UTRECHT UNIVERSITY – HUMAN GEOGRAPHY

GREEN SPACE AND ACADEMIC SUCCESS

INVESTIGATING THE ASSOCIATION BETWEEN SCHOOL PERFORMANCE AND GREEN SPACE EXPOSURE IN THE SURROUNDINGS OF PRIMARY SCHOOLS IN THE NETHERLANDS

MASTER THESIS

M. R. BUNT

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PREFACE

Before you lies the master thesis 'Green space and academic success'. It has been written to fulfill the graduation requirements of the Human Geography program at the University of Utrecht. I was engaged in researching and writing this thesis from January to July 2023.

This master thesis challenged me by having to conduct research that required different skills by doing a literature review and analyzing data in ArcGIS Pro to create maps. My basic knowledge on ArcGIS was challenged and I have learned that struggling is part of the process. Therefore, this thesis has taught me valuable lessons both professionally and personally.

I would like to thank my supervisor, Dr. Marco Helbich, for the excellent guidance and support during the process. I also want to thank the professors at the department of Human Geography and Spatial Planning for their educational support throughout the master's program.

Finally, I want to thank my family and friends for being there for me. I would also like to thank you, my reader: I hope you enjoy your reading.

Martijn Bunt

Utrecht, July 20, 2023

ABSTRACT

The Dutch system of education has been praised for its high quality for years, and Dutch students are one of the highest educated in the world. However, it has been reported that Dutch school performances have been declining since 2006, and this decline in performance is worrying since school performance is a critical predicter of long-term success and well-being. The declining performances make it relevant to explore strategies that can potentially enhance academic outcomes, and green space has been associated with academic performance through a variety of different ways and could serve as a potential solution to the declining school performances. A body of research is already conducted on the association between green space and school performance, but a research gap still exists on this association for the Dutch case. This study tried to address this research gap by conducting a literature review and executing regression analyses to investigate to what extend school performances are associated with green space exposure in the surroundings of primary schools in the Netherlands. Data was used on the average CITO-test score per neighborhood and the percentage of land use per neighborhood, along with covariates of the average socio-economic status score, average household size, and average level of urbanicity per neighborhood in the Netherlands to perform OLS and GWR analyses. Multivariate regression models revealed significant associations between academic performance and percentage of green space per neighborhood in the Netherlands. The OLS regression analysis indicates a significant association between the average CITO-test score and the percentage of green space per neighborhood in the Netherlands. The GWR analysis shows localized dynamics and indicates a statistically significant and positive association between the percentage of green space, and the average CITO-test score per neighborhood in the Netherlands in neighborhoods in the central southern part of the country in line with previous studies. The outcomes of the analyses of this study have been sufficient to answer this study’s research question, and the findings of this study can provide valuable insights for educational policymakers, school administrators, and urban planners seeking to create conducive learning environments to improve the declining school performances in the Netherlands.

Keywords: green space, school performance, Dutch education, CITO-test, percentage of green space

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1 Introduction

For years the Dutch system of education has been praised for its high quality (Scheerens, Luyten & Van Ravens, 2010). Dutch students are one of the highest educated in the world (OECD, 2018; AOb, 2019). However, the Programme for International Student Assessment (PISA) has found that the Netherlands' educational standing compared to other nations has been declining since 2006 and is now only slightly above average (OECD, 2018; CPB, 2022). Performances in reading, mathematics, and science show a declining trend since 2006, with reading even being below the OECD average in 2018 (OECD, 2018). Other studies also found evidence for declining school performances in the Netherlands (AOb, 2019; Scheerens, Luyten & Van Ravens, 2010; Vermeer, 2011; Van der Grift, 2010).

Notably, this decline seems to be associated with a growing wealth inequality among children (Netten, Voeten, Droop & Verhoeven, 2014; AOb, 2019; Kim, 2004; Klotzke & Feskens, 2021; Pong, Hao & Gardner, 2005). Students from lower socioeconomic backgrounds tend to perform worse academically compared to their peers from higher socioeconomic backgrounds (AOb, 2019; Browning & Rigolon, 2019). Limited access to qualified teachers and adequate school funding exacerbates this disparity, particularly for children from lower socioeconomic backgrounds (Dickinson & Porche, 2011; Whitehurst & Lonigan, 1998). Wealthier families often have the means to provide their children with supplementary educational support, which may improve their academic performance, while children from disadvantaged families lack such resources (AOb, 2019; Oppedisano & Turati, 2015; Idris, Hussain & Ahmad, 2020; Harris & Goodall, 2008; Muraina & Ajayi, 2011). Consequently, a growing achievement gap based on children's socioeconomic status has become evident.

