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Spatial characteristics of residents' discomfort with disseminated solar panels

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Abstract: Since the implementation of feed in tariffs (FIT: a subsidy policy to promote the spread of renewable energy), the external diseconomies of solar panels installed in excess, to earn income from the sale of electricity from photovoltaic power generation, have become apparent. The purpose of this study, therefore, is to identify the impact of the installation of photovoltaic power generation facilities on the living space of citizens. Using data collected through a web survey of residents living in five prefectures in the north-eastern Kanto region of Japan, a spatial autocorrelation analysis was conducted to identify the spatial distribution of discomfort caused by photovoltaic power generation facilities. The results clearly indicated that the spatial discomfort of these residents living in clusters, increased with the installation of the solar panels in their living space. Some of the residents intend making radical demands for corporate action to alleviate their discomfort; such actions can lead to environmental conflict. The results demonstrate that radical solutions are necessary to reduce the spread of this discomfort. By further utilizing the data obtained in this study, it will be possible to estimate the regions at risk of solar panel-related conflict more objectively.

1. INTRODUCTION

1.1 Research Goals

In light of the limited discussion concerning the spatial issues regarding citizens' discomfort with photovoltaic power generation using panels with solar cells (commonly called solar panels; SPs hereafter), the purpose of this exploratory study is to identify residents' main environmental conflicts with SPs. To determine this, we surveyed Kanto residents using an online questionnaire to determine their perceptions of SP-related environmental conflicts. The social significance of this research objective is to promote improved local environmental plans that consider the spatial aspects of SP-related conflict.

Section 2 confirms the originality of this research by reviewing both, the research on Feed-In Tariffs (FIT), which have accelerated the popularization of SPs, and the city planning research on the spatial distribution of SPs. Section 3 explains the methods of data collection and analysis. Section 4 describes the spatial autocorrelation analysis and analytical outputs. The results are discussed in Section 5, and the conclusions are provided in Section 6.

1.2 Subject and Significance

In Japan, the use of nuclear power, advertised as a cheap and safe power generation method for mass supply, caused widespread anxiety after the meltdown of the Fukushima Daiichi Nuclear Power Plant, which was a result of the tsunami caused by the Great East Japan Earthquake. As a result, the cost and safety assessments of nuclear power were reviewed (Vivoda, 2012). After the Great East Japan Earthquake, the introduction of renewable energy (RE) rapidly replaced nuclear power generation.

Goal 7 of the United Nations' Sustainable Development Goals (SDGs) advocates the construction of a clean energy society (United Nations, 2020). At present, approximately 10% of the primary energy in Japan is supplied by RE (Ministry of Economy, Trade and Industry, 2019). The Japanese government has announced an energy mix policy to maintain balance between the safety and robustness of the electric power supply, and aims to increase the ratio of RE to total energy supply to 20% or more, by 2030. To achieve this, various societal factors have been considered to rapidly increase investment in RE, one example being the momentum of FIT, a subsidy scheme to promote the introduction of RE (Dong & Shimada, 2017). Additionally, local residents' willingness to pay for the social implementation of RE facilities has been calculated, and ways to realize the policy have been discussed (Mosly & Makki, 2018; Ntanos et al., 2018; Paravantis et al., 2018).

On the one hand, there are many aspects to carefully consider the regional acceptability of RE, including the usability of RE itself, offensive odor and vibration in the generation process, noise, landscape of facilities, and so on (Baxter, Morzaria, & Hirsch, 2013; Heagle, Naterer, & Pope, 2011; Shaw et al., 2015). On the other hand, the antipathy of local residents, the method of RE resolution, and the spatial concentration of RE have rarely been discussed in the literature on the acceptability of RE. By clarifying these underrepresented factors, it will be possible to provide important information on spatial planning, such as locations of potential environmental conflicts, and whether administrative guidance is necessary for power generators.

