One Ecosystem 8: e111973
doi: 10.3897/oneeco.8.e111973

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Research Article

The influence of naturalness of the landscape structure on children's connectedness to Nature in north-eastern Italy

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Academic editor: C. Sylvie Campagne

Received: 31 Aug 2023 | Accepted: 16 Nov 2023 | Published: 29 Dec 2023

Citation: Stocco A, Tabacchi C, Barbiero G, Pranovi F (2023) The influence of naturalness of the landscape structure on children's connectedness to Nature in north-eastern Italy. One Ecosystem 8: e111973. https://doi.org/10.3897/oneeco.8.e111973

Abstract

Connectedness to Nature and the ability to perceive the restorative value of places characterised by the presence of natural elements are personal characteristics that, when appropriately measured, make it possible to predict an individual's attitude towards pro-environmental behaviour. While these characteristics have an innate basis, they are also shaped by personal experiences and various cognitive, affective and sociocultural factors. In this exploratory study in North-eastern Italy, we delve into an interdisciplinary field that explores the relationship between the environment of the residential area and its impact on children's attitudes toward Nature. To do so, we conducted a comprehensive questionnaire amongst 533 primary schoolchildren, aged 6-11 years, to gauge their connectedness to Nature, their perceptions of restorativeness in surrounding natural settings, and their schoolyard environment. Drawing from optical satellite imageries, we calculated a combined multispectral index to assess the naturalness degree of participants' residential areas, focusing on their 68 residential areas, located in three administrative Italian Regions (Trentino Alto Adige, Friuli Venezia Giulia and Veneto), which were classified into four different classes with respect to their level of presence of natural areas ("coastal," "low," "average," "high"). By performing non-parametric tests for multiple comparisons amongst groups, we detected a significantly higher level of connectedness to Nature amongst

children living in areas with high naturalness, compared to those living in areas with average or low naturalness. Perceived restorativeness scores exhibit a similar trend to that of connectedness to Nature, reinforcing the importance of natural spaces in fostering positive attitudes towards the environment. This result confirms that accessibility and the viewability of natural spaces, even semi-natural ones, seemed to play a crucial role in children's preference for these environments. However, schoolyards were consistently perceived as less regenerative than natural places, regardless of the naturalness of the neighbourhood. These findings raise intriguing questions about the potential consequences of inadequate exposure to Nature on children's affiliation to the natural world and possible subsequent effects on pro-environmental behaviour in adulthood. By shedding light on the complex interplay between personal characteristics, environment and attitudes towards Nature, our study underscores the significance of fostering a deeper connection with natural spaces to nurture a sustainable and environmentally conscious society.

Keywords

psychological ecosystem services, connectedness to Nature, Perceived Restorativeness Scale, children, pro-environmental behaviour

Introduction

For a long time during the history of their species, humans lived in transitional forests and green environments (Wilson 2002). While they adapted to live in different environments by moulding the landscape and the structure of the ecosystem, making them more comfortable and protective, humans maintained their ancestral preference for settling in green and blue areas (Campos et al. 2006, Ceola et al. 2015, Fang et al. 2018). Even in contemporary times, this affinity persists, as evidenced in our propensity to seek homes and environments nestled amidst natural landscape, especially when characterised by a certain level of "tidy wilderness" (Van den Berg et al. 2014, Ebert et al. 2022). The higher value of houses built in a green and luxuriant area or nearby areas also testifies to the preference for such a landscape, where visual contact with vegetation can be granted, attesting to the enduring allure of Nature (Alvarez and Ramirez 2004, Trojanek et al. 2018, Morano et al. 2019).

Remarkably, this preference is also detectable in children between 3 and 10 years of age, as they inherently prefer passing the time outdoors, show an instinctive capability to be fascinated by living beings and become somehow contemplative in the presence of natural environments (Barbiero et al. 2014, Berto and Barbiero 2014). Children present a still immature brain at birth (Lemaître et al. 2020) that develops through several complex processes (Kagan and Herschkowitz 2006). Therefore, children’s immature behaviour and cognition are often adaptive, holding the potential to influence future individual attitudes and behaviour (Bjorklund 1997). The perception of Nature's regenerative qualities, in particular, serves as a motivator for pro-environmental behaviour (Berto and Barbiero 2017). Unfortunately, if not adequately stimulated, the connectedness with Nature typically

weakens over the course of one's life, particularly in adolescents (Kaplan and Kaplan 2002). This weakening is attributed to differential priority in developmental patterns of the neuronal architecture, synaptic density and connection pruning processes in teenagers' brains (Choudhury et al. 2008).

Therefore, a crucial exploration lies in comprehending the developmental underpinnings of the affinity between children and Nature and of its potential for transformative impact, especially in nurturing a pro-environmental ethos within society. Central to this inquiry are two pivotal attributes: "connectedness to Nature" and the perception of the "restorativeness value" of natural environments (Berto and Barbiero 2022), meaning with “natural environments”, the terrestrial or aquatic areas hosting an ecosystem with most of its processes (IPBES 2019) naturally colonised by vegetation and wildlife. The former attribute entails an individual’s feeling of being related to natural elements, akin to a familial bond and can be measured by using psychometric scales, such as the Connectedness to Nature Scale (Cheng and Monroe 2012, Navarro et al. 2022, Mayer and Frantz 2004) and its validated version for children (Pasini 2009, Berto et al. 2015, Barbiero and Berto 2021). The latter attribute involves the assessment of a place's capacity to induce stress recovery and attention restoration and is empirically measured by tools like the Perceived Restorativeness Scale (Hartig et al. 1991, Korpela and Hartig 1996), which contributes to highlighting the environment contribution to psychophysiological balance (Kaplan 1995, White et al. 2019) and people's well-being.

