Chapter 23

Understanding Preference Differences Among Individuals for the Reduction in Flood Risk by Green Infrastructure

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Abstract The purpose of this study is to grasp, through a discrete choice experiment, the general public's preferences regarding green infrastructure that provides flood-control services. Green infrastructure, unlike artificial structures (gray infrastructure) such as continuous artificial levees, can potentially handle floods that exceed what is envisioned at the planning stages. However, there is also the possibility that they may not be able to handle the expected floods. People's preferences could be heterogeneous when it comes to an infrastructure that has such a risk. The results of the latent class model indicated that people's preferences regarding green infrastructure were heterogeneous. Respondents who regard green infrastructure as not contributing to nature conservation and as an excuse to carry out unnecessary river-management projects evaluated gray infrastructure more favorably. It was also revealed that the more confident respondents were in providing their answers, the more likely they were to support green infrastructure. These results may suggest that more understanding will be required for a consensus to be formed regarding the use of green infrastructure.

Keywords Flood risk · Green infrastructure · Preference heterogeneity · Discrete choice experiment · Latent class model

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23.1 Introduction

23.1.1 Background

Floods affect more people globally each year than any other disaster (IFRC 2020). In 2019, 127 floods affected 69 countries, killed 1586 people, and displaced ten million more (IFRC 2020; IDMC 2019). Japan, which has an annual rainfall almost twice the world's average, also suffered disasters, including floods (IFRC 2020). At least 140,000 people in Japan were affected by floods (including tidal waves and debris flows) during the 60 years between 1950 and 2010 (MLIT 2019). In response, the country has built artificial structures (gray infrastructure), such as continuous artificial levees and large dams to protect people's lives and assets from floods (Nakamura et al. 2020). These efforts have achieved some successes; for example, the flooded area in urban districts decreased significantly in the latter half of the 1980s (MLIT 2019). However, the flooded area in urban districts has not declined any further since 1990, and the number of flood victims began to rise in the 2010s (MLIT 2019).

This is partly due to fluctuations in rainfall patterns resulting from climate change. Since the 1970s, fluctuations in annual rainfall have been increasing (JMA 2021a). The number of "extremely heavy" rainfalls (50–80 mm per hour) and "intense" rainfalls (more than 80 mm per hour) is on the rise (JMA 2021b). The continuous artificial levees and large dams that have been constructed so far do not function adequately to control megafloods caused by such extreme rainfall. This is because, while many of these structures are designed to withstand, for example, a flood that may be caused by the rainfall of once-in-100-years intensity, megafloods are caused by rainfall that exceeds that level.

In response to this situation, expanding the size of gray infrastructure is being considered. However, in addition to fiscal problems, a major concern is that gray infrastructure may drastically transform the natural environment. This is because such facilities are changing flow, sediment, and large wood regimes (Lytle and Poff 2004; Nakamura et al. 2017) and exert a great negative impact on the biodiversity of aquatic and riparian organisms (Nakamura et al. 2020). The general public is becoming reluctant to accept a major expansion of gray infrastructure in part because of this scientific insight. For example, a plan was created to artificially construct a waterway stretching 40 km in the Chitose River watershed in Hokkaido, Japan, to prevent flooding. However, the plan raised concerns about its potential impact on wetlands and coastal ecosystems. After years of debate, the plan was scrapped in 1999, and a new river management project featuring a flood control basin was implemented (Yamanaka et al. 2020; Nakamura et al. 2020; Kim et al. 2021).

Against this backdrop, expectations are growing for green infrastructure. Green infrastructure can be broadly defined as a strategically planned network of high-quality natural and semi-natural areas with other environmental features and is designed and managed to deliver a wide range of ecosystem services and protect