Among the several types of REs, the installation of SPs has caused frequent problems for citizens by affecting their daily life and living space in Japan (Institute for Sustainable Energy Policies, 2017). The object of this study does not include small-scale rooftop power generation panels that have little effect on others; rather, its focus is on the large SPs installed on farmland or on the slopes of production areas, called mega-solar SPs in Japan (Fig. 1). Due to the nuclear power accident caused by the Great East Japan Earthquake, the popularization of RE is of particular social importance in Japan. It is, therefore, necessary to critically and objectively analyze the problems related to RE, to maintain the peaceful living of citizens. In Japanese newspapers, environmental conflicts concerning the installation of such large-scale SPs are reported daily.

Recent problems like conflicts between SP installers and neighbors have resulted in SPs being described as typical NIMBY ("not in my back yard") situations, and there has been strong opposition from local residents to developments, due to the spatial locations (Jones & Richard Eiser, 2010; van der Horst, 2007).

Figure 1. Large SP installed on farmland
Note: Photographed by the author

2. LITERATURE REVIEW

Prior to the implementation of FIT, case studies have focused on the distribution and technical theories regarding how SPs satisfy cities' power demand (Nguyen & Pearce, 2013; Zhang, D., Shen, & Dang, 2013), and the economic effect of RE utilization in rural areas (Tantiwatthanaphanich & Zou, 2016; Wang et al., 2015) typically.

After its implementation, research on FIT, as income compensation for RE operators, has been conducted in China, and has focused on institutional design (Ye, Rodrigues, & Lin, 2017; Zhang, M. M. et al., 2016), environmental impact (Wei et al., 2019), and the investment-inducing effect on energy business (Liu, Li, & Zha, 2016). In Japan, the research on FIT has demonstrated their large impact on the energy economy (Nakano, Arai, & Washizu, 2017).

As aforementioned, SPs have affected residents' daily lives and resulted in a typical NIMBY response (Jones & Richard Eiser, 2010; van der Horst, 2007). Although there are many conceptual opinions stating that the development of SPs, in line with the values of residents, is desirable (Schelly et al., 2021), conflicts are constantly occurring because of the current lack of progress in the implementation of such SPs. In an attempt to investigate residents' concerns with SPs, Morimoto and Yamashita (2020) analyzed the physical characteristics of SPs, and the features that caused discomfort to local residents during the facility construction process of the SPs. Morimoto and Yamashita (2020) demonstrated that the lack of information provided to citizens on SPs during the initial installation stage generated distrust, which affected their perception of the SPs after they were installed. Further, Schelly et al. (2020) and Sward et al. (2021) identified residents' preferences in terms of the location and form of the SPs to be installed, the attributes of the installation company, and the intra-regional distribution of profits. However, although the original cause of the conflicts, such as the structure of the confrontation between the SPs' expansion promoters and opponents, has been discussed (Späth, 2018), the accumulation and propagation of residents' emotions have seldom been discussed. Moreover, it has been demonstrated that negative emotions, especially anger and disgust, are propagated to others through social media (Yamashita, In press) and face-to-face (Zheng et al., 2020). Therefore, it is worth confirming whether these negative emotions toward SPs are non-linearly diffused.

We utilize Morimoto and Yamashita's (2020) use of the term "discomfort" in this paper to refer to residents' subjective sense rather than any objectively defined universal sense. Environmental conflicts can occur when not only discomfort but also residents' solutions are concentrated. The present study is original in the sense that it focuses on this point.

3. DATA AND METHODS

3.1 Data Collection

The northeastern part of the Kanto district has especially long daylight hours; thus, it occupies the top position in the ranking by prefecture for both, the introduction of new SPs over 10 kW, and the SP capacity (in kW: (Agency for Natural Resources and Energy, 2019)). Five prefectures in the northeastern part of the Kanto district (Ibaraki, Tochigi, Gunma, Saitama, and Chiba) were ranked within the top ten positions, based on the combined rankings for three years (2014–2016), before this study was conducted. Accordingly, these five prefectures were chosen for this study.

The authors designed the contents of the web questionnaire, which was deemed the most suitable method to acquire data from a broad participant pool that met specified criteria. All questions required an answer, and, except for age and household size, were formatted using the selection type mechanism. No question included a free description field. Both, the distribution and collection were conducted by Rakuten Insight Corporation, one of Japan's foremost research companies. The respondents were registered monitors with the company who were aged 20 years or older. Since the target of this study was not rooftop SPs, but the large-scale SPs that were installed on vacant lots or on farmland, the study excluded residents from the capital city of each prefecture where population and houses/buildings were concentrated.

