Ashes to Ashes, and Dust to Dust: Is Scattering Garden the Sustainable Destination for Cremated Ashes?

Sai-Leung Ng (✉ wsl7@ulive.pccu.edu.tw)

Chinese Culture University <https://orcid.org/0000-0001-9367-8539>

Research Article

Keywords: ash scattering, cremated human ashes, scattering garden, vegetation biomass, vegetation composition

Posted Date: February 9th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1232548/v1>

License: © ⓘ This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

Cremation is commonly practiced around the world because it requires small space for the disposal of ashes and also causes less environmental impacts. Among various options for ash disposal, many people choose to scatter the ashes of their loved ones in a scattering garden. Is scattering garden a sustainable solution to the disposal of cremated ashes? No research has ever attempted to answer this question based on empirical data. This study aimed at filling the research gap by characterizing and evaluating the vegetation performance of a scattering garden after it had been open for ash scattering for six years. The results indicated that, overall, approximately half of vegetation was degraded to either unhealthy or bare soil. The area of bare soil in the lawns of high scattering level was larger than that of low scattering level. Furthermore, the belowground biomass of vegetation in the lawns of high scattering level was significantly lower than that of low scattering level. It is concluded that the current practice of ash scattering in Hong Kong was not sustainable and the intensity of impacts was dependent upon the level of ash scattering. The findings of this study may provide a reference for the policy and management of ash scattering in Hong Kong and other cities around the world.

1. Introduction

Everyone's life has a beginning and an end. As death is an essential aspect of our existence that we cannot avoid, disposal of the dead is an inevitable activity of human society that is of personal, emotional, social, and environmental significance (Canning & Szmigin, 2010).

Although different cultures and traditions have their own death rites and rituals, land burial had been the commonest practice since pre-history (Decker, Muniz, & Cruz, 2018). However, we see a dramatic increase in cremation in the last half-century (Davies & Mates, 2005). Take the United States as an example, the cremation rate increased from 5.7% in 1975 to 48.7% in 2015 and since then, cremation has taken over land burial to be the commonest way of handling the dead. The rate was forecasted to further increase to 79.1% in 2035 (Statista, 2020).

Around the world, the cremation rate is often higher than 70% in those areas with a high density of population but limited land space (National Funeral Directors Association (NFDA), 2015). For example, Hong Kong sustains a population of approximately 7.5 million people on 1107 km² of land (Census and Statistics Department (CSD), 2019), approximately 90% of the deceased bodies are cremated (Food and Environmental Hygiene Department (FEHD), 2018).

The popularity of cremation reflects people holding a more relaxed stance on cremation as the social power of religion and tradition is declining (Heessels, 2012). From the viewpoint of public administration, local authorities promote cremation in order to address the constraints of cemetery capacity and provide the public with a hygienic means of disposal (Canning & Szmigin, 2010). First, cremation turns the body into ashes that greatly saves space for disposal. The Cremation Society of Great Britain adopted the motto "Save the Land for the Living" (Jupp, 2005). The total shadow price of environmental impacts

caused by burial was estimated at 67€/person and that of cremation was only 52€/person, respectively (Keijzer, 2017). Second, land burial is identified as a potential source of a wide range of environmental pollutants (Silva, 1995) (Silva & Malagutti Filho, 2009) (Aruomero & Afolabi, 2014). Not only the decomposition of the corpse produces viscous leachate that may contaminate groundwater and potentially spread diseases to the population (Pacheco, Mendes, Martins, Hassuda, & Kimmelman, 1991) (Dent, 2000) (Zychowski, 2012), but also residues of chemicals, e.g., cosmetics, dyes, and stiffeners, used in corpse makeup and preparation may cause soil contamination for a reasonable time (Üçisik & Rushbrook, 1998) (Amuno, 2013). Cremation effectively helps improve sanitary conditions by killing all viruses, germs, and bacteria carried by the body through intense heat and evaporation (Decker, Muniz, & Cruz, 2018).