School performance is a critical predictor of long-term success and well-being (Browning & Rigolon, 2019; Rauber, 2007; Feinstein & Duckworth, 2006; Ogbu & Simons, 1998; Pfeffer, 2008; Oberle, Schonert-Reichl & Zumbo, 2011). Students who demonstrate better performance at school or in college are more likely to earn higher salaries, engage more as active citizens and vote more in political elections, report higher life satisfaction and happiness, and participate in less illicit behavior than those with lower scores (Caro, Cortina & Eccles, 2015; Marshall, 2019; Osborne & Sibley, 2015; Milligan, Moretti & Oreopoulos, 2004; Dee, 2004; Tabbodi, Rahgozar & Makki Abadi, 2015). Given the worrisome decline in school performance in the Netherlands, it becomes imperative to explore strategies that can potentially enhance academic outcomes (Buckingham, 2000; Fröjd, Nissinen, Pelkonen, Marttunen, Koivisto & Kaltiala-Heino, 2008). While addressing wealth inequality is challenging, investigating other factors that influence school performance, such as green space, may provide alternative ways for improvement.

Green space has gained the attention of researchers and studies have explored the positive effects of green space on a variety of topics, such as climate change mitigation (Mathey, Rößler, Lehmann & Bräuer, 2011; Kitha & Lyth, 2011; Sánchez, Solecki & Batalla, 2018; Reis & Lopes, 2019), urban biodiversity conservation (Lepczyk, Aronson, Evans, Goddard, Lerman & MacIvor, 2017; Aronson, Lepczyk, Evans, Goddard, Lerman, MacIvor & Vargo, 2017), urban heat island effect mitigation (Shishegar, 2014; Gunawardena, Wells & Kershaw, 2017), urban water management (Alexander, Hettiarachchi, Ou & Sharma, 2019; Fryd, Pauleit & Bühler, 2012), community engagement and social cohesion (Burrage, 2011; Hassen & Kaufman, 2016), physical and mental health (Wolch, Byrne & Newell, 2014; Callaghan, McCombe, Harrold, McMeel, Mills, Moore-Cherry & Cullen, 2021; Beyer, Kaltenbach, Szabo, Bogar, Nieto & Malecki, 2014; Bogar & Beyer, 2016; Ward, Duncan, Jarden & Stewart, 2016; Lee, Jordan & Horsley, 2015; James, Banay, Hart & Laden, 2015), and even academic performance (Browning & Rigolon, 2019).

Green space has been associated with enhanced learning environments (Fägerstam & Blom, 2013; Mousel, Moser & Schacht, 2006; Greene & Byler, 2004; Lavie Alon & Tal, 2015; Lekies, Yost & Rode, 2015; Stern, Powell & Hill, 2014), stress reduction (Chawla, Keena, Pevec & Stanley, 2014; Li & Sullivan, 2016), physical health and fitness (Kuo, 2015; James, Banay, Hart & Laden, 2015; Dadvand et al., 2012; Rook, 2013), and social interactions and collaboration (Becker, Lauterbach, Spengler, Dettweiler & Mess, 2017), all of which may contribute to better academic performance.

Green space has been examined by sorts and sizes and by the amount and their proximity to school and home environments (Browning & Rigolon, 2019; McCormick, 2017; Kweon, Ellis, Lee & Jacobs, 2017; Hodson & Sander, 2017; Gilavand, Espidkar & Gilavand, 2016; Keniger, Gaston, Irvine & Fuller, 2013; Wu et al., 2014; Van Aart et al., 2018; Dadvand et al., 2015; Grahn, 1996; Wells, 2000). And studies have looked at attention and concentration test scores (Berto, Baroni, Zainaghi & Bettella, 2010; De Keijzer, Gascon, Nieuwenhuijsen & Dadvand, 2016; Lee, Williams, Sargent, Williams, & Johnson, 2015), and math, reading, and writing test scores (Beere & Kingham, 2017; Hodson & Sander, 2017; Kweon, Ellis, Lee & Jacobs, 2017; Wu et al., 2014), to examine school performances but all on the individual student level.

While there has been growing research on the relationship between green space and school performances, there is still a research gap regarding the specific association between green space exposure and school performances in the surroundings of primary schools in the Netherlands. Studies have explored the relationship between green space and academic outcomes in other contexts, such as green space characteristics, and individual student level performances. And a significant number of studies point to the positive association between green space and school performances, but not all studies support this relationship. Some studies in the review of Browning and Rigolon (2019) show non-significant associations between green space and school performances (Markevych, Feng, Astell-Burt, Standl, Sugiri, Schikowski & Heinrich, 2019). Additionally, some studies even show negative associations between green space and school performances (Beere & Kingham, 2017; Browning, Kuo, Sachdeva, Lee & Westphal, 2018; Hodson & Sander, 2017; Kuo, Browning, Sachdeva, Lee & Westphal, 2018; Matsuoka, 2010; Sivarajah, Smith & Thomas, 2018; Tallis, Bratman, Samhouri & Fargione, 2018; Wu, McNeely, Cedeño-Laurent, Pan, Adamkiewicz, Dominici & Spengler, 2014).

