to it by newly developed railways. Furthermore, there are small remnants of land owned
152 by agricultural workers, which collectively create a Satoyama environment. In addition,
153 it includes regions where farmers have historically relinquished their land due to
154 inheritance, making them highly relevant to the objectives of this research. When

investigated from the perspective of surface, areas converted from farmland to residential land have experienced may reveals whether uniform development is driving changes in temperature, humidity, and ecosystem diversity—promoting homogenization—and significantly undermining resilience.

Next, the line component investigated historic changes in temperature and humidity. Data from the Japan Meteorological Agency were used to analyse temperature and humidity in Tokyo from the 1970s to the 2000s. The study also considered the influence of groundsheets.

This study utilizes data obtained from observational investigations carried out by civic organizations. These data investigating the canopy effects of urban green spaces and roadside trees demonstrate the need to mitigate heat waves in city centres and enable comparisons with Satoyama cases. Research conducted by civil groups has shown that degraded forests in Satoyama and other urban areas can be used to confirm the line component, especially the cooling effect of the tree canopy. The lines demonstrate temporal accumulation, clarifying the outcomes resulting from damage across the surfaces. This surface-to-line method clarifies that conventional methods permitting development only in limited areas ignored the temporal accumulation of nature. Combining the perspective of historical accumulation of tree canopy cover with

the surface analysis provides a comprehensive means to understand homogenization trend of the region thorough temperature rise.

Author confirms that the study has no experiments on humans and/or the use of human tissue samples. Additionally, all methods were carried out in accordance with relevant guidelines and regulations. All data generated or analysed during this study are included in this published article.

Regulation and purpose analysis

In addition, urban redevelopment projects and development in Satoyama areas following the lifting of regulations that allowed developers to construct disordered small residential units without gardens, plants, or trees were examined to evaluate shifts in purpose. Particular attention was given to the implementation and effectiveness of green space conservation ordinances in Tokyo.

Development in Satoyama and redevelopment in urban areas are not driven by a lack of commercial or residential properties. Since the population is shrinking rather than growing, there is little need for newly built houses. In fact, the rising number of vacant properties has become a social problem. Considering resource depletion and declining consumer purchasing power, commercial facilities need to be appropriately

scaled down. Nevertheless, constructing residential and commercial facilities by clearing the few remaining spaces and green areas can be considered a deviation from the original purpose of those facilities. In other words, the sole objective is economic profit. Explicitly defining this divergence in purpose is essential to prevent the devastation.

Tree and animal behaviour analysis

Declining populations of many insects, rare species, and endemic plants have been observed due to the degradation of the Satoyama environment. The Northern Goshawk, which sits at the top of the food chain, exists in the Satoyama of the surveyed area, but its population is declining due to a decrease in nesting trees. Similarly, the woodpecker population in the survey area also declined, and changes were observed in the drumming behaviour, particularly in the Japanese pygmy woodpecker. Notably, in this specific area, after large trees were felled, the Japanese pygmy woodpecker was frequently observed drumming on metal utility poles. The common kestrel can also be cited as an example of a species that often moves from Satoyama to adjacent urban areas to hunt prey. This study investigated changes in bird behaviour using a seven-year fixed-point observation. Documenting behavioural changes in animals along a chronological axis (line-analysis) clarifies the purpose of this study.

209

210 **Results**

211 *Surface-based analysis*

212 The surface-based analysis examined historical changes in land cover and
213 urban development using aerial photographs. In 1976, forests, fields, and houses
214 remained relatively balanced, and biodiversity was maintained (Figure 2). However, in
215 1991 and 2024 (Figures 3 and 4), development and deforestation had progressed,
216 threatening wildlife, including birds, insects, and amphibians. In particular, the
217 concrete surface area increased dramatically, leading to elevated temperatures at night
218 and in the morning. Projects are reviewed in a fragmented manner during the
219 assessment process. The system is not structured to evaluate the entire area as a
220 unified whole. As a result, the decline in the overall green coverage rate cannot be
221 halted.

