Landscape and Urban Planning 226 (2022) 104470

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan

Planning the first view: Establishing a landscape monitoring scheme based on photography

Wendy Fjellstad [*], Sebastian Eiter, Oskar Puschmann, Svein Olav Krøgli

NIBIO – Norwegian Institute of Bioeconomy Research, Department of Landscape Monitoring, Norway

HIGHLIGHTS

- Landscape photographs can document the visual effects of landscape change.
- Freely selected photo locations capture rare special values best.
- Predefined locations are most representative and can capture unexpected change best.
- We recommend combining both methods when establishing landscape monitoring.

ARTICLE INFO

Keywords:
Repeat photography
Visual quality
Landscape change
Viewpoint

ABSTRACT

The visual impacts of landscape change are important for how people perceive landscapes and whether they consider changes to be positive or negative. Landscape photographs and photographs of landscape elements may capture information about the visual qualities of landscapes and can also be used to illustrate, and even to quantify, how these visual qualities change over time. We developed a methodology for a monitoring scheme, based on taking photographs from exactly the same locations at different points in time. We tested two methods: one where fieldworkers chose freely the location and direction of photographs, and one where photo locations and four out of five directions were predefined. We found that the method using predefined locations provided a representative sample of the visual qualities present in the landscape and was relatively person-independent but missed rare landscape components. The method using free selection of photo locations and directions captured rarities, but the content of the photos varied from photographer to photographer. Considering the strengths and weaknesses of the two approaches, we recommend a method that combines aspects of both when establishing a monitoring scheme based on repeat photography, with predefined locations to ensure that the entire area is covered, and additional freely chosen photo locations to capture special subject matter that would otherwise be missed.

1. Introduction

During recent decades, there has been increasing recognition of the importance of the visual landscape in landscape policy, management and planning (Fairclough, Herlin, & Swanwick, 2018; Loupa, Bianchi, Bernardo, & Van Eetvelde, 2019; Wartmann, Frick, Kienast, & Hunziker, 2021; Wascher, 2000). All kinds of changes affect landscapes, some as consciously planned landscape transformation, others as unintended side-effects of other changes in society. As land uses change, vegetation, infrastructure, buildings, waterways and landforms also change. Sometimes changes are so small, or occur so gradually, that they may not be noticed from one year to the next. Sometimes, as for many construction projects, the landscape may change almost beyond recognition in a very short time. All these changes affect how people perceive the landscape. They affect our understanding of landscape history, the way we use the landscape and the values we associate with it.

The European Landscape Convention defines landscape as: "… an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors" (Council of Europe, 2000). This definition captures both objective and subjective aspects of landscape (Lothian, 1999), accepting that landscapes contain physical objects (like trees, water, roads and houses), but also recognizing that

* Corresponding author at: NIBIO – Norwegian Institute of Bioeconomy Research, Department of Landscape Monitoring, PO Box 115, 1431 Ås, Norway.
E-mail addresses: wendy.fjellstad@nibio.no (W. Fjellstad), sebastian.eiter@nibio.no (S. Eiter), oskar.puschmann@nibio.no (O. Puschmann), svein.olav.krogli@nibio.no (S.O. Krøgli).

https://doi.org/10.1016/j.landurbplan.2022.104470
Received 27 September 2021; Received in revised form 27 April 2022; Accepted 12 May 2022
Available online 20 May 2022

the interpretation of these objects intertwines with less tangible factors in the minds of people. Despite this complexity and the many individual variations in people's perceptions of landscapes, there is general agreement that careful planning, design and management can preserve or enhance landscape character and maintain or increase the benefits that people derive from nature (Antrop & van Eetvelde, 2017; Council of Europe, 2000; Plieninger et al., 2015).

Research has demonstrated that the visual landscape contributes to people's well-being, sense of place, and to public health (de Vries et al., 2013; Twohig-Bennett & Jones, 2018; Ulrich, 1984). House prices are higher for properties with a view (Jayasekare et al., 2019) and the tourism industry specialises in using landscape images in marketing (Scarles, 2004). Attractive landscapes that are valued by people, can bring environmental, social and economic benefits and potentially contribute to sustainable development. Yet, although the visual landscape clearly matters to people, it is not a topic that is easily measured or monitored (Wartmann et al., 2021).

To illustrate changes in the visual landscape, various projects in different countries have made use of repeat photographs of "past-and-present" situations (https://www.tilbakeblikk.no/en, https://www.usgs.gov/centers/norock/science/repeat-photography-project). Some of the first uses were for geological surveys and the documentation of retreating glaciers (e.g. Hamilton, 1965; Malde, 1973; Masiokas et al., 2008). Over the years, the range of uses has broadened (Webb et al., 2010). Examples include documenting changes in the treeline (e.g. Mietkiewicz, Kulakowski, Rogan, & Bebi, 2017; Roush, Munroe, & Fagre, 2007; Van Bogaert et al., 2011), dune field organization (Wilkins & Ford, 2007), gully erosion and river channel development (Frankl et al., 2011), vegetation change (Beltran et al., 2014; Zier & Baker, 2006) and desertification (Nyssen et al., 2009). These examples are used to raise awareness, either of the changes happening in a specific area or of particular types of change. Sometimes they can contribute to debate on the ways in which landscapes might be better managed.

Repeat photography has also been used to document landscape development more generally, picking up any kind of change, or stability, that might occur (Kull, 2005). However, only few studies have attempted to systematically evaluate changes in visual qualities over time, and often these must resort to modelling and indirect measures (Grêt-Regamey et al., 2007; Schirpke et al., 2019; Schirpke et al., 2021). Recently, there have been calls to develop systematic methods specifically to document visual qualities in protected or highly valued landscapes (Eiter et al., 2019). Where such opportunities arise, there is a need for greater insight into how methodological choices can affect the results of evaluations.

When opportunistically using existing photographs, we often do not know the context in which the photographs were taken. Usually, the photographer chose the viewpoint, direction, subject and composition freely – maybe aiming to take a beautiful photograph or to illustrate a particular topic. In this paper, we refer to this as free location – free direction (FL-FD), steered entirely by the photographer.

When the aim is to monitor landscape status and change over time, we need more objective and systematic photography, both to make repeat photography easier and to capture the full range of different types of landscape change. Several initiatives of repeat photography have been established, where photographs are taken from a fixed grid of predefined points. Examples include the Land Use and Coverage Area frame Survey (LUCAS) of Eurostat (d'Andrimont et al., 2020) and the National Inventory of Landscapes in Sweden (Hedblom et al., 2020). We refer to this as predefined location – predefined direction (PL-PD), where the direction of the photos is given beforehand, or predefined location – free direction (PL-FD) if the photographer can choose the direction when they arrive at the given location.

1.1. Our objectives

Our aim was to document the advantages and disadvantages of different methods to establish landscape photography for long-term monitoring. Ultimately, the goal was to develop a method that is repeatable, relatively person-independent, provides a representative sample of the visual qualities present in a landscape, and can capture future changes. We therefore aimed to compare the content of photographs from the different approaches, examine how the different methods might affect which potential landscape changes could be captured, and assess the degree to which the results of the photography were dependent on the photographer.

In the next section, we present our study area and photographers, the details of the different methods for taking landscape photographs for monitoring, and our methods of analysis. In the results section, we compare the spatial distribution of photo points and the content of the photos from the different methods and the different photographers. Finally, we discuss our findings, focusing on strengths and weaknesses of the different methods and what this means for others wanting to use photographs to document landscape change.

2. Methods

2.1. The study area

Our study site was the northern part of the protected Cultural Heritage Environment of Bygdøy. This is an agricultural and recreational area situated on a peninsula close to Oslo city centre, South-Eastern Norway (Fig. 1). Cultural Heritage Environments are protected according to § 20 of the Norwegian Act on Cultural Heritage. The Act defines a Cultural Heritage Environment as «any area where a[n architectural or historical] monument or site forms part of a larger entity or context» (§ 2). Monitoring is necessary to ensure that cultural heritage authorities are made aware of changes and can consider management measures. The Rule of Protection of the specific area, and possibly other documents such as management plans or specialist information, define what is special and subject to conservation in that area. Thereby these documents also define what should be monitored. The Rule of Protection for Bygdøy Cultural Heritage Environment, dated 2012, states that:

> "The cultural heritage values in the area are historically connected to the functions of the Royal summer residence, Royal farm with agricultural areas, public park, recreation area on land and sea, and museum. Bygdøy Church and other properties and localities with landscape-related and historical affiliation to the Royal farm are also subject to protection". (Authors' translation)

Bygdøy Cultural Heritage Environment covers 2.2 km^2, of which 1.8 km^2 is land area. We chose an area of ca. 1 km^2 for method development since this is the size of the monitoring squares used in the Norwegian Monitoring Programme for Agricultural Landscapes, the so-called 3Q Programme. Experiences from this national monitoring programme suggest that this is a manageable area to cover in one day of fieldwork. The area on Bygdøy comprised 36 % forest, 36 % agricultural land, 12 % water, 11 % built-up area and roads, and 5 % unmanaged open land.