Matching the connectedness to Nature and the restorativeness value associated with natural environments represents a great opportunity for the study of social-ecological systems, where the entire system's dynamical evolution depends not only on the

potential of the ecosystem to offer resources and ecosystem services but also on the society's choices and collective human behavior (Liu et al. 2007, Ostrom 2009, McGinnis and Ostrom 2014). This convergence gains even more significance considering that fostering a sense of responsibility toward the environment, its status, and its resilience is inherently linked to personal connectedness and to the pleasure an individual feels to be gaining when visiting a natural space, with studies unveiling a heightened pro-environmental disposition amongst those deeply bonded with the natural world (Mackay and Schmitt 2019, Teixeira et al. 2023).

However, personal connectedness to Nature is not easy to enhance, especially in adolescence and adulthood when it is generally considered to have been established by this time: several studies demonstrated that connectedness to Nature is a stable personality trait that appears very early in childhood (Kahn 1997, Berto et al. 2015), finding it improbable that it can be later influenced by experiences in Nature during adulthood. Yet, the possibility of instilling and enhancing awareness of the importance of Nature remains a promising avenue for fostering a profound sense of ecological responsibility and stewardship. Indeed, connectedness to Nature is supposed to depend on several variables (Ulrich 1993, Hand et al. 2017, Lin et al. 2018) and is far from being considered an innate and immutable instinct (Myers 1996, Kahn 1997, Grinde and Patil 2009, Zhang et al. 2014), suggesting that a well-planned and guided exposure to Nature during the early

childhood can be beneficial in fostering connectedness to Nature (Barrable and Booth 2020) and, consequently, a positive attitude toward behaviour respectful to the natural environment and its resources.

Unfortunately, as urbanisation progresses, the availability and accessibility of spaces where to engage in contact with the natural ecosystems become increasingly variable (UNICEF 2018), potentially affecting children's affiliation and connectedness to Nature (Clayton and Karazsia 2020). This also becomes a concern for their ability to derive psychophysical benefits from the restorativeness offered by natural environments. As a concept strongly related to the healing and well-being benefits that individuals can experience through their interaction with Nature, in the scientific literature the "restorativeness" refers to the capacity of a natural environment to assist in restoring mental, emotional and physical well-being (Menardo et al. 2019). Although it has not been explicitly included amongst the ecosystem services, likewise the majority of ecosystem services mediated by psychological and cognitive processes (Bratman et al. 2019), the restorativeness of a natural environment can be classified amongst those cultural ecosystem services considered by the CICES framework as the services based on the characteristics of living systems that promote health, recuperation or enjoyment through active, passive or even merely observational interactions (CICES 2023).

Despite recent literature clearly highlighting the beneficial effects of natural green and blue landscapes on health and well-being (Lee et al. 2015, Conniff and Craig 2016, Wood et al. 2017, Beute et al. 2020, De Nocker et al. 2023) as well as the positive outcomes of interactions with Nature (Berto et al. 2015, Tillmann et al. 2018), the specific relationship between the structure of the residential environment and inhabitants' connectednessto Nature remains underexplored, particularly in children and teenagers. Moreover, available studies on the benefits of exposure to natural settings are more focused on the view of a few selected semi-natural landscapes, without a prior assessment of the naturalness of the general landscape that surrounds people in their everyday life.

To address this research gap, we conducted the first study in north-eastern Italy that investigates the relationship between residential area characteristics, connectedness to Nature, and perceived restorativeness of the surrounding areas that school-aged children attend daily. Our aims were to analyse whether and how the environmental structure and distributional features of the place of residence influence young inhabitants' connectedness to Nature and if the availability of different degrees of surrounding naturalness is driving the restorative values they attribute to the places they view and frequent every day, since their early childhood.

In such an interdisciplinary endeavour, we administered a comprehensive questionnaire to schoolchildren living in north-eastern Italy, evaluating their connectedness to Nature, along with the restorativeness value they ascribe to both their favourite natural environment and their schoolyard. Then, we integrated optical satellite imageries to assess the naturalness degree of the residential areas of the participants, unveiling the potential availability of natural environments for the region's youngest inhabitants.

Our primary research question delved into understanding whether the level of naturalness in residential areas influences children's connectedness to Nature. This exploration led us to a parallel question: are children who live in areas exhibiting different levels of naturalness likely to assign different restorativeness scores to natural settings? Therefore, we determined whether the fascination associated with the presence of natural elements remains consistent, regardless of the naturalness of the surrounding residential environment or if it changes in response to the surrounding landscape structure due to the consistent presence of man-made features.

In addition, one of our objectives was also to test whether children could perceive differences between the schoolyard, a decidedly artificial environment in the schools considered and a place they would define "natural", based on the presence of natural elements covering the majority of the area. Of course, Nature is not a binary category (e.g. natural/non-natural), but appears with varying degrees and gradients that can be subjectively assessed, especially in urban and peri-urban environments. However, previous research suggested that children are competent in distinguishing a completely artificial environment from a semi-natural or natural one. This ability is thanks, in part, to the wilderness serving as a prototype of Nature and its recognition as such is a highly generalisable characteristic (Barbiero et al. 2023). On the other hand, even the presence of a few natural elements can help children restore their attention and receive psychological benefits. Therefore, in this study, we did not delve into the distinction between different degrees of wilderness, i.e. between environments with varying degrees of preservation of the original ecosystem structure. Instead, our focus was on evaluating, on a larger scale compared to the highly localised studies currently available in literature (Moll et al. 2022), the presence and effectiveness of natural and semi-natural spaces within the residential area to provide children with opportunities for restoration and connection with Nature.

Material and methods

This interdisciplinary study used a questionnaire to gather pertinent information regarding the residential areas and daily habits of the participants. Additionally, two psychometric scales were employed to assess these factors. Simultaneously, a series of satellite images were analysed to detect, within the residential area, the places with vegetation and the presence of natural elements, including green and blue spaces.

Participants

Our study area was focused on selected residential areas within three Italian Regions: Friuli-Venezia-Giulia, Trentino-Alto-Adige and Veneto, in north-eastern Italy (Fig. 1). A total of 533 primary school children, mean age of 8 years (± 1.29 s.d., range 6-11 years) participated in the study between November 2020 and April 2021. The parents agreed with the informed consent for their children to participate. Amongst the answers, 527 out of 533 were considered in this study, with six questionnaires being dropped because they were incomplete.