222 Large-scale development projects in Satoyama areas and high-rise
223 condominium projects in the city centre have common development measures. These
224 typically involve consortium-based development, a statutory development or
225 redevelopment framework that includes numerous property owners. Upon developing a
226 legal business plan and obtaining approval from the local government, floor area ratio

227 relaxation is permitted. Landowners can acquire a portion of floor space (equivalent to
228 the value of their owned land and buildings) as floor rights at no cost. The developer
229 agrees to acquire the newly generated reserved floor space. By participating in a
230 cooperative scheme to formulate a business plan and obtaining municipal approval,
231 there is no need to acquire the land parcel by parcel. Developers can freely utilise their
232 owned building as offices, commercial facilities, or residential apartments^[19-21].

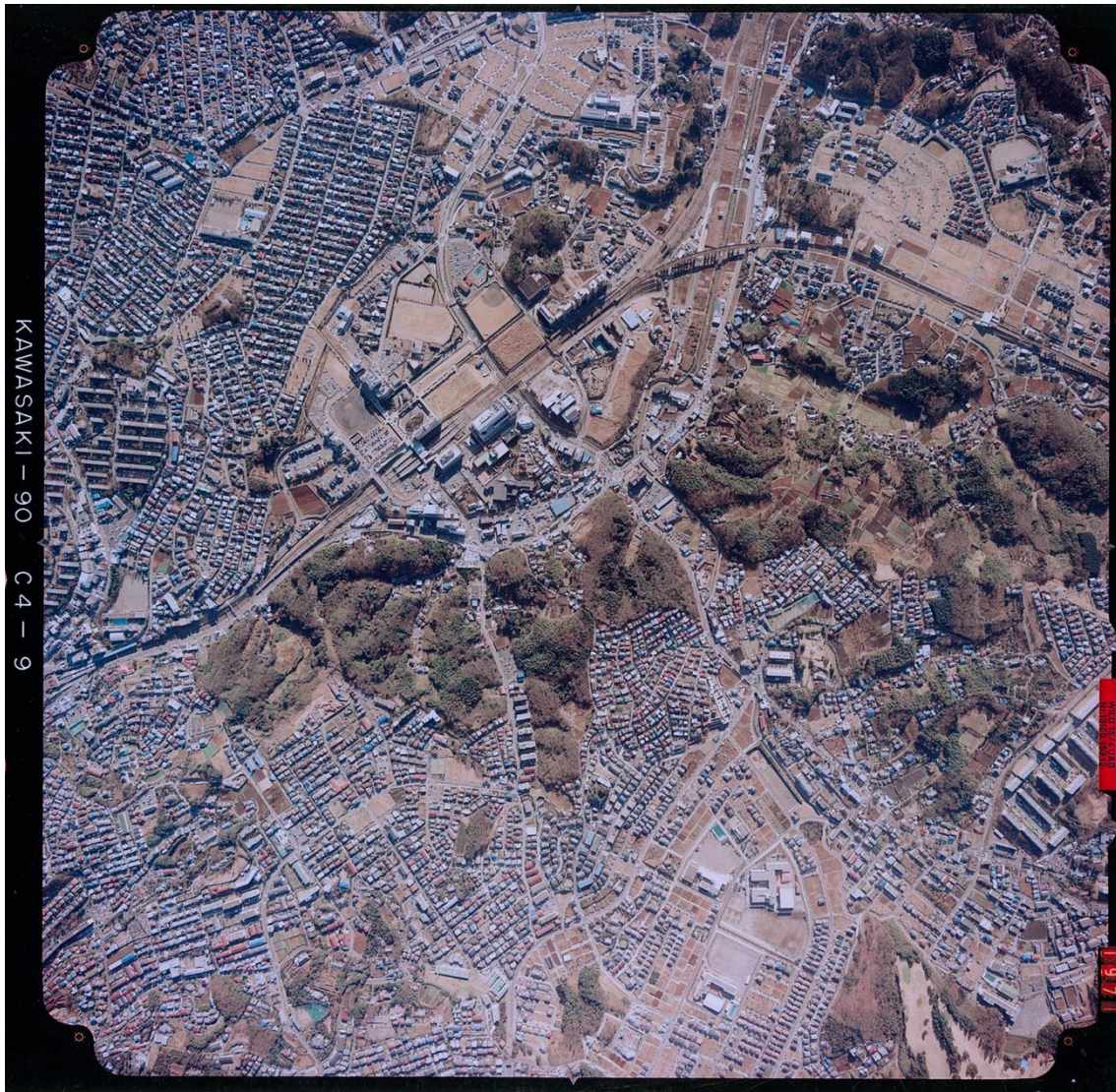
233 Municipal government and fiscally struggling local authorities utilise
234 redevelopment projects to construct much-needed facilities in the area, including the
235 expansion of a traffic circle, public facilities, and roads. Local municipalities expect
236 that an increase in homes and businesses will lead to higher tax revenues. On the other
237 hand, the number of vacant houses is increasing due to the declining birthrate and
238 ageing population. These changes have led to a surface fragmentation .