However, cremation is not the final solution to the disposal of the dead. It is just a treatment that makes the disposal more flexible. There are many options for ash disposals, such as ash scattering (either on land or at sea), urn storage (either keeping at home, at a columbarium), and burying in a cemetery, etc. (Mathijssen, 2017). Among these options, many people choose to scatter the ashes of their loved ones in a scattering garden. For example, more than 70% of the total number of cremation cases in the Netherlands were disposed of by scattering (Dijk & Mengen, 2002). Although ash scattering in Asia is not as popular as in western countries, the number of ash scattering has greatly increased in recent years. For example, in 2017, there were 5,573 cases of scattering in scattering garden, respectively, accounted for about 12.1 % of the total number of 45,883 deaths in Hong Kong (Legislative Council, 2020), increased from 4.6% in 2010 (Legislative Council, 2018).

Despite the continuously increasing demands of scattering garden, no scientific studies had ever attempted to evaluate the environmental sustainability of ash scattering using empirical data. Because ashes are an alternative form of human body, research ethics requires researchers to seek consent from the studied subjects before measurements or experiments are conducted. However, such consent is impossible to obtain, implying the existence of unsurmountable difficulty. Furthermore, researchers tended to avoid having physical contact with cremated ashes because of sensitive implications, such as cultural beliefs and issues linked to the phenomenon of death history (Decker, Muniz, & Cruz, 2018). Although a few studies had discussed the environmental implications of ash scattering, their views were diverse or even contradictory. For example, Niziolowski, Rickson, Marquez-Grant, & Pawlett (2016) indicated that cremated ashes would be toxic to plants because high sodium content of cremated ashes exceeded the tolerable limit of plants. On the other hand, (Strand, Shields, & Swiader, 2008) indicated the potential of cremation ashes as sources of phosphorus for soil additive or fertilizer, based on a laboratory experiment which used EDTA and citric acid to extract phosphorus from cremated ashes.

With this in mind, this study aimed at filling the research gap by characterizing and evaluating the vegetation performance of a scattering garden which had been open for ash scattering for six years. Specifically, the quality and quantity of vegetation of six lawns were estimated by analysing the aerial photos of the lawns; then grass samples were harvested and the weight of aboveground and belowground biomass were determined to examine the effects of ash scattering on the growth of the

plant. The findings of this study may contribute to the body of literature by providing the portrait of the vegetation performance of a scattering garden after receiving cremated ashes. Furthermore, the findings provide reference to the policy and management of ash scattering. As the global landscape becomes increasingly populated and secularized, it is believed that ash scattering will become more and more popular, especially in Asia. There is an urgent need for scientific data, guidelines, and standards that inform the policy and plan for disposal of the dead (Basmajian & Coutts, 2010).

2. Materials And Methods

2.1 Studied Area

This study selected the Garden of Remembrance (GoR) at Diamond Hill Crematorium and Columbarium as the studied area because it was the most popular venue of ash scattering in Hong Kong. In 2017, the GoR handled 2,365 cases of ash scattering, representing 42.45% of the total number of 5,573 scattering cases in Hong Kong (Legislative Council, 2020).

There were six lawns (total area = 502.76 m²) in the GoR (Figures 1). Although these lawns were varied in size, they were identical in terms of design, construction, and management. The grass in the lawn was *Zoysia* grass (*Zoysia tenuifolia*) and the soil was a mixture of peaty soil and sand (1:1), respectively. These lawns received different loadings of cremated ashes that allowed a comparison of the conditions under different levels of ash scattering. Using the overall mean scattering rate (4.41 cases/m²) as the reference, these lawns were categorized into two groups: high level of scattering (>4.41 cases/m²yr), and low level of scattering (<4.41 cases/m²yr). The lawns were watered daily and clipped once a month. Table 1 provides the basic information of these lawns.

<<Figure 1 is here>>

<<Table 1 is here>>

2.2 Vegetation Cover

The performance of vegetation was assessed in two ways. First, the quality and quantity of vegetation cover, indicating plant abundance (Kent & Coker, 1992), was determined by analysing the aerial photos of the lawns acquired by unmanned aerial vehicle (UAV). The advantages of the remote sensing and image analysis are the non-destructive nature of these techniques and at the same time, allowing an accurate estimation of vegetation types and areas (Luna & Lobo, 2016).

The UAV (Dji model: Mavic Pro) was equipped with a professional-grade camera with a 35 mm focal length and a sensor (78.8 mm X 26 mm) of 12.71 megapixels, that was mounted under the UAV. The red-green-blue (RGB) images were acquired at the heights of 25 m and 110 m above the GoR in December 2018. These images were taken around noon time to avoid the formation of shadow.