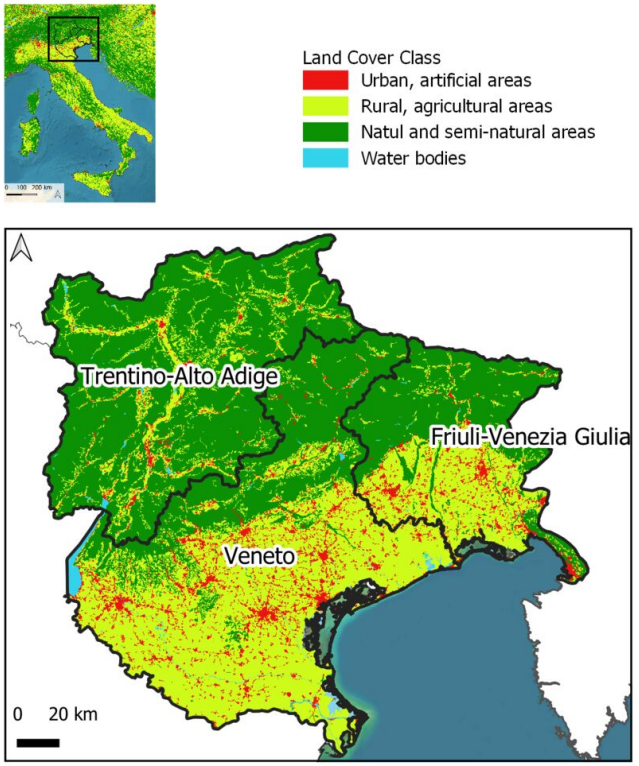

Figure 1.

The study area, in north-eastern Italy. The colours highlight the land-cover/land-use class, according to the first level of classification of the most updated version of the CORINE Land-Cover inventory.

The instrument

The study utilised an online anonymised questionnaire including questions about the age class, the attended school and the place of residence of the respondent. These questions were followed by the psychometric section, which consisted of the Connectedness to Nature Scale-children (CNS-ch) and the Perceived Restorativeness Scale-children (PRS-ch) to assess the perceived restorativeness value of both the schoolyard and the children's favourite natural place. The details of the questionnnaire can be found in Suppl. materials 1, 2.

Questionnaire

The dissemination of the questionnaire followed an intial meeting held with the headmasters of 149 schools invited to participate in the study. During these meetings, a project presentation was conducted and each school received a copy of the questionnaire.

We chose the schools to be invited, based on their geographical location within the Friuli-Venezia-Giulia, Trentino-Alto-Adige and Veneto Regions, including only the schools that have a schoolyard that can be used by children during school hours. Out of the invited schools, 34 opted to participate in the study. All these 34 schools are connected to the primary road network. Furthermore, these schools serve not only the residents of their respective town, but also frequently accommodate students from neighbouring towns. The distribution of the participant schools across the surrounding territories is as follows: five are located within the urban centres in the mainland, five in urban or periurban areas along the coastline, six in hilly and mountain areas, while the remaining schools are positioned in periurban areas, often at the interface between the urban area and the agriculturally-dominated landscapes.

Each of the participating schools facilitated the distribution of the online questionnaire via email and text messages containing a direct link to the webpage hosting the questionnaire, which was created using Google Forms and was accessible from the parents' computers or smartphones. The online format offered a notable advantage in terms of survey dissemination across a broader geographical area and, most importantly, enabled us to circumvent the restrictions related to the Covid-19 pandemic that were still ongoing in Italy during the study period.

Connectedness to Nature

To assess the connectedness to Nature of the participants, we employed the Connectedness to Nature scale for children, CNS-ch (Berto et al. 2015), based on the scale of Mayer and Frantz (2004) and adapted to primary school children, which allowed us to evaluate the extent to which a child feels part of the natural world, making it a reliable measurement of the construct "affiliation with Nature" of the biophilia hypothesis (Wilson 2002). The CNS-ch consists of seven items rated on a 5-point scale, where 0 = never and 4 = always (Suppl. materials 1, 2, question no. 4). The average score of the seven items establishes the measure of the pupil's personal relationship with Nature.

Perceived Restorativeness

The measurement of a place's restorativeness can be challenging due to the strong influence of subjective factors. We, therefore, defined the restorativeness as 'the value assigned by the respondents to an observed natural environment in scoring its capability to offer restoration of mental, emotional and physical well-being'. Therefore, we used a standardised psychometric scale to obtain quantitative values associated with the perceivable restorative characteristics of each tested environment: the Perceived Restorativeness Scale for children, PRS-ch (Pasini 2009). PRS-ch is a scale designed for school-age pupils based on the Attention Restoration Theory (Kaplan 1995) and the adult version of the PRS (Hartig et al. 1997).

In studies of the adult population, the PRS in the original version for adults has been widely used to measure the regenerative value of an environment, which is how much a specific

environment promotes the regeneration of attention from mental fatigue. Environments that score high on the scale are considered "restorative".

The PRS-ch consists of 18 items measuring the perception of four restorative factors (being-away, fascination, coherence, scope). An additional item was included after the PRS-ch items in order to assess preference: *I like that place*. Each item is rated on a 5-point scale where 0 = completely disagree and 4 = completely agree (Suppl. materials 1, 2, questions nos. 5 and 10). We then estimated the restorative value of a place by calculating the average of the scores on the whole list of 18 questions.

We first asked the children to respond to the PRS-ch items by considering the schoolyard, since this is one of the environments they are familiar with and should represent a well-known playground. Subsequently, we enquired about their favourite natural place, the frequency of their visits to that place and the activities they typically engage in while there, aiming to assess their perceptions about what they consider “natural” and somehow wilder than the schoolyard. Then, we requested their responses to the PRS-ch items considering the natural place they had mentioned.