The purpose of this study, the intended use of survey data, and the reward for participation (modest amount of electronic money) were explained to the selected participants, who either consented or declined to take part. The survey system detected and excluded unreasonably quick response actions and labor minimization actions, which were characterized by consistently selecting the same option, as these were considered invalid according to the survey company's policy.

The effect of the excluded respondents' criteria on the validity of the tabulation was also examined (Tourangeau, Conrad, & Couper, 2013). However, due to the standard specifications regarding participating in web questionnaire surveys in Japan at the time of the survey, the researchers were unable to determine these criteria; therefore, they were sampled according to the company's policy.

Table 1. Questionnaire questions for individual attributes of the respondents

No	Item	Response
Q1	Age	Age at the time of response
Q2	Sex (select one)	1. Male, 2. Female
Q3	Household size	Household size at the time of response
Q4	Annual household income (select one)	1. Under 2 million yen, 2. 2~4 million yen, 3. 4~6 million yen, 4. 6~8 million yen, 5. 8~10 million yen, 6. Over 10 million yen, 7. Do not want to answer/Do not know
Q5	Years of residence in current location (select one)	1. Under 1 year, 2. 1~3 years, 3. 3~5 years, 4. 5~10 years, 5. Over 10 years

Table 2. Questionnaire questions other than individual attributes of the respondents

<table>
<tr><th>Q6
Is there an SP that makes you uncomfortable in your daily life? (Select one)</th><th>Q7
How far is the SP from your home? (Select one)</th><th>Q8
What would you like to do to resolve that discomfort? (Select one)</th><th>Q9
Do you intend to participate in realizing the means? (Select one)</th></tr>
<tr><td rowspan="5">Yes</td><td rowspan="5">1. Under 2 km
2. 2–5 km
3. 5–10 km
4. Over 10 km</td><td>Do not want to do anything</td><td>Apathetic</td></tr>
<tr><td rowspan="2">Mild measure</td><td>Yes</td></tr>
<tr><td>No</td></tr>
<tr><td rowspan="2">Radical protests such as legal trials and disputes</td><td>Yes</td></tr>
<tr><td>No</td></tr>
<tr><td>No</td><td colspan="3">Not analyzed (not included in the sample)</td></tr>
</table>

Note 1: The distance division of Q7 assumed walking range, bicycle range, short distance automobile range, and long-distance automobile range, respectively.
Note 2: Participants who did not want a solution were asked to skip Q9 in this survey. Subsequently, skipped answers for Q9 were classified as apathy in this analysis.

Regarding the individual attributes listed in *Table 1*, the responses were allocated by age. Thus, the respondents' age was assumed to not be biased across all prefectures, but sex could not be controlled due to the investigation's budget. These individual attributes were used only to characterize the entire sample in this study. Three items were used to understand the discomfort of the residents toward SPs and analyze their spatial features in terms of the position of the SPs that caused individuals' discomfort, the preferred resolution method to reduce the discomfort, and the individuals' intention to participate in the resolution. The location of the SPs that caused discomfort was classified using distance bands from the respondents' homes.

The locations that the respondents used as their bases differed. For some, home was the standard, while for others, their workplace or their children's school routes were the standards. However, it was impossible for this complicated concept to be included as a question item in the simple survey form; therefore, the standard was unified by limiting it to the distance from respondents' homes. Details of the questions used in the analysis are illustrated in *Table 2*.

All of the participants' personal information such as their address, was strictly protected by the research company and research managers (authors of this article).

3.1 Analytical Methods

By observing the characteristics of discomfort concentration, using the survey data, spatial autocorrelation analysis was applied to identify the high potential areas of conflict. Specifically, respondents were characterized by questions Q7–Q9 in *Table 2*, and their similarities and differences were statistically visualized. Reasonable survey time and cost prohibited both, the creation of a database for all large SPs in the survey area, and the exact specification of the large SPs that the respondents' stated to be the objects of discomfort.