ArcGIS ver. 10.5 was used to correct and provide the mosaic image with geo-reference using the images acquired from the flight at 110 m above ground. The simple first-degree polynomial transformation was used because the terrain was flat and a few pairs of ground control points were available to be the reference. Images acquired from the flight at 25 m above ground were used to produce a mosaic image with a pixel resolution of 0.83 cm. The resultant mosaic approximately had a geometric error of 5 cm estimated by the visual identification of the grasses and other features of the GoR.

Envi ver. 5.3 was used to classify three classes of vegetation using the red-green-blue bands of the mosaic image. They were: (1) healthy grass, (2) unhealthy grass, and (3) bare soil (i.e., no grass). A sufficient number of representative pixels of each class were selected for the training set (Richards & Jia, 2005). To test the quality of training samples, spectral separability between classes was accessed by calculating the transformed divergence (TD) and Jeffries-Matusita (J-M) Distance of class pairs. The range of TD and J-M is 0 to 2. The value of 1.9 indicated good statistical separability. Training samples would be modified when the separability is low. Table 2 and Table 3 show the number of training pixels and spectral separability report, respectively.

<<Table 2 is here>>

<<Table 3 is here>>

Maximum Likelihood Classifier (MLC) was used, with the pavements being masked out in the process. MLC is a parametric classifier making use of Bayes' theorem of decision making, with the assumption of normally distributed classes in each band. It assigns the class to pixel based on the highest probability of membership to a class, derived from the mean vector and the covariance matrix (Zheng, Cai, & Qin, 2009). The discriminant function of each pixel was calculated using equation (1) (Richards & Jia, 2005).

$$g_i(\mathbf{x}) = \ln p(\omega_i) - \frac{1}{2} \ln |\Sigma_i| - \frac{1}{2} (\mathbf{x} - \mathbf{m}_i)' \Sigma_i^{-1} (\mathbf{x} - \mathbf{m}_i) \quad \text{- equation (1)}$$

i = class, x = dimensionality of data, p(wi) = A Priori Probability = probability that class wi occurs in the image, assumed to be equal for all class, |Σi| = determinant of the covariance matrix of the data in class wi, Σi-1 = its inverse matrix, mi = mean vector

A scoring system was proposed for the calculation of vegetation index: healthy vegetation = 1, unhealthy vegetation = 0.5, and bare soil = 0. The index ranged from 0 (100% bare soil) to 1 (100% healthy vegetation). Based on the relative area of three levels of vegetation, the vegetation index could be calculated using the equation (2). Initially, the lawn was assumed to be covered by healthy vegetation (vegetation index = 100% · 1 = 1). Any changes of vegetation composition were assumed to be the consequence of ash scattering. When more than half of vegetation became unhealthy (vegetation index = (50% · 1) + (50% · 0.5) = 0.75), the vegetation performance was considered unsatisfactory, implying that the level of scattering exceeded the acceptable level.

$$\text{Vegetation performance index} = (\text{area of healthy vegetation} \times 1) + (\text{area of unhealthy vegetation} \times 0.5) + (\text{area of bare soil} \times 0) \quad \text{- equation (2)}$$

2.3 Vegetation Biomass

Second, vegetation biomass was measured because it reflected the amount of energy stored in the plant (Kent & Coker, 1992). In this study, 90 sampling points were systematically selected from the GoR for the determination of the biomass of vegetation, based on the following criteria. First, a random start was set and samples were collected in an interval of 1.5 - 2.0 m. Second, the distance between the sampling point and the edge was as far as possible not less than 1 m. Third, the inner part of the lawn was not sampled because stepping on the lawn was prohibited. There were 64 samples in lawns of high scattering level and 26 samples in lawns of low scattering level, respectively.

At each sampling point, plant samples were harvested by a metal core sampler with a diameter of 4.8 cm. After the attached soils and ashes were carefully washed and returned to the lawn, the grass samples were oven-dried for 24 hours and the weight of aboveground and belowground biomass were determined.

Data were input to SPSS 25.0 for statistical analyses. The normality of the data was checked, skewed data were log-transformed. The homoscedasticity of the data was tested by Levene's Test of equality of error variances. One-way analysis of variance (ANOVA) and post hoc tests (LSD) were employed to evaluate the difference between high and low rates of use.