Besides the existing inconsistency in the evidence on the association between green space and school performances, there is also limited empirical evidence focused specifically on primary schools in the Netherlands. The declining school performances in the Netherlands over the last couple of years makes it relevant to examine the association between green space and school performances for the Dutch case. Addressing this research gap and studying the association between green space and school performance specifically in the Netherlands is important for understanding the localized dynamics, harnessing the potential benefits of green space within urban environments, and informing evidence-based policies and interventions to optimize school environments, ultimately benefiting the well-being and academic success of primary school students in the Netherlands and potentially beyond. Understanding the extent to which green space exposure is associated with school performance in this context can provide valuable insights for educational policymakers, school administrators, and urban planners seeking to create conducive learning environments. This study aims to analyze the association between green space and the school performances of children in the Netherlands by answering the following research question:

To what extend is school performance associated with green space exposure in the surroundings of primary schools in the Netherlands?

It is expected that school performance is positively associated with green space exposure in the surroundings of primary schools in the Netherlands. This means that better school performances are expected on primary schools with a greater exposure to green space surroundings.

2 Review and theoretical framework

2.1 Green space and school performances

Green space has garnered significant attention from researchers due to their diverse benefits and relevance across various domains. Green space is studied in the relationship to climate change mitigation, community engagement, physical health and well-being, and even academic performances. Studies indicate that exposure to green space is associated with school performances. That is through improving enhanced learning environments (Fägerstam & Blom, 2013; Mousel, Moser & Schacht, 2006; Greene & Byler, 2004; Lavie Alon & Tal, 2015; Lekies, Yost & Rode, 2015; Stern, Powell & Hill, 2014), stress reduction (Chawla, Keena, Pevec & Stanley, 2014; Li & Sullivan, 2016), physical health and fitness (Kuo, 2015; James, Banay, Hart & Laden, 2015; Dadvand et al., 2012; Rook, 2013), and social interactions and collaboration (Becker, Lauterbach, Spengler, Dettweiler & Mess, 2017).

2.1.1 Enhanced learning environments

Enhanced learning environments created by green space offer benefits that positively impact the cognitive functioning (Browning & Rigolon, 2019; Du, Zhou, Cai, Li & Xu, 2021; Finlay, Franke, McKay & Sims-Gould, 2015; Mwendwa & Giliba, 2012). One popular theory on the cognitive benefits of exposure to nature is the Attention Restoration Theory (ART). The theory suggests that exposure to natural environments can help restore and replenish our cognitive resources and attentional capacities (Kaplan & Kaplan, 1989; Ohly, White, Wheeler, Bethel, Ukoumunne, Nikolaou & Garside, 2016). According to the theory, our attentional system can become fatigued by the demands of everyday life, particularly tasks that require directed attention, such as work or studying. This mental fatigue can lead to reduced concentration, increased errors, and decreased cognitive performance. In contrast, natural environments provide a unique set of characteristics that promote attention restoration. These characteristics include being away from distractions, having a sense of being away from daily routines and responsibilities, being in an environment that is both fascinating and inherently interesting, and experiencing a sense of being away from oneself. Natural settings often have soft, fascinating stimuli, such as gentle sounds, natural light, and visually engaging elements like trees, water, and wildlife. These stimuli are thought to capture our attention in an effortless way, allowing the cognitive system to recover and replenish.

Other studies too have demonstrated that exposure to natural environments can significantly enhance attentional capacity, memory retention, and overall academic performance (Browning & Rigolon, 2019). The aesthetic appeal of green space, with their lush vegetation and natural elements, creates a visually pleasing and calming atmosphere. This serene environment helps reduce distractions and fosters focused learning (Du, Zhou, Cai, Li & Xu, 2021). People in green space are less likely to be overwhelmed by sensory stimuli, allowing them to concentrate and engage more effectively.

Furthermore, the restorative qualities of nature play a crucial role in improving cognitive functioning, information processing, and problem-solving skills among children (Finlay, Franke, McKay & Sims-Gould, 2015; Mwendwa & Giliba, 2012). Being surrounded by natural elements, such as sunlight and fresh air, promotes a healthy and stimulating learning environment. Natural light has been linked to increased alertness and improved mood, positively influencing students' overall well-being and cognitive abilities (Browning & Rigolon, 2019). The presence of green vegetation has also been associated with reduced mental fatigue and enhanced creativity, allowing students to think more critically and imaginatively.

Additionally, green space provides opportunities for hands-on learning and direct experiences with nature, which further enhance cognitive development. Students can explore and interact with the natural world, developing a deeper understanding of ecological concepts and fostering a sense of curiosity and wonder (Mwendwa & Giliba, 2012). This immersive learning environment stimulates active learning and encourages students to apply their knowledge in practical and meaningful ways.