2.2. The photographers

Five landscape professionals carried out the fieldwork, all of Northern European origin and resident in Norway for more than 13 years. Three had educational backgrounds from natural sciences (botany, landscape ecology and cartography), two from social sciences (geography). All were employees at a research institute owned by the Norwegian Ministry of Agriculture and Food. The same five fieldworkers conducted both the free selection method (FL-FD) and visited the predefined locations (PL-PD and PL-FD). They worked entirely independently and did not discuss the method or the area being photographed with one another. To avoid an issue of growing familiarity with the study area during fieldwork influencing the choice of photo viewpoints, we tested the FL-FD method first, thereby simulating the situation where a

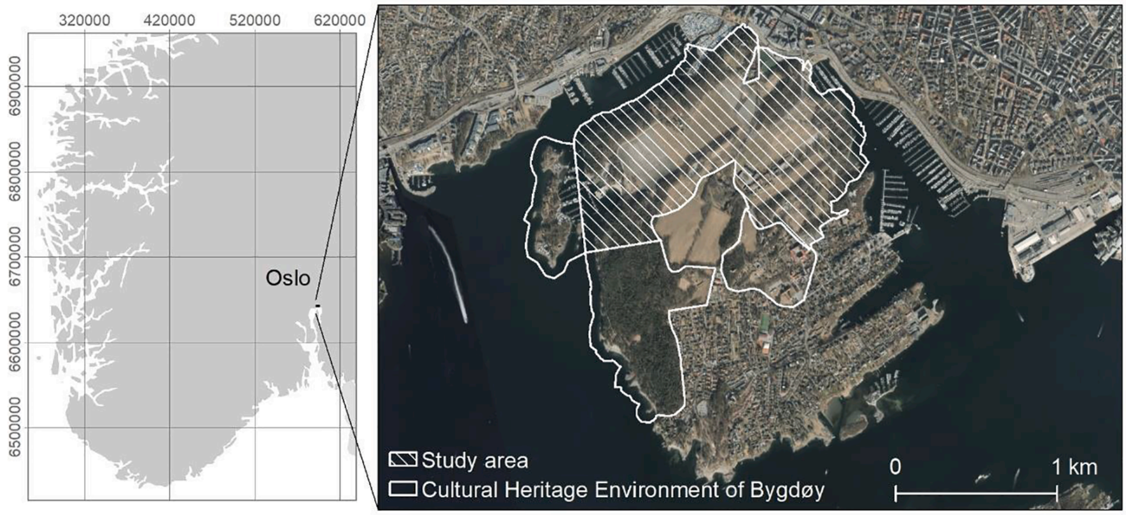

Fig. 1. Location of study area within the cultural heritage environment of Bygdøy, located on the Bygdøy peninsula, Oslo. (Source: Left map: Norwegian Mapping Authority, N5000, ETRS 1989 UTM zone 32. Right map: Norwegian Directorate for Cultural Heritage, Cultural Heritage Environments, orthophoto from Norge digitalt: www.norgeibilder.no).

fieldworker arrives at a new, unfamiliar area to establish a set of photos for monitoring.

2.3. Free selection photography (FL-FD)

In the FL-FD approach, all viewpoints were chosen freely by the photographers (Fig. 2). Prior to fieldwork, all fieldworkers were requested to read the Rule of Protection and a fact sheet by the Directorate for Cultural Heritage, to understand the characteristics of the Cultural Heritage Environment. In addition, each fieldworker received the following instructions:

While taking photos consider that:

- The photos are to be used in future monitoring.
- The area is a protected Cultural Heritage Environment (read documents).
- The viewpoints shall be easily and legally accessible.

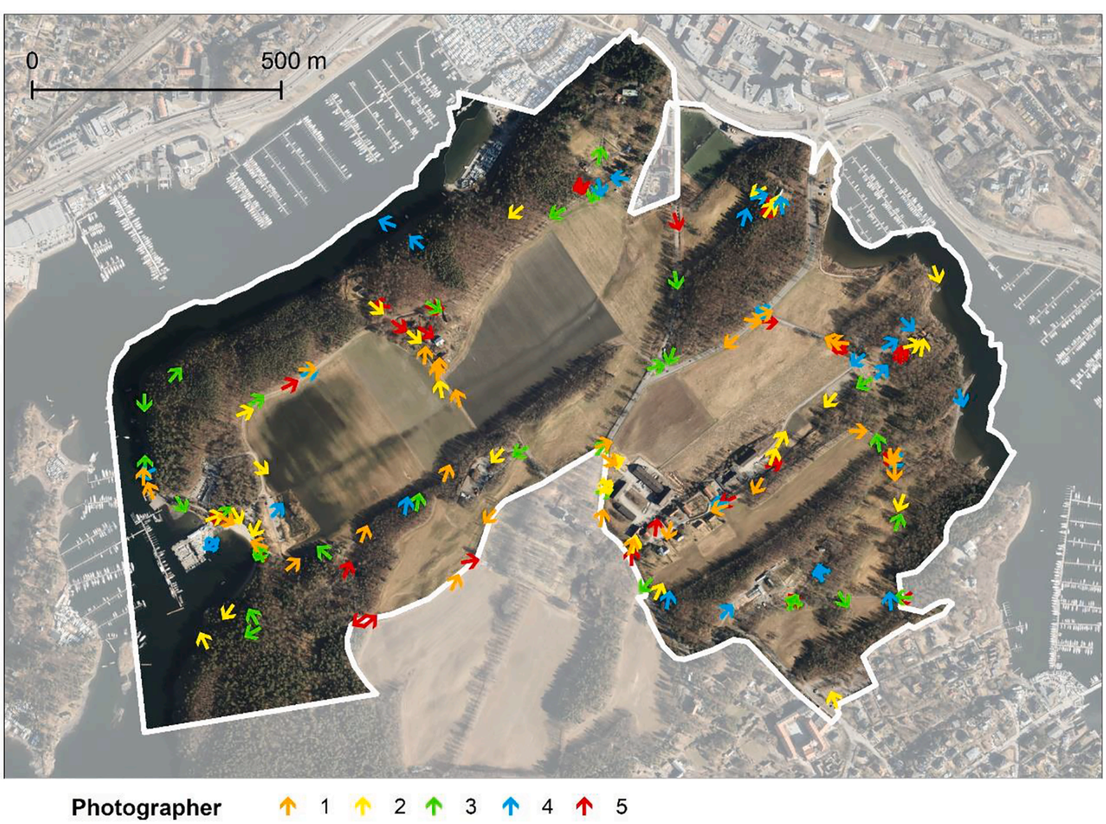

Fig. 2. Photo viewpoints and directions as chosen by the five photographers in the free location – free direction (FL-FD) approach. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

- For each photo, record GPS coordinates of the viewpoint and the view direction (360° scale, 5° accuracy).
- The height of the objective lens shall be as close to 150 cm as possible (use bamboo stick).
- Each photographer shall deliver a total of 30 pictures.
- Consider the scale of the area, dispersal, coverage and degree of detail.
- Record the time (or check that this is included in photo metadata).

The aim of the FL-FD approach was to capture the landscape character of the Cultural Heritage Environment, and important qualities of the area. The fieldworkers could take as many pictures as they wanted, but everyone should finally deliver the 30 pictures that they felt most appropriately reflected the character of the area.

Based on experiences from the 3Q Monitoring Programme, the maximum time for fieldwork was set to 4.5 hours. All photographers conducted fieldwork simultaneously, thereby under the same general weather and light conditions, although they moved around the area independently.

2.4. Photography from predefined locations (PL-PD and PL-FD)

To predefine photo locations, we started with the centre points of cells in a 200 × 200 m grid. Then, to ensure accessibility, points that were on private property or in agricultural fields were relocated to the nearest road or path. Points were dropped if the distance from the original point to the nearest road or path was greater than 50 m. This procedure resulted in 29 viewpoints, relatively evenly distributed throughout the study area (Fig. 3), which was a similar number of points to the FL-FD approach.

All photographers had experience from the FL-FD photography. In addition, the following instructions were given to the photographers:

- Use GPS (uploaded waypoint) and aerial photograph to locate the viewpoint as precisely as possible.
- Take five photographs in the directions North, East, South, West (PL-PD) and one in a free direction (PL-FD), in this order.
- The height of the objective lens shall be as close to 150 cm as possible (use bamboo stick).
- The position of the bamboo stick shall be exactly the same for all five pictures.
- Record compass direction for the PL-FD picture (360° scale, 5° accuracy).
- Record the time (or check that this is included in photo metadata).