Instead, we relied on spatial autocorrelation because we believe that the emotions toward large SPs may accumulate and increase among the same community, since emotional contagion is demonstrated at both the small and mass population levels (Kelly, Iannone, & McCarty, 2016; Kramer, Guillory, & Hancock, 2014).

We first statistically evaluated the correlation of the spatial distribution of the respondents who felt discomfort toward SPs using the Moran scatter plot proposed by Anselin (1995), which plots each point of information with the normalized (mean = 0, variance = 1) observation value as the x-axis, and the spatial lag variable of the normalized dependent variable as the y-axis.

In addition, to identify the areas with high spatial autocorrelation, local indicators of spatial association (LISA) were indicated on a map. These indicators are described in Section 4.3. Then, we evaluated the errors between the LISA that were calculated by dividing the samples by distance from the unpleasant SPs and the LISA that were calculated using all the samples and ArcGIS 10.2.

4. RESULTS

4.1 Respondents' Basic Information

Table 3 shows the survey distribution company's number of registered monitors and the actual number of distributed monitors in the five prefectures at the time of the survey (2017). Out of 680 citizens selected per prefecture (which was the upper limit calculated based on this study's survey cost), the total number of samples collected was 3,400 (Fig. 2). Questionnaires were distributed to the number of monitors indicated in *Table 3*, and the survey was stopped when 680 responses were collected from each prefecture. As shown in Q6 of *Table 2*, participants who answered that there were no large SPs that caused them discomfort in their residential areas were excluded from the tabulation. This omission was made, to avoid results like: most of the samples did not cause discomfort and that a sufficient number of samples could not be secured to evaluate the external diseconomy of the large SPs. Therefore, the rate of discomfort caused by large SPs among the entire population could not be discussed based on the data collected herein. For reference, according to the records held by the research company regarding this survey, 11,060 samples were excluded by this procedure before 3,400 samples were collected. Therefore, a total of 14,460 people did not constitute the statistical population, as the planned sample size was reached in the 14,460 respondents. It should be noted that population is not an unbiased subset of the total population when sampling using a web questionnaire survey.

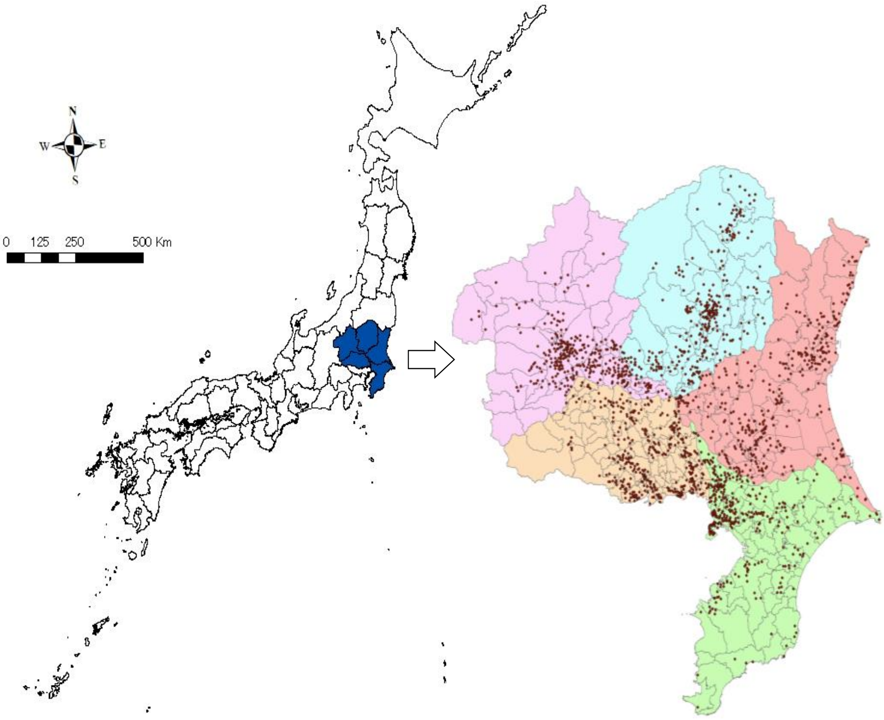

Figure 2. Questionnaire distribution area and spatial distribution of respondents

Note: The plot of the enlarged map on the right shows the location of the respondents' residence.