2.1.2 Stress reduction

Secondly, besides enhanced learning environments, green space offers profound benefits by actively contributing to stress reduction, leading to improved mental health outcomes (Beyer, Kaltenbach, Szabo, Bogar, Nieto & Malecki, 2014; Gascon et al., 2015; McCormick, 2017; Wallner, Kundi, Arnberger, Eder, Allex, Weitensfelder & Hutter, 2018). One popular theory on stress reduction is the Stress Recovery Theory (SRT). The theory, proposed by environmental psychologists Rachel and Stephen Kaplan, suggests that exposure to natural environments can promote stress reduction and psychological restoration (Kaplan & Kaplan, 1989; Ulrich, Simons, Losito, Fiorito, Miles & Zelson, 1991). According to the theory, natural environments have certain qualities, such as being rich in fascination, being away from daily demands, and providing a sense of being away or escape, which contribute to stress recovery. The theory proposes that natural environments offer a respite from the stressors and cognitive demands of daily life. They provide a sense of calmness, serenity, and psychological relief, allowing individuals to recover from mental fatigue and restore their attentional capacity. Nature's inherent qualities, such as the presence of greenery, natural sounds, and tranquil settings, can evoke positive emotions, reduce physiological arousal, and enhance well-being. The theory emphasizes the importance of incorporating natural elements and green space into urban environments, workspaces, and other settings to promote stress reduction and psychological restoration.

Other studies have examined the stress reducing effects of green space too. Research consistently shows that nature has a remarkable restorative effect on mental well-being, playing a vital role in alleviating stress and anxiety (Beyer et al., 2014). Access to green space has been associated with reduced symptoms of stress and enhanced emotional well-being among children (Gascon et al., 2015). By immersing themselves in environments with natural elements, such as trees and vegetation, children can find solace and a sense of calmness, allowing them to recharge and recover from the pressures of daily life which enhances relaxation and psychological restoration (McCormick, 2017; Wallner et al., 2018). The gentle rustling of leaves, the vibrant colors of flowers, and the serenity of open green space all work together to create a tranquil atmosphere that allows children to find respite from stressors. Spending time in green space provides a much-needed escape from the fast-paced and demanding nature of modern life, and to disconnect from academic pressure, digital distractions, and the constant stimuli of urban environments, offering a sanctuary where children can immerse themselves in the beauty and tranquility of nature, fostering a sense of connection and promoting a healthier mental state. Spending time in nature, children can also develop a greater sense of resilience, emotional regulation, and overall mental well-being. Green space provides an invaluable resource for children to enhance their coping mechanisms, build emotional strength, and develop effective stress management strategies that will serve them well throughout their lives.

2.1.3 Physical health and fitness

Thirdly, green space not only provides a conducive setting for mental well-being but also serve as a platform to engage in physical activities, further benefiting people's mental health and cognitive functioning. By offering natural environments, green space creates opportunities for outdoor play, active exploration, and physical exercise, all of which contribute to people's overall physical fitness and well-being (James et al., 2015). The combination of physical exertion and natural surroundings has a profound impact on mental health outcomes, with studies showing that engaging in physical activities in green space leads to reduced stress levels, enhanced mood, and increased attentional capacity (Dadvand et al., 2012; Rook, 2013).

Regular physical activity has also been linked to improved cognitive performance, including attention, memory, and academic achievement by children (James et al., 2015). Green space, with their open spaces and recreational facilities, offer a supportive environment for children to participate in active play, sports, and various recreational activities. Whether it's running freely on a grassy field, climbing trees, or playing team sports, these physical activities in green space promote a healthy lifestyle and positive development. Additionally, the exposure to nature while engaging in physical activities further enhances the cognitive benefits, as the combination of movement, fresh air, and natural surroundings stimulates the brain and fosters a conducive learning environment.

2.1.4 Social interactions and collaborations

In addition to the benefits already discussed, green space also serves as ideal settings to engage in social interactions, fostering the development of essential social skills, collaboration, and teamwork (Niu, Adam & Hussein, 2022; Taylor et al., 1998; Vanaken & Danckaerts, 2018). Natural environments provide a welcoming and inclusive space where people, and especially children, can come together, interact, play, and learn from one another (Taylor et al., 1998). Engaging in collaborative play within green space promotes teamwork, as children learn to cooperate, communicate effectively, and work towards common goals (Vanaken & Danckaerts, 2018). This collaborative aspect of play nurtures essential social skills such as negotiation, problem-solving, and conflict resolution. Children can navigate challenges, share responsibilities, and make decisions collectively, fostering positive social interactions and building their social competence.