2.5. Methods of analysis

We wanted to compare the content of the photographs and analyse similarities and differences between the different methods and different fieldworkers. In order to compare the different sets of photographs, we made an exhaustive list of keywords to describe the content in the photographs (Table 1). The list included words describing land use (e.g. arable field) and land cover (e.g. mixed forest), as well as more specific landscape elements such as flowers, fences, signposts, cars, people and the specific buildings mentioned in the Rule of protection. The keyword ‘grassy edge vegetation’ includes the verges along roads and paths as well as field margins and grassy strips between agricultural fields. Each photograph was assessed against all keywords, recording in a data sheet “1” if the keyword was present in the photo or “0” if it was absent. Some keywords were later grouped for the analysis to provide a better overview of the main findings (Table 1). To test statistically whether the content of the photographs differed between the three different methods

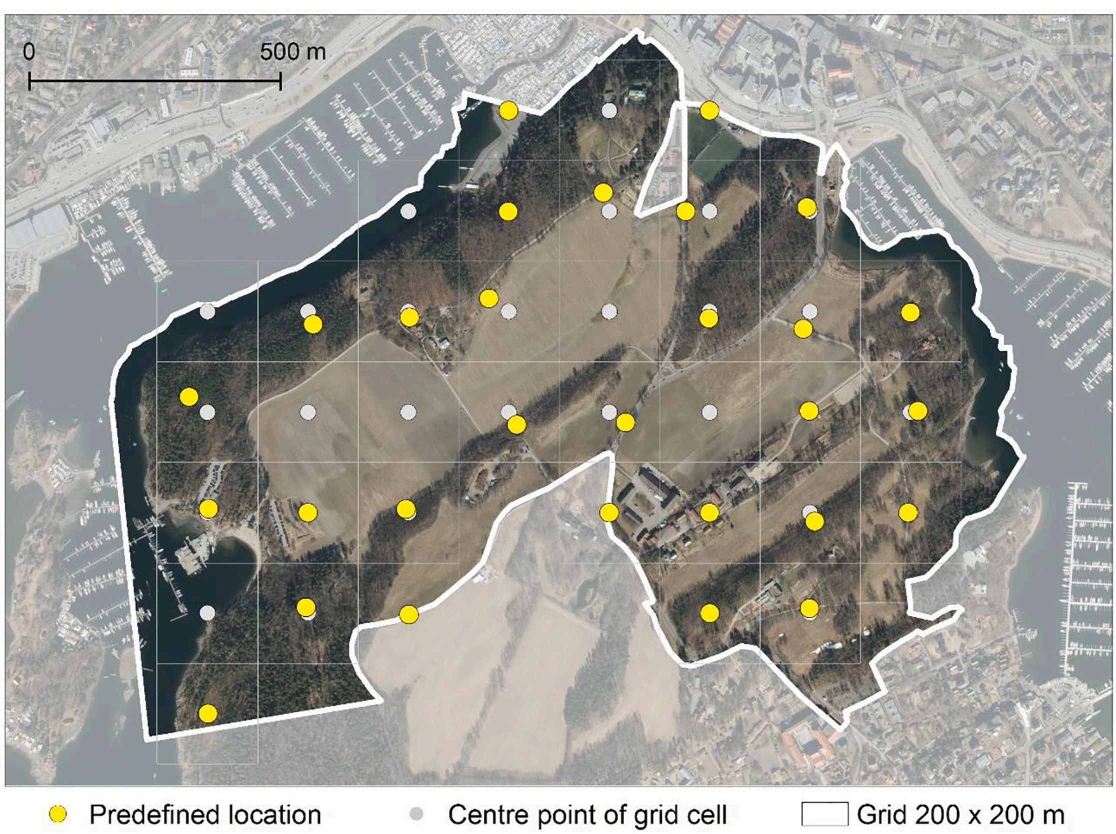

Fig. 3. The predefined locations (yellow dots) used for the PL-PD and PL-FD photos. We started with the centre points of cells in a 200 × 200 m grid (grey dots). When centre points were inaccessible, viewpoints were relocated to the nearest road or path, or removed if relocation would have been more than 50 m. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 1
The keywords used to describe the content of the photographs. Where original keywords have been grouped in the analysis, this is indicated in the description. The column "No." shows the occurrence of each keyword in the entire dataset (872 photos). This may be lower than the sum of original keywords where two or more features (e.g. different types of forest) occur in the same photograph.

Keyword	No.	Description & grouping of original keywords
Forest	763	Deciduous forest (414); Coniferous forest (5); Mixed forest (357)
Farmland	336	Arable field (152); Grassland (198); Pasture/cows/horses (42)
Fence/wall	270	Fence, stone wall (265); Gate (9)
Grassy edge	222	Grassy edge vegetation
Scrub	228	Scrub
Close-up scrub	94	Scrub is the only keyword and is in the foreground
Path	197	Path
Signs/posts/masts	241	Signposts, telegraph poles, masts etc.
Gravel road	146	Gravel road
Asphalt surface	196	Paved road (136); Pavement (54); Car park or large paved surface (70)
Vehicles	137	Cars, vans or trailers
People	42	People
Other buildings	204	Residential building (109); Solitary building (86); Business/commercial building (44); Church (5)
Special buildings	43	Special building (33); Royal farm (25); Monument, sculpture etc. (7); Gazebo (4); 'Sæterhytten' (4); Café (5); Bathing facilities (3); 'Oscarshall' (1)
Viewpoint/info/picnic site	66	Information board (31); Park furniture, picnic table etc. (39); Viewpoint (12)
Ornamental plants	133	Line of trees/avenue (60); Hedge (75); Ornamental shrubs along roads/paths/fields (9)
Garden/lawn	91	Garden (47); Lawn (74)
Flowers	44	Flowers
Solitary tree	101	Solitary tree
Park-like	53	Park-like, incl. pasture with large, scattered trees
Harbour/boat	55	Harbour (37); Boat (53)
Water	48	The sea (45); Freshwater (10)
Beach	13	Beach
Distinctive rock	13	Distinctive rock

of selecting viewpoints (PL-PD, PL-FD and FL-FD) we used the chi-square test of homogeneity. A significant test statistic indicates that the methods differ in the distribution of the variable of interest. To indicate how the groups differ, we used Bonferroni post hoc testing.

3. Results

The number of FL-FD photographs was 30 for four of the fieldworkers, and 27 for one photographer, i.e. 4 * 30 + 27 = 147 photographs in total. The number of PL-FD photographs was 29 locations * 5 fieldworkers = 145, and the number of PL-PD photographs was 29 locations * 4 directions * 5 fieldworkers = 580 photographs. The total number of photos was therefore 872.

In this section, we will first look at the spatial distribution of the photo viewpoints, and then examine the content of the photographs. Our analysis focuses on comparing the different methods, including the degree of variation between photographers.

3.1. Spatial distribution of photo viewpoints

To visualise the coverage of photos from predefined and freely chosen locations, Fig. 4 illustrates whether at least one photograph was taken in each 200 × 200 m grid cell. The photographs from predefined locations were taken in 29 cells. For the photographs from freely chosen locations, the number varies from 14 to 17, and which cells are photographed varies too. Only two cells received photo viewpoints from all five photographers, whilst five cells received viewpoints from just one photographer.

3.2. Landscape components represented in the photographs

The number of occurrences of keywords varied greatly, from specific named buildings that were represented just once or a few times in the 872 photographs, to the most common and widespread component, deciduous forest, that appeared in 414 photographs. To provide a simpler overview in the analysis, we grouped some keywords together. For example, named buildings were grouped as "special buildings", and the different types of forest (deciduous, coniferous and mixed) were grouped as forest (Table 1).