239



Fig. 2 Satoyama landscape in the research area in Tokyo, 1976. Kawasaki City Office, Aerial Photography Library, 1976.

<https://www.city.kawasaki.jp/500/cmsfiles/contents/0000024/24462/hoyuunenndo.pdf>



245

246 **Fig. 3** Satoyama landscape in the research area in Tokyo, 1991. Kawasaki City Office,

247 Aerial Photography Library, 1991.

248 <https://www.city.kawasaki.jp/500/cmsfiles/contents/0000024/24462/hoyuunenndo.pdf>

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Fig. 4 Satoyama landscape in the research area in Tokyo, 2024. Kawasaki City Office, Aerial Photography Library, 2024.

<https://www.city.kawasaki.jp/500/cmsfiles/contents/0000024/24462/hoyuunenndo.pdf>

Line-based analysis

Line-based analysis was conducted to examine historical changes in temperature and humidity. The temperature in Tokyo gradually increased from the 1970s to the 2020s ^[22], particularly in the 1990s, driven by deforestation and housing construction. Relative humidity declined after the 1990s. Furthermore, the 2000s experienced highly volatile precipitation patterns, particularly in summer and winter^[23]. Reduced humidity and intensified summer heatwaves weakened trees in Satoyama areas

of Tokyo. During the same period, tree mortality and damage associated with *Platypus quercivorus* increased.

According to the Tokyo Metropolitan Government, 86 fallen trees were recorded across 97 parks and zoos in 2025. Although the government stated that this number had not suddenly increased, many gardeners reported a decline in tree health over the years. The government reported that emergency inspections of abnormalities were conducted on 14,000 of a total of 0.8 million trees in Tokyo^[24-25].

The conversion of forest land and farmland for residential use disrupts groundwater veins and may reduce humidity. Figure 5 shows a ruptured underground water vein during a Satoyama development in 2010, causing rainwater overflow. In concrete-covered urban areas, water cannot penetrate the ground and simply flows across the surface, thus contributing to flooding, sewer overflows, and swollen rivers. Decades of urbanisation have increased flood damage during heavy downpours, and a clear linear trend has emerged.

The development of Satoyama areas in Tokyo accelerated in the 1970s. The construction of Tama New Town (total development area of 2,984 ha across four cities from 1965 to 1975), including large-scale housing projects, resulted in substantial habitat loss for many endangered species, and their numbers have never rebounded^[26].

278 The cumulative area affected by land readjustment and urban redevelopment in
279 Tokyo reached 23,550 ha in 2018, accounting for 20% of the urbanisation control area
280 (110,000 ha)^[27]. Development also proceeded in parallel in the neighbouring Kanagawa
281 Prefecture. However, the growing number of vacant properties in Tama New Town
282 poses a serious challenge.

283 Large-scale development projects continued within the study area during the
284 2000s, including a 37 ha project in which green spaces accounted for less than 1 ha.
285 The development area of the Shin-yurigaoka General Hospital in 2010 was 52,800 m²,
286 with a green conservation area of 13,200 m². From a line-analysis perspective, over 80%
287 of the development area will be covered with concrete, causing a historical loss of
288 water-retention capacity over several decades^[28].