biodiversity in both rural and urban settings (European Commission 2013). Green infrastructure in urban and surrounding rural areas can complement large-scale gray infrastructure in areas in the form of flood protection (IPBES 2019). The term “green infrastructure” is also used in the context of rainwater treatment in urban areas. However, the meaning of the term used in this study is more or less the same as this definition: ecosystem-based disaster risk reduction (Eco-DRR), which refers to “the suitable management, conservation, and restoration of ecosystems to reduce disaster risk” (Renaud et al. 2013). In the case of the Chitose River mentioned earlier, the inside of the constructed flood control basin has been restored from farmland to wetlands, resulting in the return of the red-crowned crane (*Grus japonensis*), a rare species and the national bird of Japan, to the area. While the embankment of the flood control basin is a gray infrastructure facility, the flood control basin as a whole is designed as a green infrastructure facility. In addition to the flood control basin, the formation of forests in the upper reaches of the river and the maintenance of wetlands in the river basin could become part of the green infrastructure. The above-mentioned flood control basin at the Chitose River will require maintenance and renovation expenses in the future. However, a great advantage of green infrastructures, such as forests and wetlands, is that they do not incur huge maintenance costs (Nakamura et al. 2020).

There is a major difference in the disaster-prevention functions between gray and green infrastructure. Gray infrastructure can cope with expected floods without failure (for example, a flood caused by the rainfall of once-in-100-years intensity), but it cannot handle any flooding that exceeds that level. Meanwhile, many green infrastructures could potentially handle floods that exceed those envisioned at the planning stages. However, there is also a possibility that they may not be able to deal with the expected floods. For example, although Nakamura et al. (2020) pointed out that wetlands could reduce peak river flows, there is a possibility that the capacity of wetlands to retain rainwater may be affected by seasonal factors and the cumulative rainfall leading up to the rainfall immediately before the flood. If a gray infrastructure facility (such as a dam) is compared to a glass, a green infrastructure facility may be compared to a sponge. A dry sponge can adequately absorb a glass full of water (flood), but a sponge that retains water will not be able to absorb water even if it is less than a glass full. Because green infrastructure uses the natural environment, its disaster-prevention function always involves certain risks. Gray infrastructure also has a limited capacity to absorb water, but it can certainly withstand flooding in situations with lower than an expected flood flow level.

The adoption of green infrastructure for flooding requires land-utilization planning and consensus-building, and various ecosystem services provided by green infrastructure must be considered in the process (Goldstein et al. 2012; Guerrero et al. 2017). Among these, flood control constitutes the core of ecosystem services, and people’s preferences regarding these services provide important insights into building a consensus. Meanwhile, people’s preferences regarding the flood-control services of green infrastructure could be heterogeneous. Some people may prefer expanding the size of gray infrastructure that reliably serves their functions, considering that gray infrastructure has already achieved certain results. Others may

consider the notion that rainfall has intensified and put more emphasis on green infrastructure's potential capability to handle floods that exceed those envisioned levels at the planning stages. Still, others may call for a drastic policy shift toward the adoption of green infrastructure by emphasizing its capability to preserve biodiversity and provide ecosystem services. Understanding such preferences may provide important insights into forming a consensus regarding the adoption of green infrastructure.

23.1.2 The Purpose of the Study

The purpose of this study is to grasp, through a discrete choice experiment, the preferences of the general public regarding flood-control services of green infrastructure that involve certain risks. The insights gained from this study can be used in consensus building toward the adoption of green infrastructure. A discrete choice experiment is a method of grasping the preferences of individual survey respondents by asking them to choose an option that they prefer from choice sets that combine multiple alternatives (Louviere et al. 2000). The discrete choice experiment in this study assumes that gray infrastructure can handle a flood that may be caused by the rainfall of once-in-100-years intensity. The respondents were presented with a hypothetical scenario under which a measure was implemented to address a flood that may be caused by the rainfall of once-in-150-years intensity. As a means of bolstering the flood-control services so that they could handle a flood caused by the rainfall of once-in-150-years intensity, four alternatives were created: (1) bolstering gray infrastructure, (2) bolstering green infrastructure, (3) bolstering both gray and green infrastructure at a 1:2 ratio, and (4) bolstering both gray and green infrastructure at a 2:1 ratio. Six choice sets that combine these four alternatives were created (${}_4C_2 = 6$), and the respondents were asked to choose the preferred alternative among each choice set. As mentioned earlier, it is assumed that respondents' preferences vary with respect to green infrastructure. This study, in order to grasp such heterogeneity in preferences, uses a latent class model to analyze the respondents' choices.