Land cover, naturalness and accessibility indicators

Land-cover and land-use shape the proportion between natural areas, namely areas with both non-living and living natural elements and areas covered by artificial structures and usually with soil made impermeabile with asphalt and concrete or other man-made coverings. In this study, the “naturalness” of an area is defined as the noticeable presence of wild or nature-like settings (as in Knez et al. (2018)). A place characterised by high naturalness has, therefore, distinctive features that makes it appearing natural or nature-like, due to having a high proportion of the whole area covered by natural, non-artificial ground, with green areas and eventually blue areas, free from asphalt or concrete. In these settings, the presence of artificial buildings and structures is minimal compared to that of natural elements and vegetation or sediments belonging to the aquatic ecosystem are present. Thus, the average degree of naturalness of an area is directly related to the prevalence of natural elements compared to built structures.

Folllowing this definiton of naturalness, to assess the characteristics of the residential areas, we performed a GIS analysis of the land cover by evaluating a proxy of the greenness and the built-up surfaces of the residential areas, retrieving it from remote sensing data. We acquired a series of 32 multispectral satellite images from the Copernicus portal (https://scihub.copernicus.eu/), choosing amongst optical images collected by the Sentinel-2 fleet. We selected imageries collected from March and April 2021, applying a filter to limit cloud cover to less than 9.9%.

After the pre-processing for atmospheric correction of the suitable Level 1-C images, we calculated for each of the pre-processed tiles two spectral indexes, the Normalised Difference Vegetation Index (NDVI, Rouse et al. (1973)) and the Normalised Difference Built-up Index (NDBI, Zha and Gao (2003)), using the following equations:

eq. 1

$$NDVI = \frac{(NIR \breve{} Red)}{(NIR + Red)}$$

eq. 2

$$NDBI = \frac{(SWIR \breve{} NIR)}{(SWIR + NIR)}$$

where *NIR* stands for Near Infrared spectral band (central wavelength 883 nm), *Red* stands for visible Red band (central wavelength 664 nm) and *SWIR* stands for Short-Wave Infrared band (central wavelength 1613 nm, pan-sharpened to a 10 m spatial resolution) for Sentinel-2 sensors.

Then, we combined the indexes above to obtain a *Green vs. Built Index* (GVBI) according to the following equation:

eq. 3

$$GVBI = 2NDVI \breve{} NDBI$$

The resulting GVBI enhances the bands in which plants are more reflective, while assigning negative values to built-up elements, as detected by the NDBI. This way, the higher the values, the higher the vegetation greenness, whereas bare soil and built-up show negative values. Water bodies approach 0, as further verified by using the Normalised Difference Water Index (NDWI, Gao (1996)) on the same imageries. This way, we could discriminate water-covered pixels from bare soil and built-up structures, allowing for considering the areas containing water as a contribution to the naturalness.

The reason for choosing spring-time images to calculate the GVBI was to effectively differentiate between areas characterised by year-round natural vegetation and those where vegetation is primarily due to seasonal crops, which are the most typical crops in north-eastern Italy. Indeed, during spring in northern Italy, the NDVI of cultivated fields is lower than that of the naturally vegetated areas. Further spectral information, achieved by combining the NDBI and applying filtering based on areas with high NDWI, has enabled us to enhance the precision of land-cover information.

The advantage of starting the classification by using the proposed workflow, based on the GVBI and the NDWI as proxies, is that it allows us for discriminating the presence of green and blue patches in urban areas (such as parks, gardens, trees rays and also aquatic ecosystems). In particular, the GVBI proved to detect, amongst the areas classified as "agricultural" in terms of land-use, both the cultivated and non-cultivated croplands since the non-cultivated fields result in values between 0.10 and 0.25, whereas cultivated ones have values between 0.25 and 0.59. Conversely, land patches covered by tree canopy result in values always higher than 0.60.

Once the GVBI was obtained for the study areas, we estimated the average GVBI value for a 10 km topological buffer around each of the towns mentioned by the participant children. The width of the buffer was based on the daily travelling habits of children and scholars in

Italy, as reported in the transport statistical report of the Veneto Region (Regione Veneto 2012). By considering their typical commuting range, we aimed to gather representative information about the types of landscapes children encounter daily, potentially influencing their connectedness to Nature, as suggested by the works of other authors (Cox et al. 2017, Nisbet et al. 2020) and, consequently, their ability to perceive psychophysical benefits in specific natural or nature-like environments.

The buffer areas were subsequently classified with a multi-criteria approach. An initial rough classification between areas classified as "artificial" and others considered as "agricultural" and "natural" also according to the main land use was performed according to the 2018 Corine Land-Cover dataset, available at a 100-m resolution (https://land.copernicus.eu/pan-european/corine-land-cover). Then, to have the most updated and high-resolution information about the characteristics of the residential areas, we classified the surface included in the 10 km buffer by ranking the average GVBI values in the buffer and considering the geographical location as well. Therefore, we identified four classes that differentiate from each other in terms of proximity to the coastline and the average index values (Fig. 2), to which we associated the classes "coastal", "low", "average", "high". We chose to distinguish coastal areas due to their unique characteristics. The coastlines in the considered Regions host important lagoon areas, including Venice Lagoon, Grado and Marano Lagoons and the Po River Delta. These areas offer a rich variety of natural landscapes, featuring lagoon waters, mudflats, saltmarshes, as well as beaches and dunes, which show a high capacity to provide opportunities for recreation, education and cognitive development (Newton et al. 2018, Rova et al. 2022, Gaglio et al. 2023, Stocco and Pranovi 2023). Children living in these areas encounter these distinctive landscapes on a daily basis, as roads and waterbus routes pass through the lagoons or very close to them, showcasing their natural features.

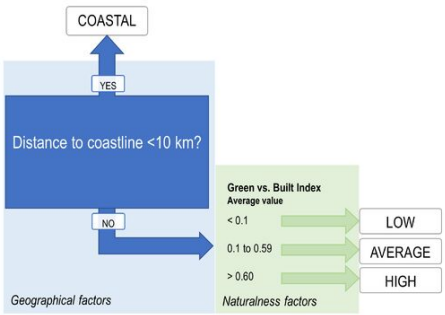

Figure 2.