289

290



Fig. 5 Satoyama development in the border area of Tokyo and Kanagawa, 2010

(photographed by the author).

In Satoyama, leaf canopies play a role in maintaining a complex but stable temperature. Throughout the year, temperature changes within the forest are moderate. It has been reported that trees in urban centres also possess very similar stability. Citizen-led temperature surveys conducted at 30 points in the Nakano district in Tokyo in August 2025 showed that temperatures differed by approximately 1.6 °C between shaded and open sunshine places^[29]. By ward, Suginami recorded the largest percentage decrease at 39.5%, followed by Nerima at 38.2%, and Setagaya and Nakano at 34.7%.

301 While the western area of Tokyo's 23 wards once featured many traditional estate
302 groves (*yashikirin*), housing trends driven by soaring land prices and inheritance tax
303 burdens—such as subdividing a single residential lot to build multiple smaller detached
304 houses—are believed to have driven the decline^[29]. These findings indicate that leaf
305 canopies of street trees reduce direct sunlight and heat. Leaf canopies a complex and
306 decisive role in temperature regulation in both Satoyama and urban city centre areas.
307 The wind cools as it rushes up the hill, weaving through various tree species in harmony
308 with the Satoyama terrain. In city centres, well-established street trees and trees in green
309 spaces reduce air temperatures in shaded areas. Trees and turfgrass together lower
310 ambient temperature and regulate humidity compared with other areas. These findings
311 indicate that the presence of trees brings stability to both the corridor structure as a
312 surface and the accumulation structure as a line.

313 Another important factor was the declining water-retention capacity of urban
314 soils associated with the removal of trees, deforestation, and widespread use of
315 waterproof ground sheets. Many local governments use groundsheets to reduce mowing
316 costs. Figure 6 shows the landscape of a slope surface covered with a ground sheet that
317 prevents grass growth. Such areas previously supported many types of plants, including
318 wild lilies, silver grass, *Aeginetia indica*, and plantains.



Fig. 6 Slope surface covered ground sheet, 2025 (photographed by the author).

Although these sheets allow rainwater penetration, covered areas lose water-holding capacity compared with uncovered areas, grasslands, and tree-covered areas. This is because grass and trees receive water from other plants. These changes accelerate water penetration and water shortages on a regional scale. Combined with the loss of canopy cover, the extensive use of weed-control sheets reduces soil humidity and intensifies urban heat conditions.

According to the Tokyo Metropolitan Government, the adoption rate of weed-control sheets combined with gravel reached 7.5% in 2026^[30]. The primary reasons

cited were labour shortages and cutting costs associated with mowing/weed control.

However, statistics show that the number of unemployed is decreasing and the number of workers is increasing year on year^[31], suggesting that the reallocation of labour may also influence these practices. Thus, the increasing heat and loss of humidity in certain areas are institutional and regional policy issues.

Greening ordinances in Japan are mainly based on municipal guidelines. In general, a housing site area of a certain size, in principle 1,000 m² or more (which can be reduced to 300 m² by the local government), is obligated to be green. In Tokyo, it is generally required to account for more than 20% of the site area, whereas the corresponding requirement in Osaka is 3%. Planting guidelines also state that there should be one tall tree (over 4 m), two medium-sized trees (1 to 2.5 m), and over three small trees (30 cm to 1 m)^[32].

Impact of regulation

The development of Satoyama and urban redevelopment involve legal mechanisms for rezoning and lifting specific regulatory requirements. Development cannot proceed unless the zoning is changed or the ordinance requirements are lifted.

For Satoyama, changing the zoning designation and converting agricultural or forest land into residential areas will increase both the land value and the sales profit.

347 Fixed asset tax for agricultural land and forestland is relatively low, at 1.4% of the
348 assessed value. However, land use regulations may be modified and areas rezoned for
349 development, often to pay inheritance taxes, regardless of the actual need for housing.
350 Consumers purchase affordably priced, newly built homes on small, subdivided plots of
351 land, while developers generate profit by selling these units in large volumes.
352 Meanwhile, vacant homes whose owners have passed away or aged out are
353 continuously increasing. Here, we observe a shift in purpose, allowing zoning
354 regulations—originally intended to preserve livelihoods and environments to be
355 repurposed for the construction of housing as a consumer commodity.