23.2 Methods

23.2.1 Literature Review

The discrete choice experiment was developed by Louviere and Hensher (1982) and Louviere and Woodworth (1983) as part of the stated preference approach. Discrete choice experiments enable the assessment of individual preferences by asking respondents to choose among various multi-attribute scenarios (Louviere

et al. 2000). It was initially used in marketing and transportation (e.g., Hensher 1994; Louviere 1994); however, it is now applied to a wide variety of fields, including environmental valuation and healthcare (e.g., Ryan et al. 2008; Hoyos 2010). While this study focuses on the single attribute of flood-control services, people's preferences regarding this matter can be understood in the same way.

To understand the preferences of survey respondents, we carried out a discrete choice experiment by giving the respondents a batch of hypothetical alternatives and asking them to choose what they would prefer the most. While there are various approaches for modeling choice results (e.g., a mixed logit model, see Train (2009) for more details.), this study used a latent class model. The latent class model was proposed by McFadden (1986) and subsequently applied to empirical studies by Swait (1994). The latent class model, which assumes that respondents are divided into several segments, estimates the preference parameters of each segment and the probability of each respondent belonging to a certain segment. In contrast to the mixed logit model (e.g., Train 1998), the advantage of the latent class model is that, by adopting a membership function for the probability of each respondent belonging to a certain segment, it can grasp not only the heterogeneity of preferences but also the basis of such heterogeneity (Boxall and Adamowicz 2002). Details pertaining to the methodological aspect of the latent class model are stated in the Appendix.

Analysis using a discrete choice experiment or a latent class model is widely practiced in the field of environmental valuation. Such analysis is also used to evaluate green infrastructure and the restoration of nature (e.g., Milon and Scrogin 2006; Birol et al. 2009; Kim et al. 2021). Birol et al. (2009) used a discrete choice experiment to evaluate wetland management methods regarding flood risk, biodiversity, and recreation. Milon and Scrogin (2006) also used a discrete choice experiment to assess people's preferences regarding ecosystem services of wetlands. They also attempted to grasp the heterogeneity of preferences using a latent class model. Kim et al. (2021) targeted the green infrastructure of the Chitose River to evaluate people's preferences regarding its ecosystem services using a latent class model.

In the context of flood risk management, the study of risk perception and risk communication has gained increasing interest (Kellens et al. 2013). There exist many case studies on perception and social behavior dealing with floods (Wachinger et al. 2013; Lechowska 2018). However, our study does not focus on risk perception of flood per se, but rather on the supply uncertainty of the flood-control services. In the literature of environmental valuation, several studies using the stated preference approach try to understand preferences over uncertain outcomes (Roberts et al. 2008). There are several studies that use discrete choice experiments in this context (Glenck and Colombo 2013; Imamura et al. 2016; Glatte et al. 2019). Imamura et al. (2016) examined people's attitudes toward disaster-prevention risk in coastal areas using a discrete choice experiment. They found that coastal citizens did not prefer the excessive degradation of ecosystems due to constructing coastal structures and argued that the introduction of green infrastructure could be a solution. This study can be positioned as one such study.

23.2.2 Survey Design

The discrete choice experiment was conducted using an online questionnaire survey. The survey respondents were provided with graphs and texts that explained the scenarios in detail. Since the purpose of this study is to evaluate the risk of flood-control services, a scenario was established under which flood-control services would be bolstered as an additional measure against intensifying rainfalls. Japan already has a gray infrastructure. Thus, a scenario for replacing it with green infrastructure would be unrealistic. A scenario under which green infrastructure is considered an addition to existing functions would be more realistic. In the survey questionnaire, Fig. 23.1 was presented to the respondents, which explained the characteristics of the existing gray infrastructure facilities.

Fig. 23.1 indicates that gray infrastructure can withstand a flood that may be caused by the rainfall of once-in-100-years intensity (safety: 100%; the probability of flooding: 0%) but cannot withstand any flood caused by rainfall that exceeds the once-in-100-years intensity (safety: 0%; flooding will certainly occur). Next, the respondents were presented with a scenario where flood-control services would be bolstered as an additional measure (Fig. 23.2). The respondents were explained that this additional measure would be implemented with the use of gray infrastructure. To advance the understanding of the survey respondents, gray infrastructure was compared to glass and green infrastructure to a sponge.