The average total number of keywords per photo (Fig. 5) was highest for the FL-FD photos (7.4) and lowest for predefined directions (PL-PD;

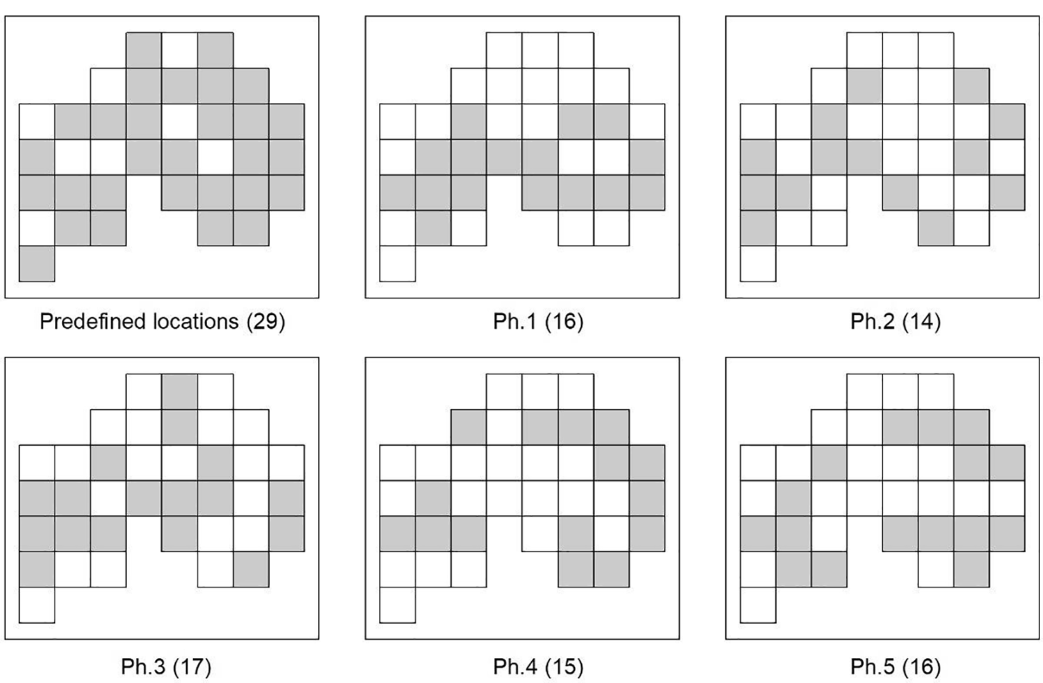

Fig. 4. Spatial distribution of the predefined photo locations and, for each of the five photographers (Ph.1–5), of the freely chosen locations. The numbers in brackets are the number of 200 × 200 m grid cells from which a photo was taken (grey cells). See Fig. 3 for landscape context.

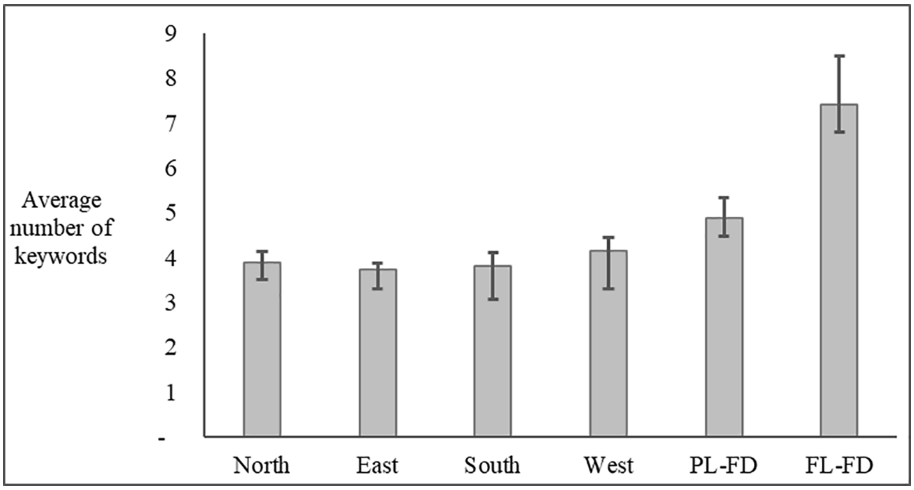

Fig. 5. Average number of keywords per photograph for the four predefined directions (PL-PD), predefined location - free direction (PL-FD), and free location – free direction (FL-FD) photographs. The error bars show the degree of variation between the five photographers.

ranging from 3.7 for East to 4.1 for West), with PL-FD being intermediate (4.9). Variability amongst photographers (Ph.1–5) was greatest for the FL-FD photos (from 6.8 for Ph.5 to 8.5 for Ph.1). However, even the lowest average number of keywords amongst the FL-FD photos was considerably higher than the highest number amongst PL-PD photos (4.4. for Ph.1 and Ph.4), or PL-FD photos (5.3 for Ph.3).

Having examined the North, East, South and West photographs as separate datasets, we found no major differences and have therefore grouped these as 'predefined directions' (PL-PD).

Amongst the PL-PD photos, the most common landscape elements were forest (86 %) and farmland (33 %) (Fig. 6). Forest could be visible in the foreground, midground or background in a photo, and was present in most of the photographs, regardless of method. The proportion of photos containing farmland reflected the area of farmland in the study area (36 %). In the FL-FD photos, farmland was "over-represented" (52 %). However, this varied between photographers, with one photographer (Ph.2) having 37 % and the others from 50 to 63 %. The proportion in the PL-FD photos, was intermediate between PL-PD and FL-FD methods at 45 – 48 %, with very little variation between photographers.

The third most common component in the PL-PD photos was scrub (32 %). This was one of the greatest differences between methods, with just 11 % occurrence in the FL-FD dataset. Again, PL-FD was intermediate at 16 %.

At the other end of the scale, water, special buildings, and flowers were all very rare amongst the photos from the predefined locations (just a few percent for both PL-PD and PL-FD) but all occurred in around 20 % of the FL-FD photos (Fig. 6). Park-like scenes, garden/lawn, solitary trees, and ornamental plants were slightly more common in all datasets, but with a similar trend of being slightly more common in the PL-FD photos and very much more common in the FL-FD method.

Chi-square tests (Table 2) revealed that the differences between methods were statistically significant for 20 keywords. The four keywords that did not differ were grassy edge, signs/posts/masts, asphalt and vehicles. Bonferroni post hoc tests showed that the PL-PD method resulted in significantly fewer occurrences for most keywords, whilst the FL-FD method resulted in significantly more occurrences. PL-FD was generally intermediate and did not contribute significantly to the difference between methods. The main exception to these trends was for scrub and close-up of scrub, which had significantly higher occurrence in PL-PD photographs, and significantly lower both for PL-FD and FL-FD. Paths also differed slightly from other keywords, with a significantly higher proportion of occurrences in PL-FD photos and FL-FD taking the intermediate and non-significant position.

3.3. Variability between photographers

In general, there was a greater degree of variability between photographers with increased freedom of choice, i.e. smallest for PL-PD, higher for PL-FD and greatest for FL-FD photos (Fig. 7). The most variable elements in the PL-PD photos were signs/posts/masts, fence/wall, solitary trees and grassy edges. The same elements were amongst the most variable in the PL-FD photos, but with the addition of other buildings and ornamental plants. There was greater variability for all elements in the PL-FD photos than in PL-PD, with the exception of fence/wall, close-up scrub, paths and distinctive rock. Beach and distinctive rock did not occur amongst the PL-FD photos.

Amongst the FL-FD photos, scrub was the most variable, being completely avoided by Ph.1 and Ph.2, in one photo by Ph.4, in 3 photos by Ph.5 and in 13 photos (43 %) by Ph.3. The second most variable element was other buildings, varying from 23 % (Ph.3) to 63 % (Ph.4) occurrence, followed by flowers, varying from 1 % (Ph.3 and Ph.5) to 11 % (Ph.3). There was greater variability for all elements in the FL-FD photos than in the PL-FD photos, except for people, harbour/boat and close-up scrub, the latter being totally absent.

4. Discussion

In comparing the different methods, we are interested in 1) how well the different photo collections "represent" the study area, and 2) the degree of variation between photographers, which gives an indication of how person-independent the method is. Ideally, we would like the photographs to capture the typical landscape character of the area, as well as capturing the unique, special features that are mentioned as reasons for protecting the area. A third consideration is that the photographs should capture potential changes in the area. We also discuss how the fieldworkers experienced working with the different methods.

4.1. Spatial distribution of photo viewpoints

With the FL-FD method, the different photographers took photographs from different parts of the landscape (Figs. 2 and 4). As a starting point for future repeat photography, the FL-FD method produced five quite different patterns of photo locations. However, the photographs can cover a large view, and may capture elements in several neighbouring cells, so it is possible that each set still captures both typical and special features. Nevertheless, the predefined locations provide a more even and regular spatial distribution of photographs. This avoids unintended spatial biases that can occur when repeat photography is based