Table 3. Number of registered monitors and actual distribution of survey sheets in five prefectures in 2017

	Ibaraki		Tochigi		Gunma		Saitama		Chiba	
Age	Mon	Del	Mon	Del	Mon	Del	Mon	Del	Mon	Del
20s	3,285	3,269	2,038	2,035	2,086	2,080	7,470	7,426	6,803	6,772
30s	10,824	10,795	7,674	7,662	7,166	7,145	27,222	16,747	24,738	16,749
40s	13,242	13,240	9,142	9,135	9,128	9,133	34,014	13,643	31,119	13,634
50s	8,113	8,111	5,356	5,351	5,395	5,389	20,784	8,770	19,402	8,765
60s~	4,468	4,472	2,786	2,787	2,639	2,639	10,927	6,246	10,897	6,249

Note: "Mon" means the number of monitors, and "Del" means the number of delivered e-mails that included the questionnaire.

Regarding the distribution of the sample's basic characteristics, the mean age of the respondents was 46.9 years (SD=13.9), and the male-to-female ratio was approximately 2:1. The average household size was 2.7 (SD=1.4), which is slightly higher than the average household size for Japanese in 2017, at 2.48. The mode of annual household income, except for option 7 (Do not want to answer/Do not know), was 4–6 million yen, the second was 2–4 million yen, and the third was 6–8 million yen, and the average annual income of Japanese households in 2017 was 5.52 million yen. Overall, household income up to 8,000,000 yen accounted for 70.0% of the total respondents. Since panel data including personal information at the national or prefecture levels were not open to the public, the exact sampling bias was not evaluated, but the demographics of the sampling were similar to the actual population demographics, except for sex.

However, the validity of the results was impaired when the residential span of respondents in the current area was too short to realize the external diseconomy of the large SPs. Therefore, it was necessary to carefully confirm the distribution of Q5 in *Table 1*. Since large-scale SPs have gradually spread since the 2011 Great East Japan Earthquake, the residency period of five years or more can be used as a criterion for judging validity. Sampling confirmed that 76.1% of the population had lived in their current residence for more than five years (*Table 4*).

Table 4. Years of residence in current location

Years of residence in current location	Number of respondents
Less than 1 year	195
1~3 years	350
3~5 years	266
5~10 years	450
10 years or more	2,139

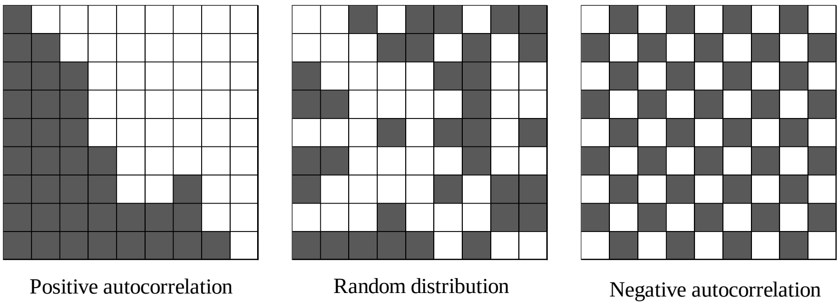

Figure 3. Interpretation of spatial autocorrelation
Note: Plots of the same color have similar spatial characteristics (expressed as binary variables s that take the values 1 and 0).

4.2 Moran's I

As shown in Fig. 3, the spatial autocorrelation is divided into "positive spatial autocorrelation," in which data with close distances demonstrate similar tendencies, and "negative spatial autocorrelation," in which data with close distances demonstrate different values.

The Moran index statistic (Moran's I) is used as a representative technique, and is classified into two types: Global Moran and Local Moran. For Global Moran, the test statistics that judge the whole spatial autocorrelation of the data are the global indicators of spatial association (GISA).