The meaning of green infrastructure was explained to the survey respondents using the example of wetlands shown in Nakamura et al. (2020). Then, a situation where flood-control services would be bolstered through green infrastructure was

Fig. 23.1 The characteristics of the existing gray infrastructure facility

Fig. 23.2 Additional flood-control services are provided by gray infrastructure

Fig. 23.3 Additional flood-control services are provided through green infrastructure only

explained (Fig. 23.3). This study assumes that there is a 50% chance that the flood-control service, if bolstered by green infrastructure, would withstand a flood caused by rainfall of once-in-150-years intensity. It would, however, not withstand a flood caused by the rainfall of once-in-200-years intensity, but there is a likelihood that it would withstand a flood caused by the rainfall of once-in-150-years or more and less than once-in-200-years intensity. It is also possible that it may not

Fig. 23.4 Gray infrastructure provides 2/3, and green infrastructure 1/3, of the additional flood-control services

be able to withstand a flood caused by rainfall of less than once-in-150-years intensity. However, the existing gray infrastructure facility certainly prevents floods caused by rainfall of once-in-100-years intensity. In the survey questionnaire, the respondents were asked whether they would choose Figs. 23.2 or 23.3 after the above explanations were provided.

Then, explanations were given regarding a situation where flood-control services would be bolstered through a combination of gray and green infrastructure (Figs. 23.4 and 23.5). Figure 23.4 shows that 1/3 of the bolstering would be discharged through gray infrastructure and 2/3 through green infrastructure (one glass and two sponges). The facility would certainly withstand a flood that may occur as a result of the heaviest rainfall of approximately 117 years. However, the probability that it will withstand a flood caused by the heaviest rainfall of 150 years or longer is lower than a situation where the bolstering would be discharged by green infrastructure alone. Figure 23.5 assumes that 2/3 of the bolstering would be discharged through gray infrastructure and 1/3 through green infrastructure (two glasses and one sponge). The facility would certainly withstand a flood that may occur as a result of the heaviest rainfall in approximately 133 years, but the probability that it will withstand a flood caused by the heaviest rainfall of 150 years or longer is lower than a situation where 2/3 of the bolstering is discharged by green infrastructure alone.

Regarding the bolstering of flood-control services, the four alternative plans have differing ratios of green infrastructure (0%, 33%, 67%, and 100%). Thus, there are six combinations that contain two alternatives each (${}_4C_2 = 6$). A choice had already been made regarding a pair that consists of an alternative plan under which

Fig. 23.5 Gray infrastructure provides 1/3, and green infrastructure 2/3, of the additional flood-control services

the bolstering would be discharged 100% by gray infrastructure and an alternative plan under which the bolstering would be discharged 100% by green infrastructure. Therefore, the respondents were asked to choose their preferred option regarding each of the five remaining pairs (choice sets). Since all combinations were presented, the number of times that each alternative appeared in the series of six choice tasks was the same.

In the online questionnaire survey, in addition to the questions for the discrete choice experiment, the respondents were also asked about their attributes (age, gender, income, etc.), whether they knew about green infrastructure, and their attitude toward green infrastructure. Regarding their attitudes toward green infrastructure, the following statements were evaluated on a seven-point Likert scale (from strongly agree to strongly disagree) (e.g. Jamieson 2004).

- Green infrastructure is necessary
- Green infrastructure will contribute to the conservation and restoration of the natural environment
- Green infrastructure should be increased in the future
- In a river management project, the method that offers the best flood prevention should be chosen regardless of whether it is related to green infrastructure.
- Green infrastructure is an excuse to carry out unnecessary river management projects

In addition, since the content of this questionnaire survey may have been difficult for the general public to understand, the respondents were also asked whether they

provided their answers with confidence. It is assumed that questions other than those for the discrete choice experiment are incorporated into the membership function for the model shown in the Appendix.

23.3 Results

23.3.1 Surveys

The online questionnaire survey was conducted in February 2019, targeting members of the general public in Hokkaido. A research firm conducted the survey. A survey request was sent to ordinary citizens registered with the firm. They were asked to provide answers on the website. In conducting the survey, care was taken to ensure that the composition of the respondents reflected that of the people of Hokkaido with respect to gender and age. A total of 1054 responses were obtained from the website. Of these responses, 914 were chosen for analysis. These were from respondents who answered all questions and did not provide answers too quickly (those who answered questions too quickly may not have read the questions well).