Classification approach implemented for classifying the residential areas into four classes.

Statistical analysis

We assessed the distribution of the collected psychometric data by performing the Shapiro-Wilk test and Bartlett's test. Since data were not normally distributed, we performed a Kruskal-Wallis H test for ranks, followed by multiple comparisons amongst groups at the post-hoc Dunn test, with a Benjamini-Hochberg adjustment of p-values to address for multiple comparisons (Dunn 1961, Dunn 1964). Pairwise comparisons of the PRS scores between the schoolyard and the natural place were tested using Welch's t-test. All the operations concerning satellite imageries and geostatistical computation were performed in QGIS 3.16.2 (QGIS Association: QGIS Geographic Information System (2022). Statistical computing was carried through R 4.1.2 (R Core team 2022) language within the Rstudio 2021.09.2 integrated development environment (RStudio team 2021).

Results

North-eastern Italy exhibits a heterogeneous land-cover and land-use landscape. It encompasses Alpine and pre-alpine regions, with woods and densely vegetated areas; the coastal areas along the Adriatic Sea, with sandy beaches, lagoons and wetlands and agricultural land predominantly in the Veneto and Friuli-Venezia Giulia Regions. In the last decades, cities and towns developed quickly especially on the coasts and within the agricultural areas behind it.

The classification of the residential areas into four classes according to the level at which they presented natural features compared to built surfaces, namely "coastal", "low", "average", "high" showed that the majority of the participants live in areas with average naturalness, followed by the group or participants who live in residential areas with a high naturalness and the group living within the coastal area; the less numerous group includes children living in areas classified as low naturalness areas (Fig. 3).

The places mentioned by the children as the preferred natural environment were clustered into eight categories. Table 1 reports the relative frequency of each expressed preference.

As shown in Table 1, most participants declared that their favourite environment is represented by park and garden settings, followed by "beach and sea". Most of the participants living in low and average naturalness areas mentioned more frequently favourite places that are located outside the 10 km buffer around their place of residence, while children living in high naturalness area and coastal area select places within their estimated movement area of 10 km radius.

CNS-ch scores

Overall, the mean value of the CNS-ch resulted in 3.25 (± 0.62). The CNS-ch scores do not differ significantly between different age groups, nor between different schools. In addition, the frequency of visits to natural environments showed no correlation with the CNS scores.

Analysing CNS-ch average scores amongst groups living in areas with different NI, the statistical analyses highlighted a significant difference between groups "average" and "high" (adj-p = 0.027) and between "low" and "high" (adj-p = 0.031), with a confidence interval of 95% (Fig. 4).

Table 1.

Natural environments indicated by the participants and relative frequency of mentioning.

Natural environment	Frequency (%)
Park and gardens	46.5
Beach and sea	22.2
Countryside	10.7
Woodland	8.2
Mountains	4.8
River and creeks	4.6
Lake	2.1
Lagoon	0.8

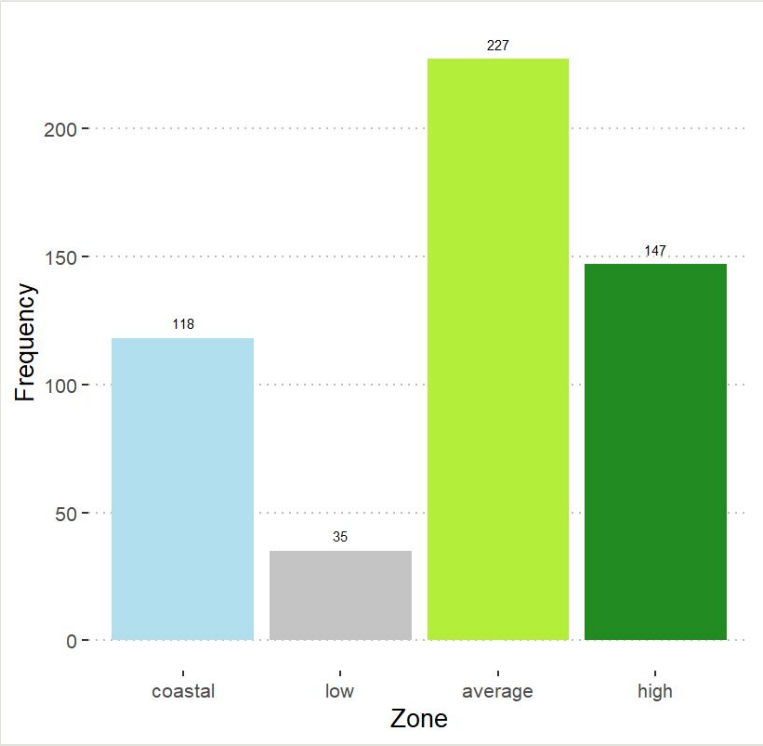

Figure 3.

Number of participants per residential area class.

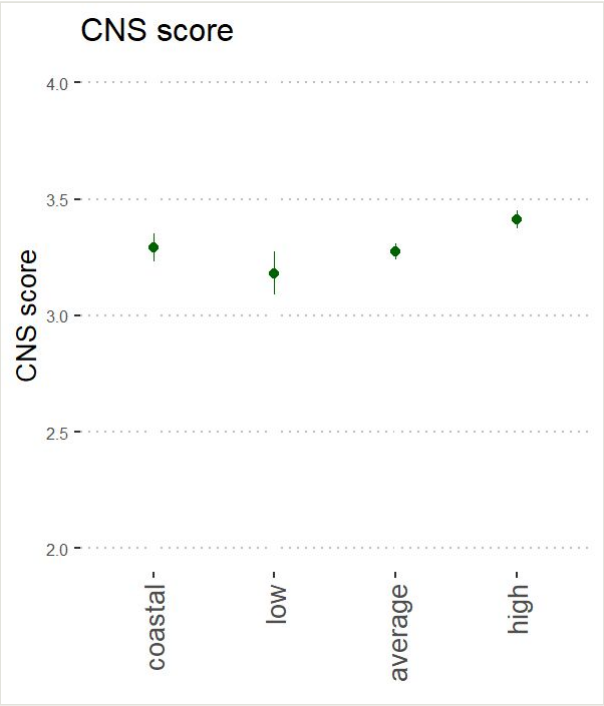

Figure 4.