For Local Moran, the test statistics that judge the existence of local spatial autocorrelation, such as hotspots (accumulation of values above the average) and cold spots (accumulation of sub-average values) are local indicators of spatial association (LISA). Since the focus of this study was to analyze the distribution and accumulation of emotions that underlie the reality of environmental conflicts in Japan at the micro-level, the use of Global Moran was omitted.

Local Moran is defined as the similarity between the deviation from the overall mean and the deviation from the mean of the observations in a neighborhood set. If the value of point "i" is similar to the surrounding value, LIi is a large, positive value. However, if it is very different, then LIi is a large, negative value. If LIi is close to 0, then there is no correlation with the surrounding values (Oi, 2016).

In this study, the coordinate of the data was determined by the

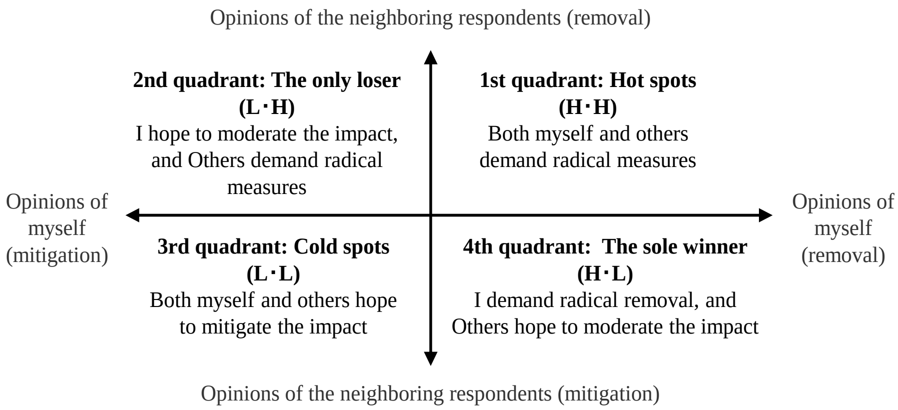

Figure 4. Moran scatter plot

Note: "Defeat" in the second quadrant and "win" in the fourth quadrant are general headings to explain this theory.

respondents' addresses (managed by the web research company). Next, their values attached to data on their emotions were determined based on their responses to Q8 in *Table 2*. Although the answers to Q8 could be treated as a category variable, the hierarchy of the strength of desire for environmental improvement was clear. Then, by substituting, "Do not want to do anything" (apathy), "Mild measures" (a soft solution), and "Strong protests such as legal trials and disputes" (a radical solution), the quantitative data used for the analysis were developed. The answers to Q9, which was a manifestation of intended actions to solve an SP-related problem, were used in interpreting and considering the analysis results.

4.3 Visualization by LISA

The Moran scatter plot used in this study is shown in Fig. 4. The x-axis illustrates the individual respondents' solutions to SPs that caused them discomfort, and the y-axis illustrates the neighboring respondents' solutions around the individual respondents.

The data for when the spatial autocorrelation was statistically significant (individual respondents) could be divided into four quadrants (Oi, 2016). The individual respondents assumed that "SPs are unpleasant," as shown in Q6 and Q7 of *Table 2*, but the neighboring respondents did not always have the same opinions about the SPs. Based on this assumption, this study examined the spatial features of the situations in which the feeling that there were "Unpleasant SPs in living areas where measures are desired" had accumulated. The removal was described as H, and the effect of relaxation was described as L. In addition, the former (H) refers to the individual respondents' opinions, and the latter (L) refers to the opinions of the neighboring respondents (10 km radius).

Fig. 4 shows that the individual respondents' feelings in the first and third quadrants coincide with the neighboring respondents' feelings, but do not coincide in the second and third quadrants. The first and second quadrants reflect the situations in which a radical feeling accumulates and becomes a premonition of environmental conflict in the region. The fourth quadrant reflects the situation in which the neighboring respondents desire a mild measure while an individual respondent strongly desires the "Removal of the offensive SPs." Under such situations, it can be imagined that disharmony