23.3.2 Descriptive Statistics

A total of 46.8% of the respondents were men, while 53.2% were women. People in their 20s comprised 13.6% of all respondents. Those in their 30s, 40s, 50s, and 60s were 16.3%, 21.8%, 20.4%, and 28.0% of the total respondents, respectively. According to the 2015 national census for Hokkaido, men comprised 48.4%, while women comprised 51.6% of the overall population in the prefecture (Statistics Bureau of Japan 2015). Those in their 20s, 30s, 40s, 50s, and 60s were 14.2%, 18.4%, 21.8%, 20.3%, and 25.3%, respectively (Statistics Bureau of Japan 2015). Thus, the composition of the respondents is very similar to that of Hokkaido residents with respect to gender and age.

The results showed that 3.6% of the respondents responded that they knew the meaning of the term “green infrastructure,” while 16.6% responded that they had heard the term. A total of 79.8% of the respondents responded that they did not know the meaning of the term. Table 23.1 indicates respondents’ attitudes toward green infrastructure. Their responses were classified into “positive” (strongly agree, agree, somewhat agree), “neutral” (cannot say either way), and “negative” (strongly disagree, disagree, somewhat disagree). Asked if they provided their answers with confidence, 23.6% gave affirmative answers, while 34.5% responded that they could not say either way. A total of 41.9% responded that they were not confident.

Table 23.1 Attitude toward Green Infrastructure

	Positive (%)	Neutral (%)	Negative (%)
Green infrastructure is necessary	57.5	38.7	3.7
Green infrastructure will contribute to the conservation and restoration of the natural environment	62.1	33.4	4.5
Green infrastructure should be increased in the future	54.9	40.4	4.7
In a river management project, the method that offers the best flood prevention should be chosen regardless of whether it is related to green infrastructure	52.5	41.1	6.3
Green infrastructure is an excuse to carry out unnecessary river management projects	15.3	60.2	24.5

Table 23.2 Estimation results by a conditional logit model

Green infrastructure ratio	Coefficient
0% (gray infrastructure)	−2.5115
33.3%	0.9196***
66.6%	1.1232***
100%	0.4687***
Number of observations	5484
Loglikelihood	−2834.06
Log-likelihood ratio index	0.23

*** $p < 0.01$, ** $p < 0.05$

23.3.3 The Conditional Logit Result

The estimation results of the conditional logit model are presented in Table 23.2. The alternative-specific constant, which is a constant term, was excluded from the estimation results because it was not statistically significant. The preference parameters are all estimated as effect-coded dummy variables (Bech and Gyrd-Hanse 2005), with a situation where every facility is a gray infrastructure facility as the base (0%). Dummy variables, in general, have a base value of zero, but effect-coded dummy variables have a base value of -1 . For effect-coded dummy variables, the coefficient for the gray infrastructure level can be calculated as the sum of the other levels multiplied by -1 ($-\{0.9196 + 1.1232 + 0.4687\} = -2.5115$). We assume that preferences are heterogeneous and that it would be unrealistic to assign 0 to a situation where every facility is a gray infrastructure facility. For this reason, we used effect-coded dummy variables. If a preference parameter is positive and statistically significant, it has a positive impact on utility. As a result, the probability increases that an alternative at such a level will be chosen. In contrast, if a preference parameter is negative and statistically significant, the probability declines when an alternative at such a level is chosen. However, the estimation results of the effect-coded dummy variables can change depending on the base value. Thus, it was

considered whether a preference parameter is positive, negative, or an absolute value. Also, we considered the difference between preference parameters. The likelihood ratio index, which indicates the appropriateness of the model, was 0.23. LRI is regarded as favorable if it is between 0.2 and 0.4 (McFadden 1978).