Furthermore, the presence of green space encourages children to engage in shared experiences, which in turn promotes the formation of friendships and a sense of community (Niu, Adam & Hussein, 2022). By participating in group activities, exploring nature together, or simply spending time in the same outdoor environment, children develop connections and a sense of belonging. The diversity of elements and open spaces in green areas facilitates social interactions, communication, and the development of social skills necessary for positive relationships and future success.

Through social interactions in green space, children not only enhance their social skills but also cultivate empathy, respect, and a greater appreciation for the perspectives and contributions of others. These experiences in green space lay the foundation for building strong social bonds, fostering social cohesion, and promoting a sense of belonging within the community.

2.2 Other factors

Through various ways is green space associated with school performances, but school performances are not only associated with green space but with a broad variety of different factors, some of which need to be taken into consideration when studying the relationship between green space and school performances. These factors include individual abilities, such as intelligence, learning styles, and personal motivation (Klotzke & Feskens, 2021; Skinner, Wellborn & Connell, 1990). And health and wellbeing, such as nutrition, sleep, and emotional well-being (Dewald, Meijer, Oort, Kerkhof & Bögels, 2010; Wolfson & Carskadon, 2003; Gumora & Arsenio, 2002). Other factors are socio-economic status (Lubienski & Crane, 2010; Marks, 2005; Droop & Verhoeven, 2003; Verhoeven & Van Leeuwe, 2012; Datcher-Loury, 1989; Kim, 2004), parental education level (Kim, 2004; Klotzke & Feskens, 2021; AOb, 2019; Pong, Hao & Gardner, 2005; AOb, 2019; Oppedisano & Turati, 2015; Idris, Hussain & Ahmad, 2020), and the home environment, such as household size (De Jong & Leseman, 2001; Serpell, 2001; Astone & McLanahan, 1991; Haveman, Wolfe & Spaulding, 1991; Downey, 1994; Idris, Hussain & Ahmad, 2020; Hill & Craft, 2003; Izzo, Weissberg, Kasprow & Fendrich, 1999; Pribesh & Downey, 1999; Downey, 1995; Blake, 2022). Furthermore, school quality, which is defined by the quality of the teachers, the school resources, and the school curriculum (Dickinson & Porche, 2011; Whitehurst & Lonigan, 1998; Alexander, Entwisle & Dauber, 1993), and peer influences through peer relationships and social interactions influence school performances (Blanton, Buunk, Gibbons & Kuyper, 1999; Greenberg et al., 2003; Pianta, Belsky, Houts & Morrison, 2007; Ryan & Ladd, 2012; Wentzel & Watkins, 2002; Battistich, 2005; Harris, 1995; DeLay et al., 2016; Howard, 2004; Wentzel, 2017). Lastly, there are factors, such as community support, cultural and social norms, and neighborhood characteristics, such as the level of urbanicity (Battistich, 2005; Scales, Benson, Roehlkepartain, Hintz, Sullivan & Mannes, 2001; Scales, Benson & Mannes, 2006; Benson, 2003; Eccles & Gootman, 2002; Baumeister

& Leary, 1995; Putnam, 2000; Perchoux, Chaix, Brondeel & Kestens, 2016). To understand the relationship between green space and school performances, it is essential to examine significant factors such as socio-economic status, household size, and level of urbanicity. These factors play a crucial role in determining the association between green space and academic outcomes.

2.2.1 Socio-economic status

Among the various factors associated with school performance, socio-economic status is widely recognized as having the most significant association (Netten, Voeten, Droop & Verhoeven, 2014; CPB, 2019; Lubienski & Crane, 2010; Marks, 2005; Caro & Lenkeit, 2012; Hoff, 2013; Sirin, 2005). A study conducted in the Netherlands in 2014 revealed a decline in school performance, particularly in reading literacy, with student's socio-economic statuses identified as a major contributing factor (Netten, Voeten, Droop & Verhoeven, 2014). The General Education Union (AOb) further asserts that wealth inequality is the primary cause of diminishing school performance among children from lower socio-economic backgrounds in the Netherlands (AOb, 2019). Parents with higher socio-economic status often have the means to provide additional educational support to enhance their children's school performance, whereas children from families with lower socio-economic status lack the resources and opportunities, leading to an inequality gap.

Socio-economic status has also been found to be associated with the amount of green space available in neighborhoods (Kabisch, 2019; Wüstemann, Kalisch & Kolbe, 2017). Studies highlight that neighborhoods with higher socio-economic status tend to have a greater percentage of green space compared to those with lower socio-economic status (Astell-Burt, Feng, Mavoa, Badland & Giles-Corti, 2014; Rigolon, 2016).