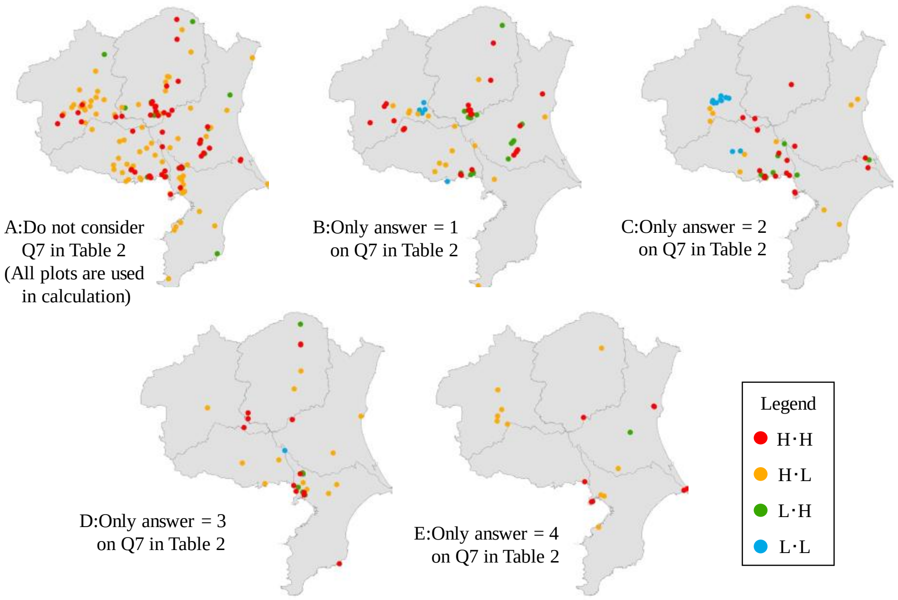

Figure 5. LISA cluster map

Table 5. Number of local spatial autocorrelations based on LISA

	Number of H•H	Number of H•L	Number of L•H	Number of L•L	Total
A: All data	69 (37.1%)	70 (37.6%)	47 (25.3%)	0 (0%)	186 (100%)
B: 0–2 km	25 (42.4%)	15 (25.4%)	14 (23.7%)	5 (8.5%)	59 (100%)
C: 2–5 km	20 (37.7%)	11 (20.75%)	11 (20.75%)	11 (20.75%)	53 (100%)
D: 5–10 km	14 (41.2%)	12 (35.3%)	7 (20.6%)	1 (2.3%)	34 (100%)
E: 10 km ~	10 (45.45%)	10 (45.45%)	2 (9.1%)	0 (0%)	22 (100%)
A-(B+C+D+E)	0	22	13	-17	18

with the neighboring respondents over environmental improvement measures is generated alongside the creation of psychological stress.

Based on the above analytical framework, the obtained results are expressed in the LISA cluster map (Fig. 5) to show the spatial distribution of respondents' opinions, on how to resolve unpleasant SPs. In this study, the spatial weight matrix to determine the autocorrelation coefficient was the inverse of the Euclidean distance without threshold. The plots that were only statistically significant with 95% probability are described.

5. DISCUSSION

Table 5 illustrates the number of local spatial autocorrelations based on LISA. The last column shows the total number of local spatial autocorrelations, using all the data, and is broken down by the distance from residents' homes to the SPs. And the last raw shows the difference between the first row and sum of other rows.

The small sample size summed up in the first row of *Table 5* (i.e., the number of relevant residents) relative to the total sample size may be due to the spatial sparseness of the sampled plots. It is expected that more rigorous results can be obtained if the analysis is based on a larger sample size. However, this is a trade-off for increased study cost. The following two points can be confirmed by dividing the sample by the distance from the residents' homes to the SPs that convey feelings of discomfort. The first is the fundamental point of whether the proximity from the residence increases radical feelings. The second is the propagation by an accumulation of feelings. In the cases of B and C in *Table 5*, people may share feelings for "the same SPs," yet in the cases of D and E, they may not always share feelings for the same SPs. However, the analytical framework reflects our hypothesis that feelings in the community may increase by "spatially" accumulating feelings of the same kind.

Regarding the first result, in *Table 5*, there is no tendency that shows that the closer the distance from the residents' homes to the SPs that cause discomfort, the higher the percentage of residents who have a radical approach toward a resolution.