Although biomass harvesting is a direct measurement of plant productivity, the method is destructive, labor-intensive, and time-consuming (Muukkonen, et al., 2006). Furthermore, because of sensitive nature of sampling human remains, a relatively small number of sample points were selected so the statistical basis of the sample size was compromised (Catchpole & Wheeler, 1992).

3. Results

3.1 Vegetation Cover

The aerial photos taken at the height of 25 m above ground were integrated into a mosaic photo (Figure 2a), then the photo was used for the classification of vegetation cover (Figure 2b). All lawns showed different degree of degradation as unhealthy vegetation and based ground were found in all lawns. Unhealthy grasses were usually found along the footpath but relatively healthy vegetation was established at inner locations away from the footpath.

<<Figure 2 is here>>

Figure 3a summarizes the results of vegetation classification. Overall, approximately half of vegetation was degraded to either unhealthy (39.6%) or bare soil (13.9%). The area of bare soil in the lawns of high scattering level was larger than that of low scattering level. For the lawns of high scattering level, up to 26.8% of vegetation cover was eliminated. The results of vegetation composition were used to calculate

the vegetation indexes using Equation 2 (Figure 3b). Overall, the vegetation index was 0.68 for the whole GoR, lower than the acceptable value of 0.75. The index of the lawns of high scattering level was 0.60, and that of low scattering level was 0.69, respectively.

<<Figure 3 is here>>

3.2 Vegetation Biomass

90 points were sampled for the determination of the biomass of vegetation. The results of the aboveground biomass and belowground biomass are shown in Figure 4, respectively. Overall, the amount of aboveground biomass ($0.5141 \pm 0.2772 \text{ kg/m}^2$) was similar to that of belowground biomass ($0.5283 \pm 0.2697 \text{ kg/m}^2$). There was no significant difference ($F = 0.067, p > 0.05$) of aboveground biomass between the lawns of high scattering level ($0.5260 \pm 0.3301 \text{ kg/m}^2$) and low scattering level ($0.5093 \pm 0.2551 \text{ kg/m}^2$). However, these figures might not truly reflect the aboveground productivity of the lawns because the lawns were clipped once a month and aboveground biomass was regularly removed. On the other hand, the results of belowground biomass were more reliable that deserved more attention (Fiala, 2010). The difference of belowground biomass between lawns under high use ($0.4131 \pm 0.1823 \text{ kg/m}^2$) and low use ($0.5752 \pm 0.2861 \text{ kg/m}^2$) was significant ($F = 7.14, p < 0.01$). The results of belowground biomass were consistent with the vegetation performance index, both indicating that the level of ash scattering significantly affected the growth of grass.

<<Figure 4 is here>>

4. Discussion

4.1 Environmental Sustainability of Ash Scattering

The results indicated that the current practice of ash scattering was not sustainable in Hong Kong. Overall, more than half of the lawn area was degraded, indicating that the performance of the GoR was not satisfactory. The vegetation index was 0.68 for the whole GoR (4.41 cases/ m^2yr), which was lower than the acceptable value of 0.75. For the lawns under low use (3.50 cases/ m^2yr), the performance was still not satisfactory as the vegetation index was 0.69. The vegetation index of lawns under high use (7.47 cases/ m^2yr) was only 0.60, indicating severe degradation. As Hong Kong, like many Asian cities, sustains a large population in a relatively small area, the high population density inevitably translates into high demands of infrastructures for the disposal of dead. The overloading of the GoR reflects the inadequate provision of venue for ash scattering, it is recommended that the government should open more GoRs to meet the increasing demand of ash scattering. Of course, it is possible for the government to promote other forms of ash scattering, e.g., scattering at sea, that help reduce the demand of GoRs. Although the current practice of ash scattering was proved to be not sustainable, this study was not able to recommend standards for the rate of ash scattering.

Ash scattering also resulted in the reduction of biomass, indicating the negative effects of cremated ashes on the plant production. The underground biomass of the lawns of high scattering level was significantly lower than that of low scattering level. Both the results of underground biomass and vegetation cover indicated that the level of ash scattering generated significant impacts on the growth of plant.