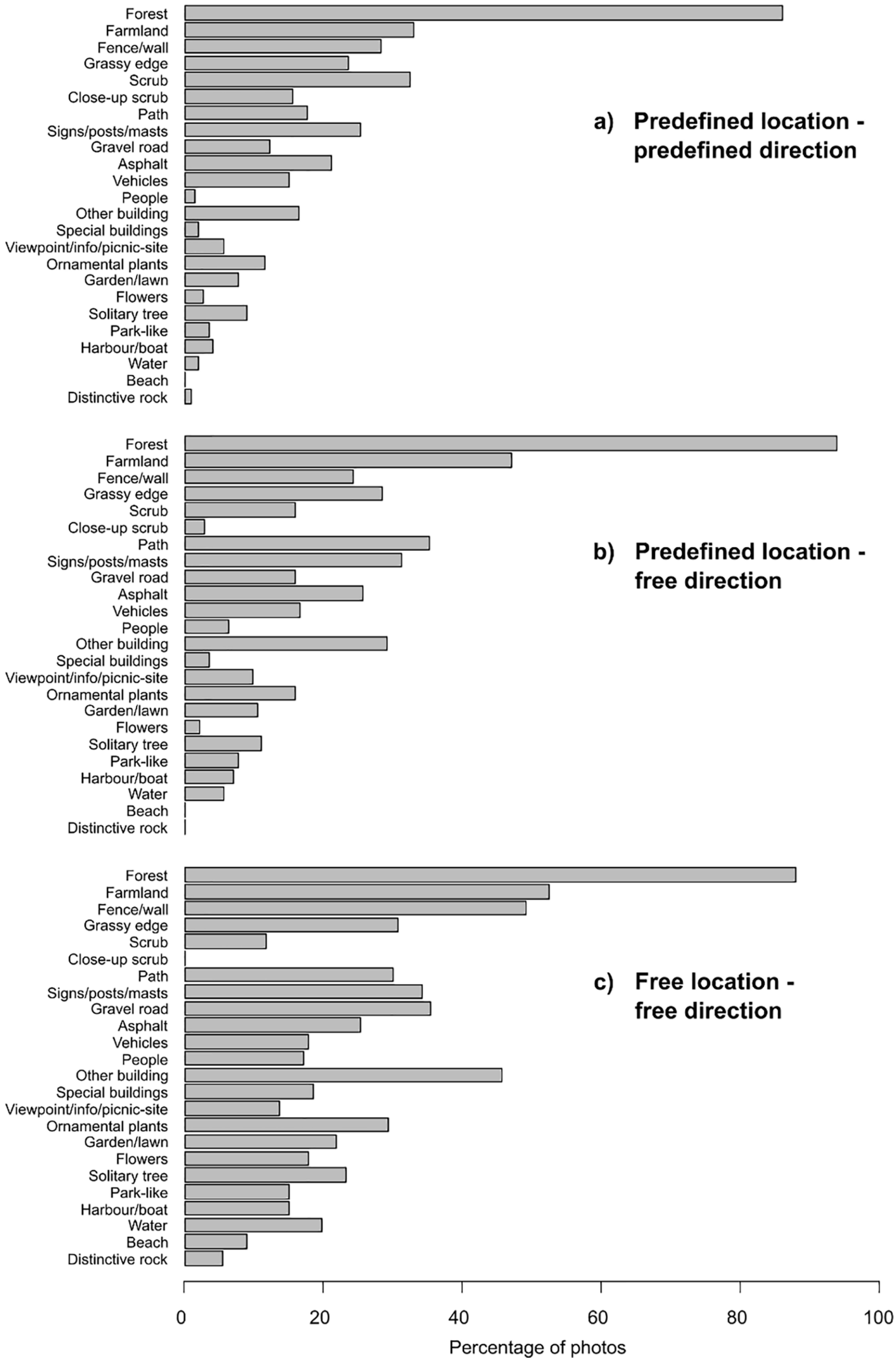

Fig. 6. Percentage of photos containing various landscape elements for the three sets of photographs: a) Predefined location – predefined direction (PL-PD: N, S, E, W), b) Predefined location – free direction (PL-FD), and c) Free location – free direction (FL-FD) photos.

Table 2
Results of statistical analyses, showing whether chi-square testing showed significant differences between the methods (Y:Yes or N:No at $P < 0.05$) and the Bonferroni adjusted residuals for each method (PL-PD: predefined location – predefined direction, PL-FD: predefined location – free direction, FL-FD: free location – free direction). Negative residuals indicate a lower occurrence than would be expected by chance, positive residuals indicate a higher occurrence.

Keyword	Sig. diff. btwn methods (χ^2)	PL-PD		PL-FD		FL-FD	
Forest	Y	−2.06		2.51		0.10	
Farmland	Y	−4.79	*	2.27		3.78	*
Fence/wall	Y	−2.57		−1.95		5.18	*
Grassy edge	N						
Scrub	Y	5.94	*	−3.09	*	−4.41	*
Close up scrub	Y	6.36	*	−3.41	*	−4.62	*
Path	Y	−4.98	*	3.97	*	2.33	
Signs/posts/masts	N						
Gravel road	Y	−5.02	*	−0.31		6.64	*
Asphalt	N						
Vehicles	N						
People	Y	−6.68	*	0.86		7.57	*
Other buildings	Y	−6.90	*	1.74		6.97	*
Special buildings	Y	−5.83	*	−0.90		8.25	*
Viewpoint/info/picnic site	Y	−3.23	*	1.04		3.03	*
Ornamental plants	Y	−4.28	*	0.22		5.18	*
Garden/lawn	Y	−3.88	*	−0.04		4.93	*
Flowers	Y	−4.68	*	−1.79		7.68	*
Solitary tree	Y	−3.63	*	−0.23		4.80	*
Park-like	Y	−4.58	*	0.83		4.95	*
Harbour/boat	Y	−4.01	*	0.32		4.74	*
Water	Y	−6.58	*	0.01		8.29	*
Beach[a]	Y	−5.12	*	−1.62		8.07	*
Distinctive rock[a]	Y	−2.16		−1.62		4.34	*

* $P < 0.05$.
[a] Chi-squared approximation may be incorrect due to low number of observations.

on few historical photographs (Roush, Munroe, & Fagre, 2007; Zier & Baker, 2006). This may be particularly important when re-photographing in the future, if landscape changes have changed the level of visibility in the landscape. For example, a photo point with an open view may capture a large area at the time of the first photography. However, a line of trees or a housing development in the future may obstruct the view and could leave a large portion of the landscape undocumented. Whilst it may be possible in some landscapes to predict relatively stable areas to photograph from, at least in the short term, in a populated, cultural landscape, it is almost impossible to predict how future changes may affect access to and the view from photo locations. An even coverage of photo locations thus makes monitoring less vulnerable to unpredictable future changes.

Closely linked to the issue of spatial distribution is the number of photographs taken. If enough photographs are available, the photographs for analysis can be selected to avoid bias (Zier & Baker, 2006), possibly using different sub-groups of photos to study different issues. This is becoming a common technique with the immense increase in photographs available from social media (Figueroa-Alfaro & Tang, 2017; Muñoz et al., 2020). Nevertheless, even when vast numbers of photographs are available, there can still be bias towards the most popular and accessible areas (Muñoz et al., 2020). If the aim is to document an entire landscape, including the remoter, quieter corners, then an even and regular distribution of points will provide the most complete documentation.

4.2. Landscape components and variability between photographers

The photographs from different methods differed in their content, with the same common elements documented by all methods, but rarer elements photographed far more often in the FL-FD method. The only keywords that did not differ significantly between methods were grassy edge, signs/posts/masts, asphalt and vehicles. In our assessment of the photographs, we recorded only presence/absence of keywords, not their amount or prominence in the photo. It is possible that these elements, which were ubiquitous in the landscape, often accompanied the main theme of the photo as unavoidable or unthought-of extras. The fact that paths were documented more in the PL-FD method is easy to explain considering that many of the predefined locations were relocated to the nearest path in the forest. When surrounded by forest and scrub, which were often captured in the four cardinal directions, the free choice of direction was generally along the path, which provided more of an open view. This fits well with Appleton's (1975) prospect-refuge theory.

The content in the PL-PD and PL-FD photos was more independent of photographer, whilst the FL-FD photos varied quite considerably from one person to another. Since the photographers were all landscape professionals of Northern European origin, they may not reflect the views of the public (Tveit, 2009) or non-Western visitors (Hägerhäll et al., 2018). Nevertheless, the content of photographs taken using the FL-FD method reflects some commonly observed preferences in visual quality. The over-representation of agricultural land can be seen as a preference for openness, often considered a key determinant of landscape preference (Appleton, 1975; Hanyu, 2000; Kaplan & Kaplan, 1989; Nasar et al., 1983; Tveit et al., 2006). However, it might also be influenced by the attempt to cover a relatively large area per scene or by the background of the photographers, all being employed at an institute owned by the Norwegian Ministry of Agriculture and Food. Interestingly, the fieldworker with the lowest proportion of FL-FD photos containing agriculture (37 %) was a botanist by training. This result, and the generally broader range of content in the FL-FD photos, suggests that the FL-FD approach is more person-dependent. Although the fieldworkers had somewhat different educational backgrounds, they had been working at the same research institute for years and were therefore perhaps relatively homogeneous in their landscape perspective. Thus, our results may even under-estimate the degree of person-dependence of the FL-FD method.

There are several other theories that may explain preferences for certain elements. For example, the preference for flowers could relate to the concept of vividness, defined as "some recognizable level of landscape diversity and/or landscape contrast that seems to visibly exist between the various elements within the scene" (Clay & Smidt, 2004). This might also explain the preference for blue water in a scene, although that has also been linked to evolutionary psychology, based on the idea that early humans needed water to be present in their habitat for survival (Orians, 1980).