Scores of the CNS-ch scale in the four groups of participants, grouped according to the class of the residential area. The dot represents the mean CNS-ch value of the group, the bar represents the standard error. The Y-axis has been truncated and starts at a value of 2 to highlight the values that all fall within a narrow range.

PRS-ch scores

The comparison between the PRS-ch scores related to the favourite natural place (A) and the one related to the schoolyard (B), showed that the restorativeness value of the natural environments was significantly higher than the schoolyard value ($p = 2.1 \bullet 10^{-16}$) for all groups (Fig. 4). The maximum score for the PRS-ch associated to the natural places was shown in the group "high", which is contrasted by the minimum PRS-ch score for the schoolyards ($p = 2.2 \bullet 10^{-16}$).

The restorative values assigned to the favourite natural environments in groups "high" and "coastal" were significantly higher than the restorative value of the favourite natural environments values in group "average" (adj-p = 0.003 compared to "high", adj-p = 0.008 compared to "coastal", Fig. 5). On the other hand, the schoolyard restorative values were significantly different between groups "high" and "average" (adj-p = 0.02), as well as between "coastal" and "high" (adj-p = 0.03), with the restorativeness of the schoolyard in the group "high" lower than the perceived restorativeness of the schoolyard in all other residential areas.

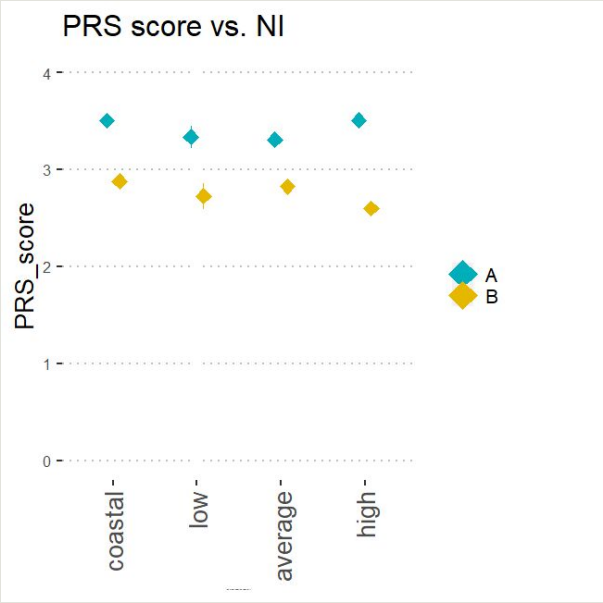

Figure 5.

Restorativeness of the preferred natural place (A, turquoise) and the schoolyard (B, dark yellow dots) as perceived in the different groups. The dot represents the mean values and the bar represents the standard error.

Interestingly, the trend followed amongst groups by PRS-ch scores for the favourite environment and the CNS-ch scores are similar, even if the variables are only moderately correlated (Spearman's r = 0.49, p = 2.2 ●10^{-16}); conversely, a low correlation was found between PRS-ch score for the schoolyard and CNS-ch scores (Spearman's r = 0.36, p = 2.2 ●10^{-16}), as well as between PRS-ch score for the favourite environment and the PRS-ch score for the schoolyard (Spearman's r = 0.38, p = 2.2 ●10^{-16}).

No significant differences were found amongst the PRS-ch scores of different favourite natural places (Fig. 6).

However, a slightly higher value in the PRS-ch was found for the group of children who declared reaching the natural places only to play, compared with the group of children who go there to play sports or other structured activities: the mean PRS-ch was respectively 3.46 ± 0.54 for the former and 3.37 ± 0.55 for the latter (not significantly different). An increase in the visit frequency does not correspond to an increase in the PRS scores.

Discussion

Recognising the multifaceted significance of Nature in upholding and enhancing human life (Costanza 2000, Díaz et al. 2015, MEA 2005), scientists and policy-makers are intensively seeking strategies to safeguard and increase Nature conservation, while achieving

sustainable uses of the natural resources and the associated ecosystem services (Lokhorst et al. 2014).

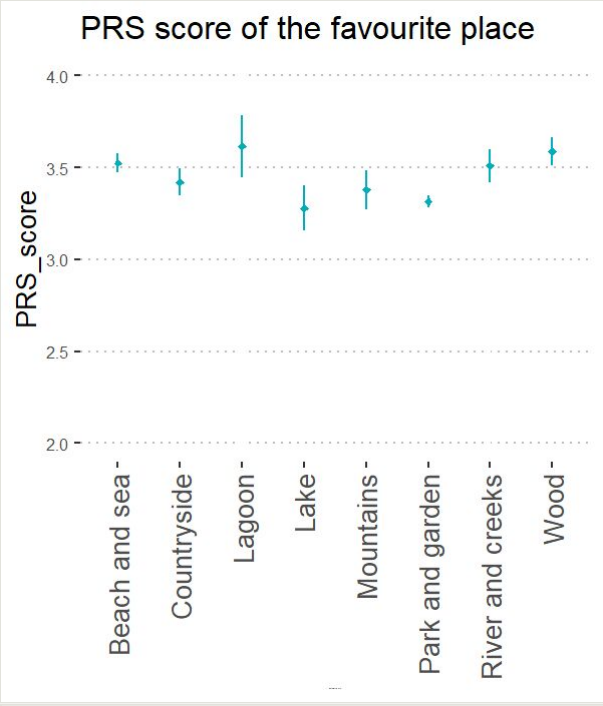

Figure 6.

Perceived restorativeness of different favourite natural places mentioned by the interviewed children. The dot stands for the mean PRS score for each place and the bar for the standard error. The y-axis has been truncated, starting at value of 2 to emphasise the scores.