4.2 Spatial pattern of degradation

There were a few factors explaining the spatial pattern of degradation. The first factor was the location. Whilst higher levels of use were found at the lawns near the entrance of the GoR, lower levels were at those lawns at the peripheral locations. For example, Lawns 1 and 2 enjoyed highest levels of scattering as they were located at the convenient locations, but Lawns 5 and 6 had low levels of scattering because of far distance to the entrance of the garden. The second factor was the lawn size. Second, surrounding features or landscape might also affect the level of scattering. For example, Lawn 4 was a relatively sensible choice for scattering because of the nearby bridge and stream; but Lawn 6 was not popular because of the adjacent power cable tower. The last factor was the accessibility, unhealthy grasses were usually found along the footpath but relative healthy vegetation was established at inner locations away from the footpath, indicating that impacts on the vegetation probably were associated with pedestrian traffic. Globally, the demand of venues for ash disposal is in increases. Many countries, e.g., Singapore (The National Environmental Agency, 2021), Taiwan (Atlas Obscura, 2021), Poland (Długozima & Ewa, 2020), and the United States (Detroit Free Press, 2021) have developed their scattering gardens for ash disposal. If there is proper management, scattering gardens are green urban spaces with cultural and natural values. They could provide a public service and be integrated into the green infrastructure planning system (Nordh & Evensen, 2018). These findings may cast light on the design of scattering gardens in the future.

4.3 Limitations

This paper has three limitations that future studies should address. First, although this study demonstrated that ash scattering affected both vegetation cover and productivity, the mechanism is still unknown. Soil is believed to play an important role in mediating the effects because soil is the substrate for the growth of plants (Tan, 2014). Future studies should examine the relations between plants and soil by measuring some physically and chemically properties of the soil. Second, a few variables were not controlled in this study. For example, the amount of cremated ashes was varied in scattering cases, also the ashes were not evenly applied to the lawns but up to the preference of the persons who scattered the ashes. Considering cremated ashes are human bodies, it is impossible to conduct a controlled laboratory-typed experiment. Although the scope and depth of discussion in this study was compromised with the limitations, some findings are timely and meaningful to the policy and management of ash scattering in Hong Kong. Third, it is arbitrary to define the change of 50% healthy vegetation to unhealthy as unacceptable. Actually, different conclusions may be drawn if different benchmarks were set dependent upon the goals and practical needs.

5. Conclusions

This study represented the first empirical study to evaluate the environmental sustainability of the practise of ash scattering in Hong Kong. Two complementary methods were employed to study the vegetation performance of a scattering garden which had been open for ash scattering for six years. The results indicated that, overall, approximately half of vegetation was degraded to either unhealthy or bare soil due to ash scattering. The vegetation performance index was 0.68 that is lower than the accepted level of 0.75, indicating that the current practise of ash scattering is not environmentally sustainable. The higher the use rate resulted in a larger area of bare soil and lower value of vegetation performance index. On the other hand, the belowground biomass of lawns under high use was significantly lower than those lawns under low use, indicating the negative effects of cremated ashes on plant biomass. However, the difference in the aboveground biomass between lawns was not significant. The findings of this study may provide a reference for the policy and management of ash scattering in Hong Kong and other cities around the world.

Declarations

Acknowledgments

It will be provided later.

Ethical approval

Compliance with ethical standards and standards of research involving animals is not applicable to this study.

Consent to Participate

Compliance with ethical standards and standards of research involving humans is not applicable to this study.

Consent to Publish

This paper was written by one single author.

Authors Contributions

This paper was written by one single author.

Funding

This study was supported by a research fund (Ref: FEHD A&D SDT 31-138/8/1) from the Food and Environmental Hygiene Department (FEHD), the Hong Kong Special Administrative Region Government.

Declaration of competing interest

The author declares that I have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

The ownership of the data belongs to the Food and Environmental Hygiene Department (FEHD), the Hong Kong Special Administrative Region Government. The data that support the findings of this study are available on request from the Food and Environmental Hygiene Department (FEHD), the Hong Kong Special Administrative Region Government.