Regardless of the reasons for preferences, the main point here is that, even amongst this relatively homogenous group of fieldworkers, there was considerable variability in what they chose to photograph. Even when the direction was predefined, we saw variation in the occurrence of signs, posts, masts, fences and edge vegetation. These narrow features could be excluded from the edge of a photograph, whilst still being true to the main direction. The result suggests that some fieldworkers, either consciously or unconsciously, consistently excluded such features more than others. The more choice the fieldworkers were given, the greater the variability in the resulting photographs. This has important consequences if future monitoring is to be based on the initial choices of a single person.

4.3. Reflections by fieldworkers

After both rounds of fieldwork, we conducted semi-structured interviews with all fieldworkers to record experiences and reflections about working with predefined and freely chosen locations. The interviews revealed that the fieldworkers generally found it easier to cover the area within the allocated time using predefined locations. Here too there were differences between fieldworkers, some completing the work

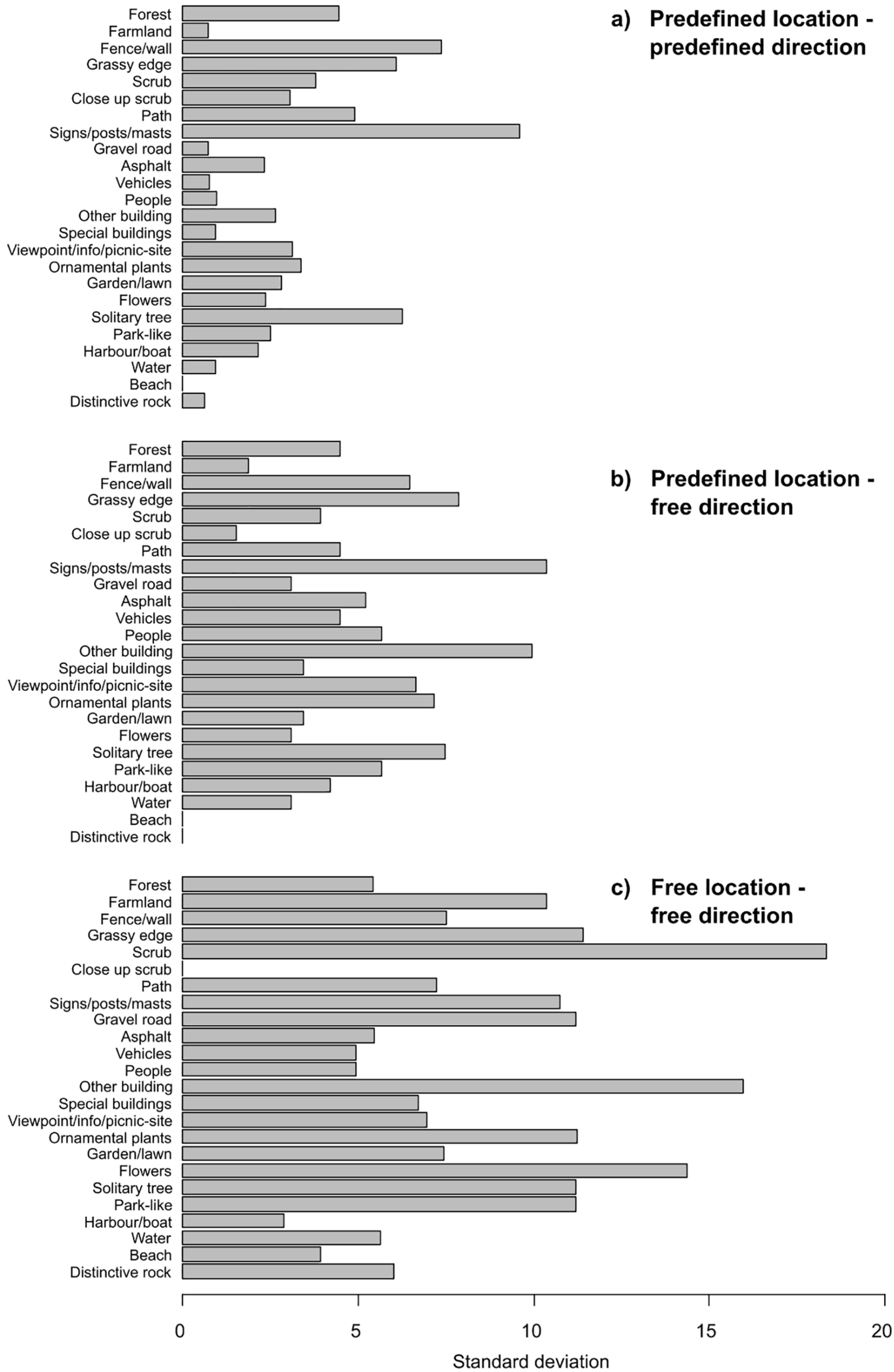

Fig. 7. Standard deviations between the five photographers of the proportion of photographs containing various landscape elements for the three sets of photographs: a) Predefined location – predefined direction (PL-PD: N, S, E, W), b) Predefined location – free direction (PL-FD), and c) Free location – free direction (FL-FD) photos. A higher standard deviation indicates greater variability between the photographers.

with freely chosen locations in good time, whilst others felt stressed at the end and felt that they had not captured all parts of the landscape. All photographers completed the photography from predefined locations within the allotted time.

The fieldworkers had different approaches in collecting their set of photographs from freely chosen locations. Some took photographs from more than 30 locations and made their selection later, after having looked through the photographs again. Others took only the photographs they felt were needed to capture the important aspects of the landscape. One photographer felt that 27 photographs was sufficient, whilst others felt that a set of 30 was too few.

There were also some nuanced differences in the fieldworkers' interpretation of the task or degree of focus on different aspects. Some were more focused on documenting the cultural heritage values mentioned in the Rule of Protection for Bygdøy, such as the Royal farm with agricultural areas, public park, recreation areas, and the special buildings mentioned in a fact sheet about the area. Others had more focus on documenting areas that could be vulnerable to change in the future. For example, Ph.3, has long experience of documenting forest regrowth on former agricultural land in Norway, which may explain his apparent preference for scenes containing scrub.

4.4. Strengths and weaknesses of the methods

Taking photographs from predefined and freely chosen locations both had methodological strengths and weaknesses, which related to both the thematic and geographical coverage of the area (Figs. 8 and 9). These issues were highly inter-related since the exact location of the photo point greatly influenced the content of the photograph.

Predefined photo locations ensured a relatively complete and uniform geographical coverage of the area. Nevertheless, the points could not be placed in an entirely regular grid due to accessibility issues (private property or farmland). The fact that these points were moved to the closest path or road resulted in a large proportion of photos that showed roads, paths and verges, with accompanying elements such as fences, information boards, signs and telegraph poles, etc. These elements were clearly over-represented in relation to their area as a proportion of the entire study area. On the other hand, landscape visual quality is generally perceived by people moving along paths and roads (Kull, 2005; Muñoz et al., 2020), so the results are probably quite representative for how people moving through the area would experience this landscape. A disadvantage of predefined photo locations, however, was that occasional highlights along a route could easily be missed. Research in cognitive psychology indicates that people's memories of experiences are very highly influenced by peak moments and surprising events, whilst the duration of experiences tends to be forgotten (Ariely & Carmon, 2000). Therefore, the occasional special view may be far more important for people's landscape experience than "representative" views.

Freely chosen photo locations, on the other hand, were well suited to capturing the special views that are likely to shape people's landscape experience (Fig. 9). Whilst the method does not provide representative scenes of the physical landscape, the photos may be quite representative for the overall impression that people remember from the area, i.e. the images that they take away in their heads. A disadvantage of freely chosen locations, however, was the unpredictability of finding and recording these special views. Even if the photographer is careful to cover the whole area, they may be more likely to photograph a certain "type" of scene the first time they see it, and then not feel the need to take more photos of similar scenes later. Thus, the starting point of their route may add an element of chance in what is captured. In addition, there is great subjectivity of the concept of "special". Previous research has shown that people's perceptions of landscape and appraisal of landscape attractiveness depend on their socio-cultural background and their familiarity with particular landscape types (Buijs et al., 2006, Dramstad et al., 2006; Häfner et al., 2017). This may cause photographer bias in what is recorded.

In a method aiming to record landscape change over time, both chance effects and the subjective decisions of a particular photographer should be avoided since they could mean that changes in specific landscape types could be missed in future repeat photography. As mentioned in the methods section, we minimized the issue of growing familiarity by taking photos from freely chosen locations first, to simulate the situation where a fieldworker arrives at a new, unfamiliar area to establish a set of photos for monitoring. All fieldworkers took more photographs, closer together, at the start of the day as they met new landscape content. Once content was captured in earlier photos, they took fewer photos and the photo points became more widely spread. This resulted in very uneven geographical coverage, and thus a poor foundation for capturing future changes throughout the entire study area. Photos taken from predefined locations are not influenced by familiarity since the locations are established before going into the field.