Research conducted by Kabisch (2019) and Wüstemann, Kalisch, and Kolbe (2017) support the notion that socio-economic status plays a role in determining the presence and accessibility of green space. Their findings suggest that neighborhoods characterized by higher socio-economic status tend to have a greater abundance of green space, such as parks, gardens, and recreational areas. This association can be attributed to various factors, including greater investment in urban greening, higher maintenance efforts, and the ability of wealthier neighborhoods to allocate more resources to the development and preservation of green space.

Furthermore, studies by Astell-Burt, Feng, Mavoa, Badland, and Giles-Corti (2014) and Rigolon (2016) have provided empirical evidence supporting the positive correlation between socio-economic status and the proportion of green space within neighborhoods. These findings imply that neighborhoods with higher socio-economic status are more likely to have a higher percentage of their area covered by green space. This pattern can be attributed to the preferences and priorities of wealthier communities, as well as the potential benefits associated with green space, such as improved aesthetics, enhanced property values, and better overall neighborhood quality.

2.2.2 Household size

The average household size per neighborhood is important to consider when studying the association between green space and school performances. Studies point out that children's school performances decrease when the number of sibling increases (Downey, 1995; Blake, 2022; Wagner, Schubert, & Schubert, 1985). Household size can have implications for the availability of resources and support within the family (Downey, 1995; Barnett, 2004; Guo & Harris, 2000). Larger households may be more likely to experience financial constraints or have lower socioeconomic status, which can affect access to educational resources, extracurricular activities, and quality schooling. This could be because resources such as financial means, educational materials, and parental attention may need to be divided among more children, potentially leading to reduced support for each child's academic endeavors (Black, Devereux & Salvanes, 2005; Chevalier & Lanot, 2002; Downey, 1995; De Graaf, 1988;

Hotz & Pantano, 2015). Conversely, smaller households, particularly those with higher socioeconomic status, may have more resources available per child, allowing for greater support and investment in education, potentially contributing to better academic outcomes.

The presence and interactions with siblings can also impact school performance (Stafford, 1987; Faraone, Biederman, Lehman, Spencer, Norman, Seidman & Tsuang, 1993; Hotz & Pantano, 2015). In larger households, children may have more opportunities for social interaction and collaboration with siblings, which can positively influence their learning and cognitive development (Smith, 1990). On the other hand, larger households may also introduce distractions or competition for attention, potentially impacting a child's focus and academic achievement (Brody, 2004).

Household size has also been identified as a factor associated with green space. Research conducted by Coolen and Meesters (2012) and Bertram and Rehdanz (2015) demonstrates that there is a notable association between household size and the demand for a garden or green space, particularly in urban areas. Larger household sizes often entail a greater need for outdoor spaces, such as gardens or nearby green areas, to accommodate the recreational and social needs of the residents (Coolen & Meesters, 2012). With more individuals living within a household, the pressure on green space within urban areas tends to be higher compared to smaller household sizes (Bertram & Rehdanz, 2015; Browning & Cagney, 2002; Brown & Bentley, 1993). The demand for green space by larger households can be attributed to several factors. Firstly, larger households may require additional space for children to play and engage in outdoor activities. Access to green space provides opportunities for recreational activities. Moreover, larger households often seek green space as spaces for social gatherings, relaxation, and leisure, allowing family members to connect with nature and enjoy outdoor amenities.

2.2.3 Urbanicity

Urbanicity refers to the degree of urban development and the characteristics of an urban environment, including population density, land use patterns, and infrastructure (Vlahov & Galea, 2002; Dahly & Adair, 2007; Adelman, 2002; Browning & Locke, 2020). The level of urbanicity represents a potentially significant factor in understanding the variations observed in studies exploring the relationship between greenspace and academic performance. Certain advantages of green space may exhibit greater strength in urban areas, while others may be stronger in rural areas (Markevych, Schoierer, Hartig, Chudnovsky, Hystad, Dzhambov & Fuertes, 2017; Verheij, Maas & Groenewegen, 2008).

Urbanicity has been found to be significantly associated with the availability and accessibility of green space in an area (Perchoux, Chaix, Brondeel & Kestens, 2016). Research by Browning and Locke (2020) highlights this relationship, demonstrating that higher levels of urbanicity are generally linked to a lower percentage of green space within a given region. The association between urbanicity and green space can be explained by the dynamics of land-use competition that occur in densely populated urban areas (Jensen, Baird & Blank, 2019). As urban areas experience high population density and increased urbanization, there is often a greater demand for land to accommodate various infrastructures, buildings, and other urban developments (Kasznar, Hammad, Najjar, Linhares Qualharini, Figueiredo, Soares & Haddad, 2021; Johansson, Laflamme & Hasselberg, 2012). Urban areas often face challenges in providing adequate green space due to limited land availability and competing land uses (Lovell, 2010), which can result in the loss of green areas (Clark, 1951; Wu & Murray, 2005).