23.3.4 The Latent Class Result

The estimation results of the latent class model are presented in Table 23.3. The number of segments is specified in the table. There are three segments. Segments are often determined by considering the interpretability of the results, in addition to statistical indicators (Swait 1994; Scarpa and Thiene 2005; Hynes et al. 2008). AIC, AIC3, and BIC indicated that a six-segment model, a five-segment model, and a three-segment model would be the most appropriate. Thus, the most appropriate number of segments differed depending on the statistical indicators. If the number

Table 23.3 The estimation results by the latent class model

	Coefficient		
	Segment 1: Green infrastructure oriented (24.2%)	Segment 2: Gray infrastructure oriented (13.4%)	Segment 3: Intermediate (62.5%)
<i>Green infrastructure ratio</i>			
0% (gray infrastructure)	−7.6866***	4.3394***	−5.2154
33.3%	1.3699***	−0.4523***	2.1526***
66.6%	2.8622***	−1.3531***	2.4041***
100%	3.4545***	−2.5340***	0.6587***
<i>Membership function</i>			
Constant	−2.6608***	−1.5545**	0 (fixed)
Green infrastructure will contribute to the preservation and restoration of the natural environment (seven-point Likert scale)	0.0345	−0.3737***	0 (fixed)
Green infrastructure is an excuse to carry out unnecessary river management projects (seven-point Likert scale)	0.0323	0.3605***	0 (fixed)
I answered this survey confidently (dummy variable: Yes = 1)	0.4265***	0.1175	0 (fixed)
Number of observations			5484
Number of respondents			914
Loglikelihood			−2088.30
Log-likelihood ratio index		0.45	

*** $p < 0.01$, ** $p < 0.05$

of segments is higher than four, segments will emerge that are difficult to interpret. Thus, we adopted a three-segment model.

The estimation by the latent class model included gender, age, income, and so on as part of the membership function. However, none of the differences were statistically significant. Regarding the variables related to attitude, the statements “Green infrastructure is necessary” and “Green infrastructure should be increased in the future” were excluded because they overlap with discrete choice experiment questions. However, the statement “In a river management project, the method that offers the best flood prevention should be chosen regardless of whether it is related to green infrastructure” was not statistically significant. Whether respondents provided their answers confidently was also included in the membership function because it influenced segmentation. Table 23.3 shows a model that retains only the statistically significant variables.

As the table shows, the classification is as follows: segment 1, 37.0%; segment 2, 38.0%; and segment 3, 24.9%. Regarding the estimated coefficients of the membership function, it should be noted that the parameter for Segment 3 was standardized as 0 for standardization. Therefore, the interpretation of the parameters of Segments 1 and 2 is that their values are relative to Segment 3. As in the case of the preference parameter, if the membership parameter is positive and statistically significant, the evaluation rating is high regarding the applicable questions, and respondents who answered “yes” are more likely to be classified as part of a segment. If the parameter is negative and statistically significant, the likelihood of being classified becomes lower.

23.4 Discussion

23.4.1 *The General Attitude toward Green Infrastructure*

While only 3.6% of the survey respondents responded that they knew the meaning of the term “green infrastructure,” 79.8% said that they did not know the term. Thus, green infrastructure may not be familiar to most members of the general public. After the meaning of green infrastructure was explained, the respondents were asked whether they thought green infrastructure would be necessary. In response, 57.5% gave positive answers. Although 38.7% of the respondents were neutral regarding this issue, only 3.7% provided negative answers. They provided similar responses to the statement “Green infrastructure will contribute to the preservation and restoration of the natural environment” and the statement “Green infrastructure should be increased in the future.” Regarding the statement “In a river management project, the method that offers the best flood prevention should be chosen regardless of whether it is related to green infrastructure,” 57.5% gave positive answers. As expected at the outset, the provision of flood prevention services is regarded as the priority in a river management project. In Japan, bid-rigging was sometimes practiced for many large

public works projects, including river management projects. For this reason, there was a certain number of people who chose the statement “Green infrastructure is an excuse to carry out unnecessary river management projects.” Overall, most people were unfamiliar with the term “green infrastructure.” Thus, even though people’s attitudes toward green infrastructure are favorable in general, they have not been solidified at this time.