References

1. Amuno S (2013) Potential ecological risk of heavy metal distribution in cemetery soils. *Water, Air and Soil Pollution* 224:1435–1447
2. Aruomero A, Afolabi O (2014) Comparative assessment of trace metals in soils associated with casket burials: Towards implementing green burials. *Eurasian Journal of Soil Science* 3(1):65–76
3. Atlas Obscura (2020) Burying the Dead in Taipei's Public Parks. (Newspaper article on 10 Feb 2020) (webpage: <https://www.atlasobscura.com/articles/taipei-tree-burial-public-park>, assessed on 15 Dec 2021)
4. Basmajian C, Coutts C (2010) Planning for the disposal of the dead. *Journal of the American Planning Association* 76(3):305–317
5. Canning L, Szmigin I (2010) Death and disposal: The universal, environmental dilemma. *Journal of Marketing Management* 26(11–12):1129–1142
6. Catchpole W, Wheeler C (1992) Review estimating plant biomass: A review of techniques. *Aust J Ecol* 17:121–131
7. Census and Statistics Department (CSD) (2019) Hong Kong Annual Digest of Statistics 2019. Census and Statistics Department, Hong Kong
8. Davies D, Mates L (2005) *Encyclopaedia of Cremation*. Ashgate, London
9. Decker CJ, Muniz E, Cruz N (2018) Environment systems: A new concept on cremation. *Journal of Sustainable Development of Energy, Water and Environment Systems* 6(2):363–380
10. Dent B (2000) Decay products in cemetery ground waters, geology and sustainable development: Challenges for the third millennium. 31st International Geological Congress. Brazil Secretariat Bureau, Rio de Janeiro, pp 6–17
11. Detroit Free Press (2019) Metro Detroit cemeteries shift toward unique final resting place: Cremation gardens. (Newspaper article on 12 Sep 2019) (webpage: <https://www.freep.com/story/news/local/michigan/oakland/2019/09/12/cremation-garden-cemetery-burial-flowers-remains/2140016001/>, assessed on 15 Dec 2021)

12. Dijk S, Mengen M (2002) Lijkbezorging in Nederland. Evaluatie inspectierichtlijn, overzicht van de branche en inzicht in naleving van regelgeving. RIVM, Bilthoven
13. Długożima A, Ewa K (2020) How to Enhance the Environmental Values of Contemporary Cemeteries in an Urban Context. *Sustainability* 12:2374
14. Fiala K (2010) Belowground plant biomass of grassland ecosystems and its variation according to ecological factors. *Ekológia* 29(2):182–206
15. Food and Environmental Hygiene Department (FEHD) (2018) A Guide to After-Death Arrangements. Food and Environmental Hygiene Department, Hong Kong
16. Heessels M (2012) Bringing Home the Dead. Ritualizing Cremation in the Netherlands. Radboud University, Nijmegen
17. Jupp P (2005) From Dust to Ashes, Cremation and the British Way of Death. Palgrave Macmillan, Basingstoke
18. Keijzer E (2017) The environmental impact of activities after life: life cycle assessment of funerals. *Int J Life Cycle Assess* 22:715–730
19. Kent M, Coker P (1992) Vegetation Description and Analysis: A Practical Approach. Belhaven, London
20. Legislative Council (2018) 2 13). *New Allocation Arrangement for Public Niches and Green Burial Initiatives. LC Paper No. CB(2)832/17-18(07)*. Retrieved from Legislative Council Panel on Food Safety and Environmental Hygiene: <https://www.legco.gov.hk/yr17-18/english/panels/fseh/papers/fseh20180213cb2-832-7-e.pdf>
21. Legislative Council (2020) 1 14). *Promotion of Green Burial. LC Paper No. CB(2)482/19-20(05)*. Retrieved from Legislative Council Panel on Food Safety and Environmental Hygiene: <https://www.legco.gov.hk/yr19-20/english/panels/fseh/papers/fseh20200114cb2-482-5-e.pdf>
22. Luna I, Lobo A (2016) Mapping crop planting quality in sugarcane from UAV Imagery: A pilot study in Nicaragua. *Remote Sensing* 8:500
23. Mathijssen B (2017) The ambiguity of human ashes: Exploring encounters with cremated remains in the Netherlands. *Death Stud* 41(1):34–41
24. Muukkonen P, Mäkipää R, Laiho R, Minkkinen K, Vasander H, Finér L (2006) Relationship between biomass and percentage cover in understorey vegetation of boreal coniferous forests. *Silva Fennica* 40(2):231–245
25. The National Environmental Agency (2021) Ash Scattering Facilities (webpage: <https://www.nea.gov.sg/our-services/after-death/ash-scattering-facilities>, assessed on 15 Dec 2021)
26. National Funeral Directors Association (NFDA) (2015) NFDA 2015 Cremation and Burial Report Research, Statistics and Projections. National Funeral Directors Association, Brookfield, WI
27. Niziolomski J, Rickson J, Marquez-Grant N, Pawlett M (2016) Soil Science Related to the Human Body After Death. Literature Review Produced for the Corpse Project. Cranfield University, Cranfield