Regarding the second result, we examined the fallacy of composition by focusing on A-(B+C+D+E) in *Table 5*. The difference of H•L is 22, and the difference of L•H is 13, even though the difference of H•H is 0. This shows slightly more radical results than the synthesis of the statistical analysis results (maps b–e in Fig. 5), in which the unpleasant SPs are divided according to the distance from the respondents' homes. At present, it is not possible to conclude the reason from the respondents' information such as age, sex, household income, and years of residence; however, there is a possibility that unpleasant feelings toward SPs are transmitted among residents in certain areas.

Finally, the possibility of developing accumulated intentions (*Table 5*) into environmental conflicts was speculated from the results of the intention to take action (Q9 in *Table 2*), to resolve discomfort. Out of 69 samples in which the accumulation of H•H was confirmed after considering all the data, 26 (38%) respondents answered "Yes" to Q9 in *Table 2*. That is, they wanted to relieve the discomfort by themselves. Out of 70 samples in which the integration of H•L was confirmed, 20 (29%) respondents replied that the resolution to the discomfort would be carried out by themselves. Out of 47 samples in which the integration of L•H was confirmed, 0 respondents replied that the resolution to the discomfort would be carried out by themselves. In the regions where these samples were distributed, there was a high possibility of environmental conflict due to the accumulation of respondents' dissatisfaction.

The purpose of this study was not to point out the regions with a high risk of conflict individually; therefore, we did not consider them spatially, for this study. However, it is possible to infer the regions where the respondents' dissatisfaction was congregated by using an exploratory analysis of the spatial autocorrelation analysis results.

6. CONCLUSION

The risk of environmental conflict is an important regional problem that the administration should manage before installing SPs. In Japan at the time of study, the environmental assessment of the installation of SPs was not so negative. SPs were introduced to utilize clean energy, but this caused some residents discomfort because of the rapid increase in SP installation in their residential areas. Thus, the residents' desires to resolve their discomfort using radical solutions might have increased in the region. Therefore, it is necessary to develop the popularity of RE via communication strategies that provide affected populations with information and by enriching the environmental assessments that are conducted before the introduction of SPs, so that residents can appropriately cope with the changes. Otherwise, there is a risk of introducing environmental conflicts and impeding the smooth implementation of RE.

This study confirms the accumulation and propagation of discomfort to SPs, which may spread not only through daily conversation among residents, but also via social media and mass media. Attention should be paid to the authenticity of the information provided by these media types.

The limitations of this study are summarized by the following two points.

First, the respondents who answered “No” to the question “Do you feel uncomfortable with the large SPs around you?” were excluded from the analysis. This was reasonable in that it effectively considered a large number of residents who felt discomfort, given that the main objective of this study was to conduct a spatial analysis for the concentration of discomfort. However, the sample collection ignored the opinion that the large SPs, which existed in residential areas did not cause discomfort. This problem should be quantitatively addressed in future research to establish the number of residents who do not feel discomfort, and their reason(s).

Second, the sample size was small, compared to the size of the survey area, and the spatial distribution of discomfort by demographics such as age, sex, family size, and annual income were not analyzed. As a countermeasure, a survey frame, that limits the scope of the research, based on the results of this study, as well as concentrates the sample collection in that scope, may be effective.

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APPENDIX

The Global Moran is defined by the following equation:

$$GI = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij} (y_i - \bar{y})(y_j - \bar{y})}{\sum_{i=1}^{n} (y_i - \bar{y})^2}$$

where, n: the number of samples, $S_0 = \sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}$: Standardized constant (sum of all elements of the weight matrix), and $\bar{y}$: Mean of the observed values. When GI is positive, it is a positive spatial autocorrelation, and when it is negative, it is a negative spatial autocorrelation.

The Local Moran is defined by the following equation.

$$LI_i = \frac{y_i - \bar{y}}{k} \sum_{j=1}^{n} w_{ij} (y_j - \bar{y})$$

where, k is a proportional constant and K=$(1/\mathrm{n}) \cdot \sum_{i=1}^{n} (y_i - \bar{y})^2$. The other parameters are the same as with the definition of the Global Moran.