23.4.2 Interpretation of the Results of the Discrete Choice Experiment

The results of the conditional logit model shown in Table 23.2 are the average evaluation results of the respondents. The preference parameter for gray infrastructure was low: -2.5115 . Meanwhile, the rating rises when green infrastructure is mixed. However, the rating declines once again when green infrastructure becomes 100%. These results may indicate that the respondents regarded green infrastructure as desirable and provided high evaluations, but they still hesitated to support a complete switch to green infrastructure, which is a concept that they learned for the first time.

Fig. 23.6 shows a diagram that makes the results of the latent class model easier to understand. Segment 3 comprised 62.5% of all respondents. The changes in the value of the preference parameter are also similar to those of the conditional logit model. For this reason, the results of this group are reflected strongly in the results of the conditional logit model, which reflects average answers.

Fig. 23.6 The Estimation Results by the Latent Class Model

Next, Segment 2 is highly likely to include people who responded negatively to the statement “Green infrastructure will contribute to the preservation and restoration of the natural environment” and affirmatively to the statement “Green infrastructure is an excuse to carry out unnecessary river management projects.” As for the preference parameter, the evaluation rating for gray infrastructure is the highest, and the rating declines as the ratio of green infrastructure increases. Thus, respondents who find problems with green infrastructure tend to support existing gray infrastructure. Segment 2 can be named “gray infrastructure oriented” segment.

Meanwhile, Segment 1 is not different from Segment 3 regarding the attitude toward green infrastructure. However, Segment 1 included more people who provided their responses confidently in the discrete choice experiment. Fig. 23.6 shows that the value of the preference parameter for Segment 1 is similar to that of Segment 3 and that the two differ only with respect to the evaluation of “100% gray infrastructure” and “100% green infrastructure.” Segments 1 and 3 can be named “green infrastructure oriented” and “intermediate” segment, respectively. This may be interpreted to mean that people, as they increase their understanding of green infrastructure, provide a low evaluation of “100% gray infrastructure” and a high evaluation of “100% green infrastructure.” Whether the respondents knew about green infrastructure was also included in the membership function for analysis, but the coefficient was not statistically significant. What mattered was not whether the respondents knew about green infrastructure, but whether they provided their responses confidently. This is an intriguing point.

23.4.3 Several Perspectives toward Consensus Building

This study seeks to use the obtained insights to help build a consensus regarding the adoption of green infrastructure. Several issues can be raised from this perspective. First, the green infrastructure is unfamiliar to most people. For this reason, awareness should be raised. The issue was explained only briefly in the survey questionnaire, but the overall evaluation of green infrastructure was high, and there were relatively few negative responses. This is a significant advantage when considering the use of green infrastructure.

On the other hand, 41.9% of the respondents did not respond to this questionnaire with confidence, while 23.6% said they provided their answers confidently. Those who were not confident greatly exceeded those who were, indicating that the content of the survey was difficult for many people. A total of 52.5% of the respondents provided affirmative answers to the statement “In a river management project, the method that offers the best flood prevention should be chosen regardless of whether it is related to green infrastructure,” meaning that they were highly interested in flood-prevention services. However, the general public who is familiar with conventional river management projects (i.e., people who think that river management projects are based on risk-free gray infrastructure) may have found it difficult to understand immediately that green infrastructure carries certain risks.

Still, those who provided their responses with confidence are more likely to be included in Segment 1, a group of people who highly evaluated a plan to bolster flood-control services through green infrastructure alone. This may indicate that the better the people understand the issue, the more likely they are to support green infrastructure. Conversely, this means that those who insist on gray infrastructure may do so because of a lack of understanding. This does not argue that green infrastructure should be forced by people. However, if many people oppose green infrastructure, it may be necessary to consider whether they do so because green infrastructure is not adequately understood. It is also important to note that Segment 2 tended to think that green infrastructure is an excuse to carry out unnecessary river management projects. As shown in Fig. 23.6, the preference for Segment 2 has an opposite trend to that of Segments 1 and 3. Clearing the doubts of people, including Segment 2, is also important in building consensus for introducing green infrastructure.