28. Nordh H, Evensen K (2018) Qualities and functions ascribed to urban cemeteries across the capital cities of Scandinavia. *Urban Forestry & Urban Greening* 33:80–91
29. Pacheco A, Mendes J, Martins T, Hassuda S, Kimmelman A (1991) Cemeteries- A Potential Risk to Groundwater. *Water Sci Technol* 24(11):97–104
30. Richards J, Jia X (2005) *Remote Sensing Digital Image Analysis: An Introduction*, 4th edn. Springer, Berlin
31. Silva L (1995) *Cemeteries in Environmental Issues*. Seminary National Cemetery and Environment, São Paulo
32. Silva R, Filho M, W (2009) Cemeteries: Potential sources of contamination. *Science Today Magazine* 44(263):24–29
33. Statista (2020) 7 30). *Cremation Rate in the United States from 1975 to 2035*. Retrieved from Statista: <https://www.statista.com/statistics/251702/cremation-rate-in-the-united-states/>
34. Strand R, Shields F, Swiader J (2008) *Cremation Ash as Phosphorous Source for Soil Additive or Fertilizer. Patent App. 11/634,612*. Washington, DC: U.S. Patent and Trademark Office
35. Tan K (2014) *Environmental Soil Science (3rd edition)*. Boca Raton: CRC
36. Üçisik A, Rushbrook P (1998) *The Impact of Cemeteries on the Environment and Public Health*. WHO Regional Office for Europe, Copenhagen
37. Zheng M, Cai Q, Qin M (2009) The effect of prior probabilities in the maximum likelihood classification on individual classes. *Photogram Eng Remote Sens* 9:1109–1117
38. Zychowski J (2012) Impact of cemeteries on groundwater chemistry: A Review. *CATENA* 1(93):29–37

Tables

Table 1 Description of Lawns of the Garden of Remembrance at Diamond Hill Crematorium and Columbarium

Lawn no.	Area (m ²)	Number of scattering cases ^a				Scattering rate ^b (cases/m ² yr)	Level of scattering
		2016	2017	2018	Average (2016 – 2018)		
1 + 2	49.7	416	472	440	442.7	8.91	High ^c
3	284.1	938	1065	992	998.3	3.51	Low ^d
4	65.9	396	449	419	421.3	6.39	High ^c
5	72.8	250	284	264	266.0	3.65	Low ^d
6	30.2	83	95	88	88.7	2.94	Low ^d
Overall	502.76	2,083	2,365	2,203	2217.0	4.41	–

(note: ^a Internal statistics of Food and Environmental Hygiene Department (FEHD);

^b Scattering rate = Average number of scattering cases (2016 - 2018) / Area;

^c High level of scattering if scattering rate > 4.41 cases/m²yr;

^d Low level of scattering if scattering rate < 4.41 cases/m²yr)

Table 2 Number of selected training pixels

Vegetation type	Number of training pixels
Healthy grass	2,201
Unhealthy grass	1,304
Bare soil	1,568

Table 3 Spectral separability report of the classification

bare (ROI_final):
healthy (ROI_final): (1.99009889 1.99967857)

unhealthy (ROI_final): (1.92224458 1.99979507)

healthy (ROI_final):
bare (ROI_final): (1.99009889 1.99967857)
unhealthy (ROI_final): (1.89900942 1.99088503)

unhealthy (ROI_final):
bare (ROI_final): (1.92224458 1.9979507)
healthy (ROI_final): (1.89900942 1.99088503)

Pair Separation (least to most):
healthy (ROI_final) and unhealthy (ROI_final) - 1.89900942
bare soil (ROI_final) and unhealthy (ROI_final) - 1.92224458
bare soil (ROI_final) and healthy (ROI_final) - 1.99009889

Figures

Figure 1

Layout of the Garden of Remembrance at Diamond Hill Crematorium and Columbarium (Left, a sketch map; Right: an aerial photo taken at the height of 110m above ground)

Figure 2

Vegetation of six lawns. (Left, the mosaic image taken at the height of 25 m above ground; Right: vegetation classification)

Figure 3

Vegetation performance under different levels of scattering (Left: vegetation composition; Right: vegetation index)

Figure 4

Biomass of grass under different levels of scattering (Left: aboveground biomass; Right: belowground biomass)