356 A similar trend can be observed in urban redevelopment projects.
357 Redevelopment associated with the reconstruction of the National Stadium accelerated
358 in 2012. In 2013, the surrounding area was designated as a District for Promotion of
359 Redevelopment, with the height limit raised to 75 m, thus enabling the construction of
360 skyscrapers.

361 The original purpose of designating Areas for the Promotion of
362 Redevelopment was to relax regulatory constraints and encourage the redevelopment of
363 underutilised land, such as abandoned factories and railway yards. Consequently, its

application to Scenic Zones was legally invalid^[33]. From this perspective, the emphasis of planning policy may have shifted to economic utilisation through development.

House construction without soil or gardens is increasing. From 1970 to 1980, many cities in Tokyo had municipal ordinances requiring them to plant trees in certain areas of the garden. However, in the 1980s, many cities lifted these regulations to meet the trend of downsizing in urban areas and to prioritise the interests of construction companies. Because ordinances are left to the discretion of local governments, housing styles with no gardens, plants, or concrete gardens became popular. Small-area housing has also increased due to lower costs for consumers. In other words, housing has become a means of economic benefit. The Tokyo Olympic 2020 project further relaxed height limits for buildings around the green forest in Jingu Gaien (Meiji Shrine Forest Garden).

The rebuilding of the Olympic stadium was a stepping stone for the outer garden redevelopment. To protect the scenic environment, the Tokyo Metropolitan Government designated the zone as a scenic district and strictly prohibited the construction of buildings over 15 m in height^[34].

Impact of the land use to Animal behaviour

381 The effects of these changes on wildlife are reflected in alterations to animal
382 behaviour. Figure 7 shows a Japanese pygmy woodpecker on a big tree in a Satoyama,
383 Tokyo. The large trees were felled by 2020, and the Satoyama field was subsequently
384 converted into 50 houses in 2026. Following the felling, woodpeckers were observed
385 drumming on metal poles (Figures 8 and 9). Woodpeckers frequently choose metal for
386 drumming as it is the loudest available substrate^[35–39].

387

388



a.



b.



c.

Fig. 7 Large hackberry tree, wild cherry tree, and a Japanese pygmy woodpecker
(photographed by the author).

392 **a.** Japanese pygmy woodpecker (*Dendrocopos kizuki*), body size 13–15 cm, March
393 2015

394 **b.** Hackberry tree with holes excavated by woodpeckers.

395 **c.** Hackberry tree (left side of the road), cut down in 2016, and cherry tree (right side of
396 the road), felled in 2020. Photographs were taken on February 15, 2013, March 26,
397 2015, and May 1, 2015, respectively. After tree felling, the woodpecker drummed on
398 the metal telephone pole.