A powerful way to ensure a future in which people are aware of the importance of Nature, and, thus, are willing to conserve it, could find its basis in enhancing a strong connectedness to Nature since early childhood, as well as the personal ability to perceive restorativeness in the nearby natural spaces. Indeed, it has been reported that adult individuals possessing a heightened sense of affiliation with Nature avoid behaviour harmful to the environment and living beings (Bruni et al. 2015, Geng et al. 2015). Moreover, children more connected to Nature tend to exhibit sustainable behaviour from a young age and exhibit a greater willingness to actively participate in pro-environmental actions as they grow up (Liu et al. 2019, Barrera-Hernández et al. 2020). Empowering the children to establish an emotional affiliation with living beings and to find restoration in natural contexts (Hartig et al. 1991, Berto et al. 2018) serves as a precursor to their willingness to engage with, appreciate and respect such settings (Lokhorst et al. 2014, Tang et al. 2015, Sella et al. 2023). However, connectedness to Nature and pro-environment attitudes result from a complex combination of innate factors and a set of learned rules (Barbiero and Berto 2021) and may decrease through adolescence if not adequately supported in early childhood. Due to the involvement of cognitive processes in

early childhood, personal exposure to Nature from childhood is the best way to foster a positive emotional connection with Nature (Kellert 1985, Sobel 1993, Kahn 2002, Barbiero and Berto 2021). Therefore, it is interesting to investigate whether the environmental characteristics of the residential area, where children spend the first years of life, are amongst the factors that can influence children's affiliation with Nature.

This study represents the first scientific multidisciplinary work dwelling on children between the ages of 6-11 to assess their connectedness to Nature in relation to the structure of the residential areas in three Regions of north-eastern Italy, retrieved through remote sensing data indexes that detect natural and nature-like areas in contrast to artificial and built surfaces. Our findings showed that a higher levels of naturalness in the residential areas was associated with a significantly higher connectedness to Nature of the children living there, while highlybuilt residential areas result in significantly lower connectedness to Nature.

However, Nature connectedness results relatively highly also in children living in residential areas with average naturalness, dominated by rural landscapes. This confirms that children are born with a "physiological" affiliation with Nature (Guiney and Oberhauser 2009) and suggests that even agricultural areas can play a role in nurturing biophilic traits of a person in the evolutive age. Although farmlands and croplands may not always guarantee free access for the fruition of environmental affordances, outdoor play in a vegetated landscape, even if represented by a rural landscape dominated by crops, can be helpful in maintaining connection with Nature. In this regard, no significant differences have been detected in analysing the PRS-ch scores by type of preferred natural place, even when comparing fascinating and mysterious mountains, valleys or riverbanks, with farmlands or urban parks in the study area. However, countryside and farmlands were assigned a higher PRS value than urban parks and garden, despite being both vegetated areas with living elements. The reason for this might be found in the fact that periurban and agricultural areas maintain a more "wild" quality when seen through the eyes of a child, if compared to urban parks. Urban parks are typically geometric, often enclosed by buildings and elements clearly recognisable as artificial or industrial. In contrast, cultivated fields, or related areas within agricultural landscapes, provide a higher level of heterogeneity and a sense of "controlled disorder", a characteristic that has been proven to be associated with Nature (Riboulot-Chetrit et al. 2018, Hoyle et al. 2019). In the context of our study, this may suggest that, provided the child is allowed to play and explore, it is probably enough to have a slightly higher level of wilderness compared to the built environment to benefit from the feeling of "being-away" and all the related traits that result in a more pleasant experience in a natural setting. Such a hypothesis, although deserving of further investigations, aligns with the Affordance Theory in Outdoor Play (Waller et al. 2017) and confirms the findings of other authors who reported that outdoor recreation opportunities are still valuable for restoration, even in non-ideal settings (Van den Berg et al. 2014, Parry and Gollob 2018).

This study also confirmed that children are inherently capable of perceiving the difference in the restorativeness potential of a natural environment if compared with a built environment, in accordance with previous literature (Nilsson et al. 2011, Astell-Burt et al.

2014, Barbiero et al. 2014, Berto et al. 2018, Shu and Ma 2018, Barbiero and Berto 2021), as testified by the comparison between the PRS-ch scores in natural places to the PRS-ch scores for the schoolyard. Interestingly, children living in high-naturalness residential areas presented a more significant gap between the PRS-ch score assigned to the natural place and the PRS-ch score assigned to the schoolyard, likely suggesting that their increased exposure to a wider set of natural settings sharpens their ability to distinguish between genuinely natural and semi-natural or artificial environments. This may not be as prominent amongst children who have been less exposed to truly natural landscapes and who are perhaps more accustomed to urban green spaces that may serve as their reference point for comparing with their schoolyard.

In connection with this point, the favourite places where the children participating in this study reported spending their spare time were, in most cases, parks, gardens and beaches (a result comparable to that recorded by adults in similar conditions by Barbiero et al. (2023)). Such places are easily accessible, but present a very limited degree of wilderness and mystery. We must, therefore, ask if the place declared as the preferred one is really the most favourite one or whether the choice is strictly related to the places where children have the easiest chance to be admitted or accompanied by parents and relatives living in northern Italy. In other words, it is legitimate to ask whether children, if placed in conditions that empower them to choose their favourite place amongst a whole catalogue of natural ecosystems, would express the same choice as in this study or would instead prefer an environment with different features and signs of wilderness.

The availability of natural spaces in residential neighbourhoods turns out to be essential (UNICEF 2018), especially from the point of view of a child whose possibility to engage in frequent trips is limited and develops only at a limited distance from home or from school. Indeed, participant children living in areas with low and average naturalness mentioned more frequently, as favourite natural places, locations that stand outside the 10 km buffer around their place of residence or even outside of their municipality. Conversely, children living in high naturalness areas and coastal areas selected places within their municipality or in very close proximity. Family habits might come into play in this, as previously argued also by Tomasso and Chen (2022) and connectedness to Nature may still be influenced by family habits or cultural factors (Teixeira et al. 2023, Wu et al. 2023). Nevertheless, in light of our results, it turns out that accessibility and viewability of genuine natural spaces serve as a compelling factor deserving attention from urban planners (as already suggested by Tillmann et al. (2018)), particularly within the context of northern Italy, which boasts amongst the highest land consumption rates in the country (Fabian and Bertin 2021).