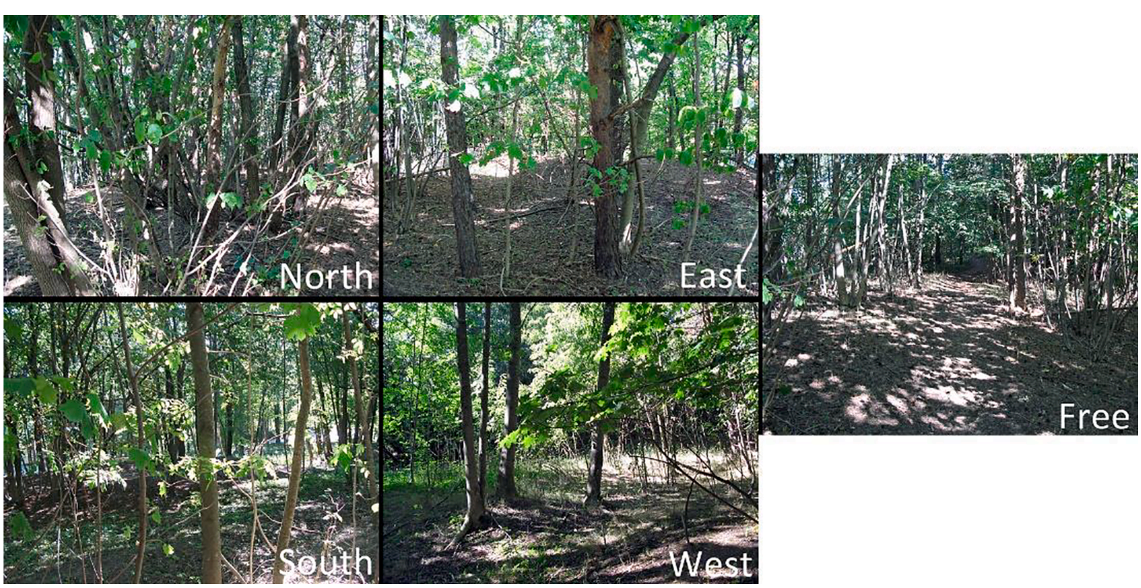

Fig. 8. Photographs from one viewpoint using the predefined location approach, showing the four predefined directions (PL-PD) and free direction (PL-FD). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Fig. 9. Photographs from the free location - free direction (FL-FD) method. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

4.5. Methodological limitations

We wanted to test the objectivity of different methods of photography by comparing the content of the resulting photographs. However, recording the content of photographs is, in itself, a subjective exercise. Elements in the foreground of the picture are easily noticed and recorded, but elements in the background might not be noticed, or might be considered irrelevant and therefore consciously omitted.

Whether an element is recorded or not might also depend on the knowledge, experience or eye for detail of the person doing the assessment. For example, one person might notice the crowns of two coniferous trees in background forest and record “mixed forest”, whereas another – perhaps not recognising the tree species, or less interested in this far-off detail, might record deciduous forest. Therefore, we had to consider in our analysis whether apparent differences between photographers were due to real differences in content in the photographs or due to different assessment of the photographs. This was why we decided not to distinguish between different types of forest in our discussion of results (in addition to this not being part of the defined interest in this particular landscape).

The effects of personal differences could, of course, be minimized by having a single person assess all photographs (Roush, Munroe, & Fagre, 2007). However, this was not possible logistically in our study. Nor would it be realistic for a long-term monitoring. Advances in photo element recognition through artificial intelligence (AI) may provide a solution for classifying photographs in the future (Simonyan & Zisserman, 2015). Indeed, it seems likely that AI will bring great possibilities for analysing landscape change from repeat photographs (Bayr & Puschmann, 2019). Other tools and technologies, such as monoplotting, are also increasing the information value of repeat photographs (Bayr, 2021; Mietkiewicz et al., 2017).

4.6. Implications for monitoring

From the discussion above, questions arise concerning exactly what aspects of landscapes we want to monitor using repeat photography. In our case study, the landscape was protected and the values to be protected and preserved were defined and documented. In this case, it would therefore be relatively easy to decide whether future changes might be considered positive or negative. In the general landscape, however, it may be less clear which elements are important or what kinds of changes are desirable or acceptable. According to the European Landscape Convention definition (Council of Europe, 2000), people’s perceptions are an integral part of the landscape concept, and monitoring landscape change must therefore try to capture these perceptions. One option is to link monitoring of the physical landscape, to monitoring of people’s landscape perceptions, identified through questionnaires. This has been practiced in Switzerland (Hegetschweiler et al., 2020, Wartmann et al., 2021), and was initiated for Norway in the 2020 version of the Norwegian Monitor survey (see Hellevik, 2016 for a general description of the survey).

The results of this study also have some relevance for general landscape management. The analysis of the photos taken from predefined locations, in particular, highlighted how important details along paths and roads can be for overall landscape experience. Tall vegetation along a road or path blocks the view to the landscape beyond and totally changes the experience for observers. Through relatively minor management practices, such as holding vegetation short for at least some stretches of a route, the visual quality of an area may be dramatically enhanced. Similarly, the occasional well-placed viewpoint with a simple bench may be enough to lift the ordinary to a more special and lasting landscape experience for the viewer.

5. Conclusion

Standardisation enables more efficient and effective repeat photography and increases the comparability of photos from different time periods. This applies regardless of whether locations are freely chosen or predefined. The purpose is to enable other photographers to easily revisit viewpoints and repeatedly photograph the same landscape segment that was shown in previous photos. Results showed that using freely chosen photo locations provided exclusively relevant photographs and captured existing landscape values well. However, photo locations were distributed unevenly, which means that important future changes in parts of the area may not be captured by repeat photography. Using predefined photo locations resulted in a higher number of photos, but many were “uninteresting”, e.g. photos showing only dense vegetation. On the other hand, the entire area was covered in a time efficient manner, with very little difference between fieldworkers, and the regular spread of photo points means that also unforeseen landscape changes can be captured by repeat photography. Our final recommended method combines the two approaches, with predefined locations to ensure that the entire area is covered, but with the option to add additional freely chosen photo locations to capture especially good subject matter that would otherwise be missed.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

Thanks to Frode Bentzen and Gunnar Engan for participating in fieldwork and to the Norwegian Directorate for Cultural Heritage, who funded early stages of methodological development. The fieldwork described here, and preparation of the manuscript, were financed by the Norwegian Ministry of Agriculture and Food through the Research Council of Norway, Grant no. 194051. We thank three anonymous reviewers for their valuable feedback on the manuscript.