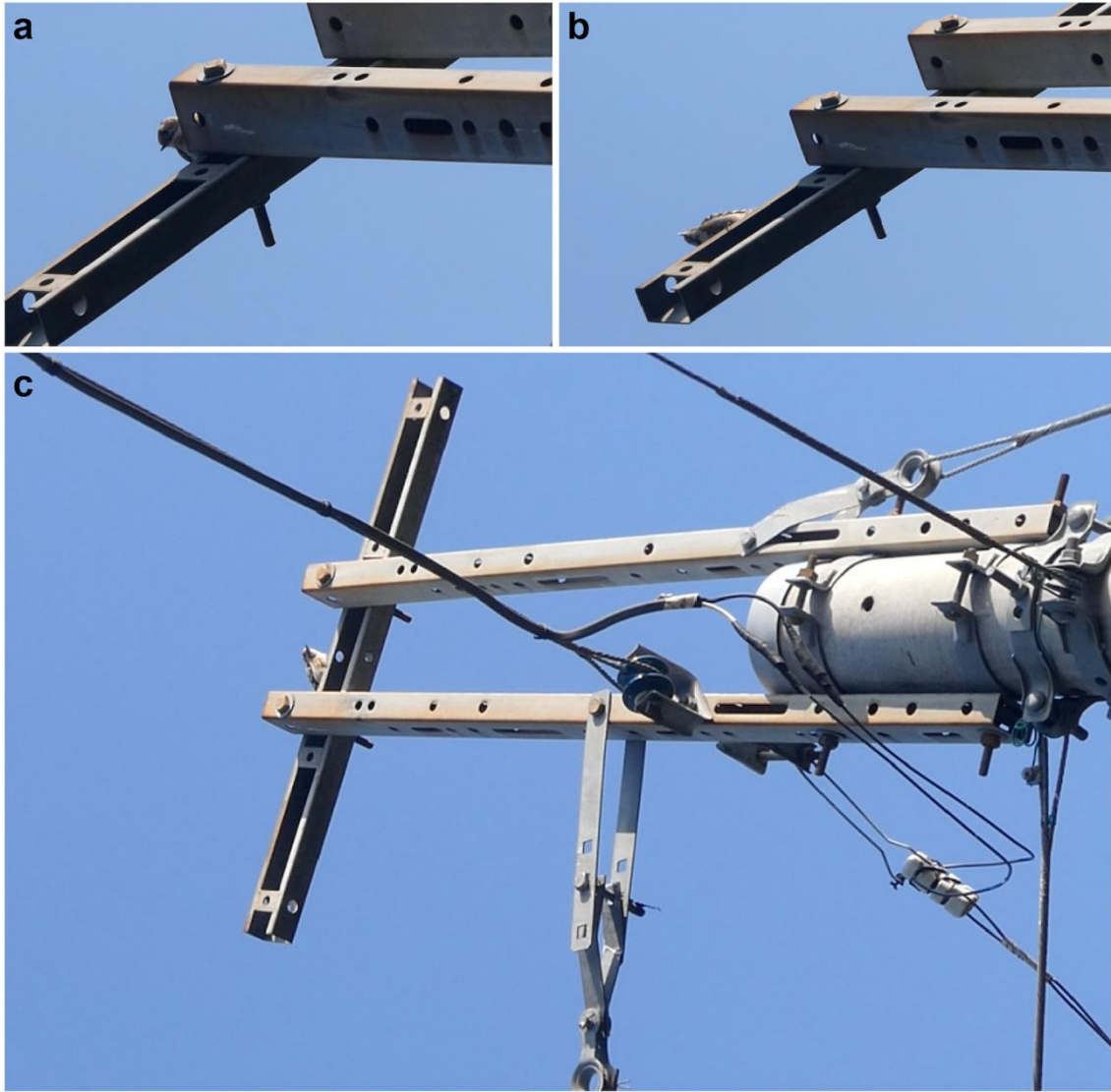


Fig. 8 Japanese Pygmy Woodpecker (April 11, 2020)

a. Bird drumming the plate

b. Bird moving on the plate to compare the sounds

c. Bird on the pole structure

(photographed by the author)



Fig. 9 Japanese pygmy woodpecker moved to another pole after the removal of the big tree. About 60 m south of the original pole.

March 19, 2021 (photographed by the author)

In 2026, a common kestrel moved from the Satoyama to the city to hunt for prey. Figure 10 shows the same individual, having moved from the Satoyama to a pole in the city. Such behaviour has not been reported previously.