Consequently, urban environments tend to have a lower proportion of green space compared to suburban and rural areas. As one moves farther away from the urban core into the suburbs and eventually rural areas, the percentage of green space per area tends to increase. Studies such as Maas, Verheij, Groenewegen, De Vries, and Spreeuwenberg (2006) have shown that suburban and rural areas typically exhibit a higher proportion of green space. The lower population density and less intense land-use pressures in these areas allow for greater opportunities to preserve or develop green space.

3 Methods

3.1 Study Area

This study researches the association between green space and school performances on the neighborhood level. Considering that children devote a significant portion of their time at school (Brons, Bolt, Helbich, Visser & Stevens, 2022), and that most children attend primary school in the same neighborhood as where they live (Van Velzen & Helbich, 2023), makes it relevant to examine the association between green space and school performance on the spatial granularity of neighborhoods. Neighborhoods can vary in terms of their green space availability, average socio-economic status, average household size, level of urbanicity, and average school performances (Browning & Rigolon, 2019; Netten, Voeten, Droop & Verhoeven, 2014; Downey, 1995; Browning & Locke, 2020). Studying these factors on the neighborhood level, the heterogeneity that exist across different geographical areas can be better examined (Browning & Rigolon, 2019; Wardrop, Jochem, Bird, Chamberlain, Clarke, Kerr & Tatem, 2018; Fotheringham, Charlton & Brunsdon, 1998), and helps to mitigate confounding factors that exist at larger spatial scales (Wardrop, Jochem, Bird, Chamberlain, Clarke, Kerr & Tatem, 2018), furthermore it also enables the identification of local patterns and disparities that might exist (Fotheringham, Charlton & Brunsdon, 1998; Cepeda-Carrion, Cegarra-Navarro & Cillo, 2018). Studying the association between green space, socio-economic status, household size, level of urbanicity, and school performances on the spatial granularity of neighborhoods provides a more contextually rich and comprehensive understanding of the factors that contribute to differential educational outcomes.

A dataset from Centraal Bureau voor de Statistiek was used to mark the boundaries of all neighborhoods for the analysis (CBS, 2021). According to this dataset, 14.175 neighborhoods exist in the Netherlands, of which 14.080 contain data on the area per neighborhood. On average, such a neighborhood is 249,1 ha (standard deviation [SD] ± 542).

3.2 CITO-test scores as the outcome variable

To examine the association between green space and children's school performances, the average CITO-test score per primary school in the Netherlands is used to determine children's school performances. The CITO-test is one of a few obligatory tests primary schools can choose from for their students to undertake in their final year to determine what level of education the students will undertake in middle school (DUO, 2023; CITO, 2023). The CITO-test scores range from 501 to 550. A lower score means that the child will study more practical oriented education in the middle school, and a higher score means a more theoretical oriented education. Since 2006, the average test score has been 535, with the only exceptions of 2011 (536), 2019 (536), 2020 (no test because of COVID-19 pandemic), and 2021 (534). The average CITO-test score per primary school in the Netherlands is a standardized variable to be used to determine children's school performances. The CITO-test consists of different components that test children's language, study, math, and world-orientation skills, and the results give a well indication of children's general school performances. Data on the CITO-test scores was retrieved from Dienst Uitvoering Onderwijs (DUO). A file named '*Gemiddelde eindscores bo sbo – 2021 – 2022*' contains data on the average final CITO-test scores per primary school in the Netherlands for the year 2022 (ROD, 2022).

3.3 Green space

The percentage of green space per neighborhood in the Netherlands is used to examine the association between green space and school performances. Data was used from Landelijk Grondgebruik Nederland (LGN), which contains a map of the Netherlands from the year 2021 where fifty different land uses are classified (LGN, 2021). The projection of this data shows a map of the Netherlands with polygons in different colors that represent all the different land uses in the Netherlands. The dataset has a resolution of five-by-five meters, where the most common land-use in that area determines the land-use classification for the whole pixel (LGN, 2021).

Since, this study focusses on green space, only land use classes that contained green space were used which were reclassified into one class. The selection of which land used can be identified as green space was done based on literature that have executed similar research (Van Velzen & Helbich, 2023; Wolch, Byrne & Newell, 2014; Callaghan, McCombe, Harrold, McMeel, Mills, Moore-Cherry & Cullen, 2021; Kweon, Ellis, Lee & Jacobs, 2017). Twenty-seven different land uses were selected and reclassified into one class that contains all green space in the Netherlands. Land uses such as agricultural grassland, forests, and grassland were reclassified as green space, and land uses such as agricultural land, built-up areas, and roads and train tracks were left out of the analysis (see Appendix 1).