23.5 Concluding Remarks

We conducted a discrete choice experiment to grasp the preferences of the general public regarding the bolstering of flood-control services using green infrastructure that carries certain risks. While people's awareness of green infrastructure was low, they generally provided a favorable evaluation after the issue was explained. Green infrastructure, a new concept for many respondents, is a preferable option. However, on average, their evaluation of a plan to rely entirely on green infrastructure was not particularly high in part because they had not solidified their stance regarding this issue. Nevertheless, their preferences regarding green infrastructure are heterogeneous. Those who found problems with green infrastructure provided a high evaluation of gray infrastructure. It was also revealed that those who provided their responses confidently tended to have a high evaluation of green infrastructure. These results may indicate that the general public's understanding of the mechanism of green infrastructure is inadequate at this time; also, some members of the general public are suspicious of green infrastructure. Therefore, more understanding as well as removing doubts about green infrastructure is required when it comes to building a consensus on the adoption of green infrastructure.

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Appendix

Data from the choice tasks for the discrete choice experiment, performed six times per respondent, were quantified using a random utility model. In the random utility model, it is assumed that the utility function is determined by the sum of the factors that influence the utility (the ratio of green infrastructure in this study) and the random term that is unobservable and stochastic. The utility function for alternative plan i is defined as $U_i = V_i + \varepsilon_i$. U_i is the total utility for alternative plan i , and V_i is its observable deterministic term (the ratio of green infrastructure). Meanwhile, ε_i is an unobservable random term. The probability that alternative plan i will be chosen from combination C is the same as the probability that U_i will be larger than U_j . Thus, it can be described as follows:

$$\Pr(i) = \Pr[U_i > U_j] = \Pr[V_i - V_j > \varepsilon_j - \varepsilon_i] \forall j \neq i, \forall j \in C.$$

It is assumed that, in the most basic conditional logit model that does not presuppose classification (i.e., respondents are not divided into several segments with homogeneous preferences like the latent class model) and presupposes that the utility of the respondents is homogeneous (McFadden 1973), the error term is distributed as type-I extreme values. In this case, the probability that alternative plan i will be selected can be expressed as follows:

$$\Pr(i) = \exp(\mu\beta x_i) / \sum_{j \in C} \exp(\mu\beta x_j).$$

Here, x_i is a vector of the observed variables, and β is a vector of utility or preference parameters. β can be estimated by the maximum likelihood method, and the scale parameter μ is assumed to be 1 in a single sample (Ben-Akiva and Lerman 1985). The conditional logit model does not presuppose classification. Thus, it is equivalent to evaluating the average preferences of respondents.

In contrast, the latent class model assumes that respondent n belongs to latent class s , which cannot be observed in advance. Swait (1994) assumes a latent membership likelihood function $M_{n|s}^* = \gamma_s' z_n + \zeta_{n|s}$. Here, z_n represents the socioeconomic and/or attitude characteristics of respondent n (in this study, the respondents' attributes and attitude toward green infrastructure), γ_s' is a vector of membership parameters, and $\zeta_{n|s}$ is an unobservable random term. For the error terms, a type-I extreme value distribution, which is independently distributed, is assumed for individuals and segments. The probability that respondent n is classified as part of segment s is as follows:

$$P_{n|s} = \exp(\lambda \gamma_s' z_n) / \sum_s \exp(\lambda \gamma_s' z_n),$$

where λ is a scale parameter. The joint choice probability of a respondent belonging to segment s regarding the six choice sets can be expressed as follows:

$$P_{n|s}(i_1, i_2, \dots, i_6|s) = \prod_{t=1}^6 P_{n|s}(i_t|s) = \prod_{t=1}^6 \exp(\mu_s \beta_s x_{i,t}) / \sum_{j \in C} \exp(\mu_s \beta_s x_{j,t}),$$

where β_s and μ_s are the utility and scale parameters specific to segment s , respectively, and t is the number of choice sets presented to each respondent. Ultimately, the unconditional probability of respondent n belonging to segment s regarding the series of alternatives can be obtained by the following formula:

$$P_n(i_1, i_2, \dots, i_6) = \sum_s [\exp(\lambda \gamma_s z_n) / \sum_s \exp(\lambda \gamma_s z_n)] \cdot \prod_{t=1}^6 [\exp(\mu_s \beta_s x_{i,t}) / \sum_{j \in C} \exp(\mu_s \beta_s x_{j,t})].$$

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