References

Antrop, M., & Van Eetvelde, V. (2017). *Landscape Perspectives: The Holistic Nature of Landscape*. Netherlands: Springer.
Appleton, J. (1975). *The experience of landscape*. Limited, London: William Clowes & Sons.
Ariely, D., & Carmon, Z. (2000). Gestalt characteristics of experiences: The defining features of summarized events. *Journal of Behavioral Decision Making, 13*(2), 191–201.
Bayr, U., & Puschmann, O. (2019). Automatic detection of woody vegetation in repeat landscape photographs using a convolutional neural network. *Ecological Informatics, 50*, 220–233.
Bayr, U. (2021). Quantifying historical landscape change with repeat photography: An accuracy assessment of geospatial data obtained through monoplotting. *International Journal of Geographical Information Science, 35*(10), 2026–2046.
Beltran, R. S., Kreidler, N., Van Vuren, D. H., Morrison, S. A., Zavaleta, E. S., Newton, K., … Croll, D. A. (2014). Passive Recovery of Vegetation after Herbivore Eradication on Santa Cruz Island. *California. Restoration Ecology, 22*(6), 790–797.
Buijs, A. E., Pedroli, B., & Luginbuhl, Y. (2006). From hiking through farmland to farming in a leisure landscape: Changing social perceptions of the European landscape. *Landscape Ecology, 21*(3), 375–389.
Clay, G. R., & Smidt, R. K. (2004). Assessing the validity and reliability of descriptor variables used in scenic highway analysis. *Landscape and Urban Planning, 66*(4), 239–255.
Council of Europe. (2000). *The European Landscape Convention*. Florence: Council of Europe.
D'Andrimont, R., Yordanov, M., Martinez-Sanchez, L., Eiselt, B., Palmieri, A., Dominici, P., … van der Velde, M. (2020). Harmonised LUCAS in-situ land cover and use database for field surveys from 2006 to 2018 in the European Union. *Scientific data, 7*(1), 352-352.
De Vries, S., van Dillen, S. M. E., Groenewegen, P. P., & Spreeuwenberg, P. (2013). Streetscape greenery and health: Stress, social cohesion and physical activity as mediators. *Social Science & Medicine, 94*, 26–33.
Dramstad, W. E., Tveit, M. S., Fjellstad, W. J., & Fry, G. L. A. (2006). Relationships between visual landscape preferences and map-based indicators of landscape structure. *Landscape and Urban Planning, 78*(4), 465–474.
Eiter, S., Fjellstad, W., Puschmann, O., & Krøgli, S. O. (2019). Long-term monitoring of protected Cultural Heritage Environments in Norway: Development of methods and first-time application. *Land, 8 (5), 75*, 22 p.
Fairclough, G., Herlin, I. S., & Swanwick, C. (Eds.). (2018). *Routledge Handbook of Landscape Character Assessment: Current Approaches to Characterisation and Assessment*. London: Routledge.
Figueroa-Alfaro, R. W., & Tang, Z. (2017). Evaluating the aesthetic value of cultural ecosystem services by mapping geo-tagged photographs from social media data on Panoramio and Flickr. *Journal of Environmental Planning and Management, 60*(2), 266–281.
Frankl, A., Nyssen, J., De Dapper, M., Haile, M., Billi, P., Munro, R. N., … Poesen, J. (2011). Linking long-term gully and river channel dynamics to environmental change using repeat photography (Northern Ethiopia). *Geomorphology, 129*(3), 238–251.
Grêt-Regamey, A., Bishop, I. D., & Bebi, P. (2007). Predicting the Scenic Beauty Value of Mapped Landscape Changes in a Mountainous Region through the Use of GIS. *Environment and Planning B: Planning and Design, 34*(1), 50–67.
Häfner, K., Zasada, I., van Zanten, B. T., Ungaro, F., Koetse, M., & Piorr, A. (2017). Assessing landscape preferences: A visual choice experiment in the agricultural region of Märkische Schweiz. *Germany. Landscape Research, 43*(6), 846–861.
Hägerhäll, C. M., Ode, S.Å., Englund, J.-E., Ahlner, F., Rybka, K., Huber, J., & Burenhult, N. (2018). Do Humans Really Prefer Semi-open Natural Landscapes? *A Cross-Cultural Reappraisal. Frontiers in Psychology, 9*, 822.
Hamilton, T. D. (1965). Comparative glacier photographs from northern Alaska. *Journal of Glaciology, 5*(40), 479–487.
Hanyu, K. (2000). Visual properties and affective appraisals in residential areas in daylight. *Journal of Environmental Psychology, 20*(3), 273–284.
Hedblom, M., Hedenås, H., Blicharska, M., Adler, S., Knez, I., Mikusiński, G., … Wardle, D. A. (2020). Landscape perception: Linking physical monitoring data to perceived landscape properties. *Landscape Research, 45*(2), 179–192.
Hegetschweiler, T. K., Fischer, C., Moretti, M., & Hunziker, M. (2020). Integrating data from National Forest Inventories into socio-cultural forest monitoring – a new approach. *Scandinavian Journal of Forest Research, 35*(5–6), 274–285.
Hellevik, O. (2016). Extreme non-response and response bias. *Quality & Quantity, 50*(5), 1969–1991.
Jayasekare, A. S., Herath, S., Wickramasuriya, R., & Perez, P. (2019). The price of a view: Estimating the impact of view on house prices. *Pacific Rim Property Research Journal, 25*(2), 141–158.
Kaplan, R., & Kaplan, S. (1989). *The Experience of Nature: A Psychological Perspective*. Cambridge, UK: Cambridge University Press.
Kull, C. A. (2005). Historical landscape repeat photography as a tool for land use change research. *Norwegian Journal of Geography, 59*(4), 253–268.
Lothian, A. (1999). Landscape and the philosophy of aesthetics: Is landscape quality inherent in the landscape or in the eye of the beholder? *Landscape and Urban Planning, 44*(4), 177–198.
Loupa, R. I., Bianchi, P., Bernardo, F., & Van Eetvelde, V. (2019). What matters to people? *Exploring contents of landscape identity at the local scale, Landscape Research, 44*(3), 320–336.
Malde, H. E. (1973). Geologic bench-marks by terrestrial photography. *US Geological Survey Journal of Research, 1*(2), 193–206.
Masiokas, M. H., Villalba, R., Luckman, B. H., Lascano, M. E., Delgado, S., & Stepanek, P. (2008). 20th-century glacier recession and regional hydroclimatic changes in northwestern Patagonia. *Global and Planetary Change, 60*(1–2), 85–100.
Mietkiewicz, N., Kulakowski, D., Rogan, J., & Bebi, P. (2017). Long-term change in sub-alpine forest cover, tree line and species composition in the Swiss Alps. *Journal of Vegetation Science, 28*(5), 951–964.
Muñoz, L., Hausner, V. H., Runge, C., Brown, G., & Daigle, R. (2020). Using crowdsourced spatial data from Flickr vs. PPGIS for understanding nature's contribution to people in Southern Norway. *People and Nature, 2*(2), 437–449.
Nasar, J. L., Julian, D., Buchman, S., Humphreys, D., & Mrohaly, M. (1983). The emotional quality of scenes and observation points: A look at prospect and refuge. *Landscape Planning, 10*(4), 355–361.
Nyssen, J., Haile, M., Naudts, J., Munro, N., Poesen, J., Moeyersons, J., … Pankhurst, R. (2009). Desertification? Northern Ethiopia re-photographed after 140 years. *Science of the Total Environment, 407*(8), 2749–2755.
Orians, G. H. (1980). Habitat selection; general theory and applications to human behaviour. In J. S. Lockard (Ed.), *The Evolution of Human Social Behaviour*. New York: Elsevier.
Plieninger, T., Bieling, C., Fagerholm, N., Byg, A., Hartel, T., Hurley, P., … Huntsinger, L. (2015). The role of cultural ecosystem services in landscape management and planning. *Current Opinion in Environmental Sustainability, 14*, 28–33.
Roush, W., Munroe, J. S., & Fagre, D. B. (2007). Development of a spatial analysis method using ground-based repeat photography to detect changes in the alpine treeline ecotone, Glacier National Park, Montana, U.S.A. *Arctic, Antarctic, and Alpine Research, 39*(2), 297–308.
Scarles, C. (2004). Mediating landscapes: The processes and practices of image construction in tourist brochures of Scotland. *Tourist Studies, 4*(1), 43–67.
Schirpke, U., Altzinger, A., Leitinger, G., & Tasser, E. (2019). Change from agricultural to touristic use: Effects on the aesthetic value of landscapes over the last 150 years. *Landscape and Urban Planning, 187*, 23–35.
Schirpke, U., Zoderer, B. M., Tappeiner, U., & Tasser, E. (2021). Effects of past landscape changes on aesthetic landscape values in the European Alps. *Landscape and Urban Planning, 212*, Article 104109.
Simonyan, K., & Zisserman, A. (2015). Very deep convolutional networks for large-scale image recognition. *International Conference on Learning Representations.* arXiv: 1409.1556.
Tveit, M., Ode, A., & Fry, G. (2006). Key concepts in a framework for analysing visual landscape character. *Landscape Research, 31*(3), 229–255.
Tveit, M. S. (2009). Indicators of visual scale as predictors of landscape preference; a comparison between groups. *Journal of Environmental Management, 90*(9), 2882–2888.
Twohig-Bennett, C., & Jones, A. (2018). The health benefits of the great outdoors: A systematic review and meta-analysis of greenspace exposure and health outcomes. *Environmental Research, 166*, 628–637.
Ulrich, R. S. (1984). View through a window may influence recovery from surgery. *Science, 224*, 420–421.
Van Bogaert, R., Haneca, K., Hoogesteger, J., Jonasson, C., De Dapper, M., & Callaghan, T. V. (2011). A century of tree line changes in sub-Arctic Sweden shows local and regional variability and only a minor influence of 20th century climate warming. *Journal of Biogeography, 38*(5), 907–921.
Wartmann, F. M., Frick, J., Kienast, F., & Hunziker, M. (2021). Factors influencing visual landscape quality perceived by the public. *Results from a national survey, Landscape and Urban Planning, 208*, Article 104024.
Wascher, D. M. (Ed.). (2000). *The Face of Europe*. European Centre for Nature Conservation (ECNC Technical report series): Policy perspectives for European Landscapes. Tilburg.

Webb, R. H., Boyer, D. E., & Turner, R. M. (2010). *Repeat Photography: Methods and Applications in the Natural Sciences*. Washington D.C.: Island Press.
Wilkins, D. E., & Ford, R. L. (2007). Nearest neighbor methods applied to dune field organization: The Coral Pink Sand Dunes, Kane County, Utah, USA. *Geomorphology, 83*(1), 48–57.
Zier, J. L., & Baker, W. L. (2006). A century of vegetation change in the San Juan Mountains, Colorado: An analysis using repeat photography. *Forest Ecology and Management, 228*(1), 251–262.