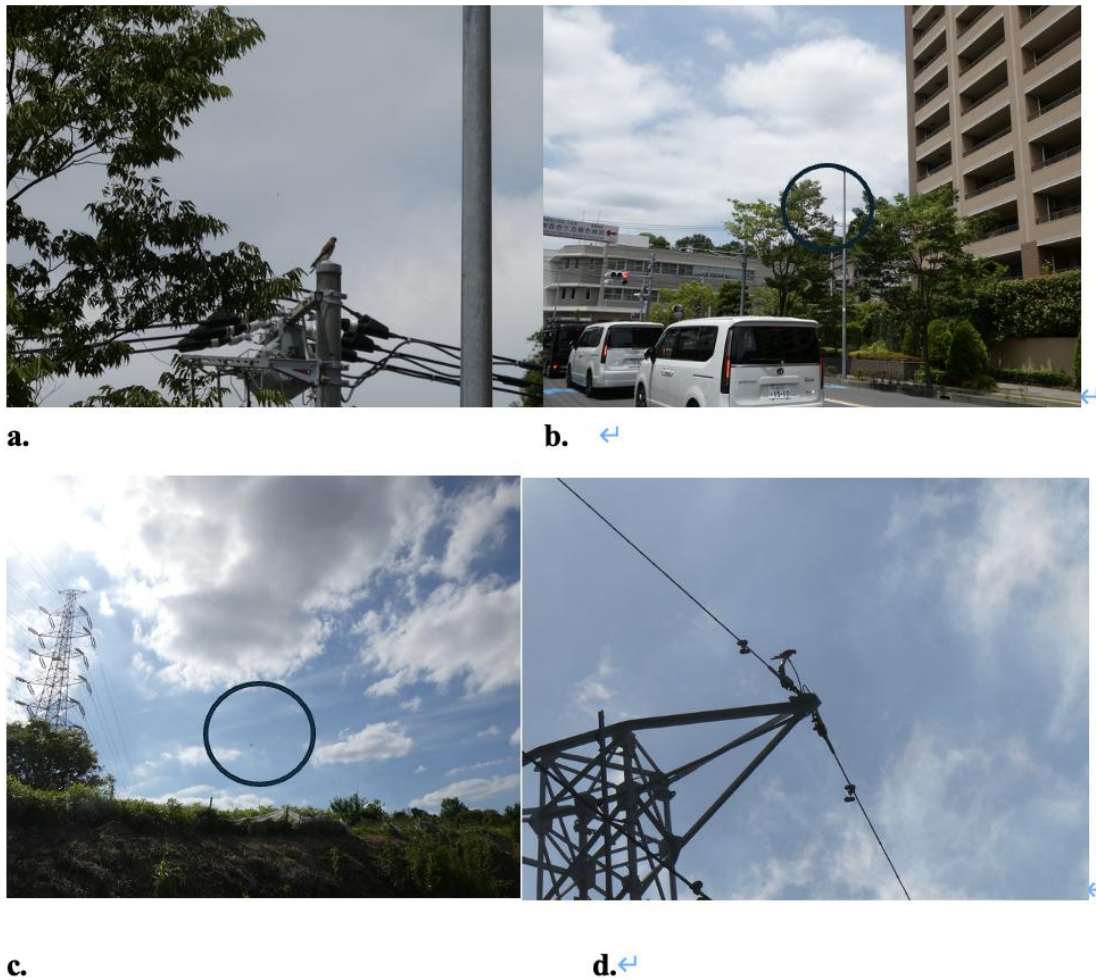


Fig. 10

a. Common Kestrel in the City, an enlarged photo of **b.** **b.** Common Kestrel
c. Common Kestrel in the Satoyama, same individual, in the circle. **d.** An enlarged
photo of the bird.
Common Kestrel (*Falco tinnunculus*) in search of prey from Satoyama areas to urban
areas. June 6, 2026 (photographed by the author).

Discussion

421 Japan's population is shrinking, and its housing market is oversupplied. The
422 increasing number of abandoned houses has been a serious nationwide problem since
423 the 2000s. Nevertheless, new housing continues to be constructed through forest
424 conversion. Developments observed in the study areas show that housing has
425 increasingly become a commodity, rather than a necessary living place. The resulting
426 landscapes, characterised by limited plants, trees, or insects, are extremely homogenous.
427 However, humans and land should not be treated merely as consumer products, as they
428 are essential for resilience during disasters and environmental crises. This trend
429 suggests that development has shifted to a completely different purpose than its original
430 purpose. Figure 11 shows the structural model for the original and additional
431 purposes^[40]. The model diagram designates the escalation of purpose-modifying acts as
432 "Social Cancer". Deforestation in Satoyama , the loss of urban green spaces, uniform
433 urban redevelopment, and the widespread use of weed-control sheets work in
434 combination to cause rising temperatures and increasing dryness. It can be said that
435 these are expanding rapidly and impairing the regional homeostasis. Therefore, the
436 spread of homogeneity has led to this outcome.