A limitation of this study is that it focused solely on schoolchildren in north-eastern Italy. Due to this geographical constraint, the results may not be generalised to other, even nearby, populations. Moreover, whether the different levels of connectedness to Nature and capability to find restoration in natural ecosystems can also shape the future attitude towards sustainable behaviour is a challenging question, deserving further, more focused research. Nevertheless, this work enhances the importance of investigating the availability of natural or, at least, semi-natural environments in the residential area to pave the way for future sustainability. Such an approach should inspire urban planners and decision-makers

to carefully monitor the structure of urban and periurban areas, also taking advantages of new technologies, based on remote sensing and then striving to ensure equity for citizens in the spatial distribution of green and blue spaces. The possible strategies to achieve this goal are numerous and encourage exploration and creativity. Amongst the most effective actions, there are the creation of mini-forests in urban environments in place of typical urban parks (Lewis 2022), the valorisation of trees and natural elements amongst streets and buildings (Threlfall et al. 2017), the creation of green spaces for physical activity (Hunter et al. 2015) and the extensive use of nature-based solutions, in full accordance with the United Nations' Post-2020 Global Biodiversity Framework strategy (UN 2021).

Of course, the increase in semi-natural spaces and natural environments is to be considered just a part of a wider strategy, that should encompass also social and pedagogical changes. In fact, no predictive relationship was observed between an increase in the declared frequency of visits to natural environments and the CNS-ch or PRS-ch scores. In accordance with the previous literature (Capaldi et al. 2014), this suggests that it is the quality and intensity of the direct experience with Nature that modulates the ability to perceive the restorative benefits of an environment and not the simplistic indicator of the frequency of visits. This finding aligns with other studies that suggest how children in the developmental age require not only the experience of Nature, but also the presence of a more experienced guide, with whom they have a personal relationship (King et al. 2003), in order to derive the psychophysiological benefits from enjoyment in natural settings. In this regard, it is noteworthy that, in this study, schoolyards always resulted in less restorative potential than natural places (even in the case where the mentioned natural place was mostly frequented to play sports or other activities with rules, which is supposed to prevent free exploration of the place by children). Given that children spend a significant portion of their daily time in the schoolyard under the guidance of teacher, with whom they establish an educational bond, it could be advisable to make these educational spaces “greener and richer” for the benefit of children. If considering the existing body of research highlighting the positive outcomes associated with greener schoolyards (van Dijk-Wesselius et al. 2018 , Luís et al. 2020) and of biophilic designed classrooms (Barbiero et al. 2021), the incorporation in the schoolyards of more natural elements not only helps children in having a quality break during school hours, but could also make a huge difference in fostering their Nature connectedness. This is particularly true when considering ameliorations of the schoolyards and the classrooms along with proper training for teachers (Ernst and Theimer 2011, Barrable and Booth 2020, Anđić and Šuperina 2021), who might be empowered in nurturing children's ability to find relief and restoration also in other natural settings. Such an approach could be of particular relevance in areas characterised by low naturalness, where children lack access and views of green or blue landscapes in the immediate surroundings.

Conclusion

In the context of research on natural environments and their benefits to humans, this work aimed at integrating the geophysical characteristics of an inhabited place and the results of

the young inhabitants' psychometric scales, gauging their connectedness with Nature and the perceived restorativeness of the environments they daily experience. Such an approach proved to be a promising method to bolstering the body of empirical evidence that demonstrates how natural ecosystems are capable of providing mental health benefits to humans, in a crucial, but hitherto underexplored set of ecosystem services related to human psychological and cognitive functions.

Since the results highlighted that a higher naturalness in the residential area is significantly associated with a higher connectedness to Nature and to a higher capability to appreciate natural environments, we suggest that, to foster both today's well-being and future sustainability, decision-makers should consider a comprehensive approach encompassing the evaluation and the enhancement of the naturalness within residential areas. This approach, coupled with the enrichment of school environments and teacher training, holds the potential to yield immediate short-term benefits, offering children residing in low naturalness, heavily urbanised residential zones more restorative spaces, that rekindle their bond with Nature and foster their cognitive development through a direct contact with Nature.

Moreover, given that today's children will become the citizens and the decision-makers of the future, it is essential to also try to consider these interventions as possible cornerstones for accompanying society towards future sustainability. Such a multifaceted strategy may, in fact, extend its impact over the long term, by cultivating children's capacity to engage, find restoration and thrive in natural environments. This way, a resilient framework emerges, leveraging heightened connectedness to Nature to shape a disposition for respectful and protective behavioru towards ecosystems, their irreplaceable services and their non-human inhabitants.

Acknowledgements

The authors are grateful to the children, the families and the teachers who participated in the study.

Author contributions

Authors' contribution according to the CREDIT taxonomy:

Conceptualisation: A.S., C.T., G.B., F.P.; Data curation, formal analysis, investigation: A.S., C.T.; Methodology: A.S., C.T., G.B., F.P.; Software A.S.; Supervision and validation: G.B., F.P.; Writing – original draft: A.S.; writing – review and editing: A.S., G.B., F.P.

Conflicts of interest

The authors have declared that no competing interests exist.

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Supplementary materials

Suppl. material 1: Annex I - Italian version of the Questionnaire doi

Authors: Stocco A., Tabacchi C., Barbiero G., Pranovi F.
Data type: Italian version of the Questionnaire.
Download file (809.29 kb)

Suppl. material 2: Annex II - English version of the Questionnaire doi

Authors: Stocco A., Tabacchi C., Barbiero G., Pranovi F.
Data type: Questionnaire and scales translated into English.
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