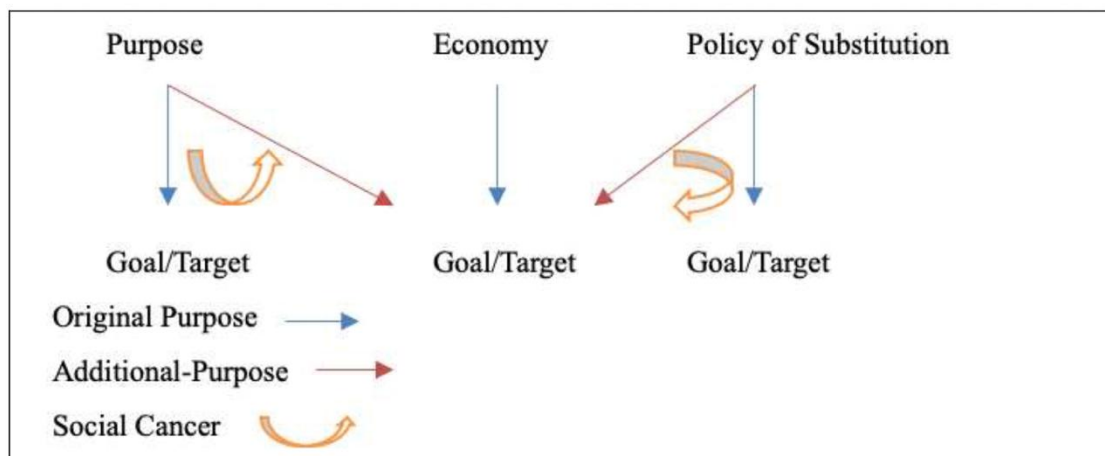


Fig.11 Structural model of the changing the purposes^[40]

In this case, housing construction projects have the original purpose of providing shelter, with additional purposes of selling and making a profit.

Similar dynamics can be observed in the increasing use of grass sheets and the decline of street trees. Adequate eco-friendly management and control have been replaced by other priorities, such as reducing labour and costs, without reviewing wasteful budget spending. Likewise, the sale of Satoyama land to pay inheritance tax reflects a structural policy issue beyond the original purpose and may be amended in the context of green space conservation. These changes in purpose can be attributed to several factors, including a lack of policy evaluation, strong urban-development pressure in Satoyama landscapes, and the loss of a diverse community of plants that retain water to prevent soil drought and reduce heat.

Satoyama landscapes represent a unique combination of urban areas, forests, and agricultural fields that highlight forest logging and regeneration. In these diverse

landscapes, many birds, animals, and insects coexist and tend to select different activities to display their communication behaviours, as observed in the woodpecker case examined in this study. Forest conservation (and management) is also important for maintaining tree health under increasing heat stress^[41-47]. Individual trees can indicate the characteristics of specific regional forests and facilitate the assessment of interspecific activity.

Ex-post evaluations of development projects in this region have not been conducted continuously. Continuous monitoring as a line (routine) activity is highly desirable. Furthermore, it is essential for the administration to establish a framework that verifies regional transformations on a comprehensive, area-by-area basis (surface) rather than on an individual project basis, implementing it in a form such as a local ordinance. This will lead to the reinstatement of previously abolished regulations on securing green spaces.

Conventional economic development and recovery, including heatwave disasters, focus on capital investment and increasing traffic, income, and infrastructure investment^[48-53]. However, green recovery considers individual areas and species based on the notion that no individuals should be left behind. Sustainability, both as a surface

and as a line, is being lost. This demonstrates that the loss of homeostasis throughout the region has heightened its susceptibility to climate change and disasters.

While the results of this study are based on observations of a limited number of cases, the findings of this study suggest that effective green recovery requires action at both policy and local scales. Practical approaches may include reusing vacant houses and restoring abandoned houses to nature. More broadly, research and policy should focus on documenting ecological loss and restoring degraded landscapes. This may represent an important step toward improving ecological resilience and environmental sustainability.

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