3.4 Covariates

3.4.1 Socio-economic status

When studying the association between green space and children's school performances, it is essential to acknowledge the significant impact of socio-economic status. Extensive research has consistently highlighted the crucial role socio-economic status plays in shaping children's academic achievements (Lubienski & Crane, 2010; Marks, 2005; Droop & Verhoeven, 2003; Verhoeven & Van Leeuwe, 2012; Datcher-Loury, 1989; Kim, 2004). Moreover, studies have also indicated a connection between socio-economic status and green space (Kabisch, 2019; Wüstemann, Kalisch & Kolbe, 2017). Considering socio-economic status as a significant variable in this study is imperative. Accounting for socio-economic status, helps to better understand the interplay between green space and children's academic performance, while also recognizing the potential confounding effect of socio-economic factors. This comprehensive approach allows for a more nuanced analysis and provides valuable insights into the complex relationship between green space, socio-economic status, and school performances.

To obtain data on socio-economic status per neighborhood, the Dutch Centraal Bureau voor de Statistiek (CBS) provides relevant information based on financial wealth, level of education, and recent employment history for the year 2019 (CBS, 2022). The CBS data utilizes a numeric indicator, which represents the sum of partial scores obtained from the three separate categories. These scores range from -2 to +1, with a higher score indicating a higher socio-economic status per neighborhood. The composite nature of the socio-economic status score, considering three distinct factors, makes it a reliable indicator for socio-economic status that can be effectively utilized in this study (Lubienski & Crane, 2010; Marks, 2005; Droop & Verhoeven, 2003; Verhoeven & Van Leeuwe, 2012; Datcher-Loury, 1989; Kim, 2004). By incorporating socio-economic status into the analysis, this research aims to account for its potential influence and better understand the relationship between green space and children's school performances.

3.4.2 Household size

The average household size of neighborhoods in the Netherlands is considered as a crucial controllable variable. It is selected as a relevant covariate due to the observed variations in school performances among households of different sizes. Previous studies consistently indicate that an increase in household size is associated with a decrease in school performances (Downey, 1995; Blake, 2022; Wagner, Schubert, & Schubert, 1985). Household size has also been identified as a factor associated with green space. Various studies demonstrate that there is a notable association between household size and the demand for green space (Coolen & Meesters, 2012; Bertram & Rehdanz, 2015). By incorporating household size as a covariate, this study aims to account for this confounding factor and enhance the accuracy of isolating the association between green space and school performances.

To obtain data on average household sizes per neighborhood for the year 2021, the Centraal Bureau voor de Statistiek (CBS) is the primary source (2021). The CBS data provides insights into household sizes ranging from 0 to 6 persons per household. By leveraging this data, the research can account for the variations in household sizes across neighborhoods, enabling a more comprehensive analysis of the relationship between green space and school performances.

3.4.3 Urbanicity

The level of urbanicity of neighborhoods in the Netherlands is also considered as an important controllable variable. It is chosen as a relevant covariate due to the distinct features and dynamics typically found in urban areas compared to rural or suburban areas (Markevych, Schoierer, Hartig, Chudnovsky, Hystad, Dzhambov & Fuertes, 2017; Verheij, Maas & Groenewegen, 2008). The advantages and effects of green space can vary between urban and rural areas. By incorporating urbanicity as a covariate, this study aims to account for these confounding factors and enhance the accuracy of isolating the association between green space and school performances (Browning & Locke, 2020).

To obtain data on the level of urbanicity per neighborhood for the year 2021, the Centraal Bureau voor de Statistiek (CBS) is the source of information. The CBS data provides a classification of urbanicity into five classes, ranging from 1 to 5, with 1 representing the highest level of urbanicity. The level of urbanicity is based on the number of addresses per square kilometer (CBS, 2023). The highest level of urbanicity corresponds with 1500 to 2500 addresses per square kilometer, while the lowest level of urbanicity corresponds with up to 500 addresses per square kilometer. By utilizing this data, the study can capture the varying degrees of urbanicity across neighborhoods, allowing for a more comprehensive analysis of the relationship between green space and school performances.

3.5 Statistical analyses

3.5.1 Descriptives

Descriptives are used to assess characteristics of the data. Analyzing descriptives provides a foundation for understanding the data, examining patterns and characteristics of variables, and establishing context for the main analyses (De Vocht, 2019). The descriptives analyses provide the basis for two bivariate analyses to assess multicollinearity between different variables in this study. Assessing the multicollinearity is important, because highly correlated independent variables can hinder the interpretation of individual effects (Chen, 2012; Dunlap & Kemery, 1987). A global Ordinary Least Square (OLS) regression analysis and a Geographically Weighted Regression (GWR) analysis offer valuable insights into the relationships between the variables of interest and provide a comprehensive understanding of their spatial dynamics (Shoff, Yang & Matthews, 2012).

3.5.2 Global OLS regression analysis

The study utilizes global OLS regression analysis to investigate the overall association between the percentage of green space and average CITO-test scores per neighborhood, while accounting for average socio-economic status score, average household size, and level of urbanicity as controllable variables. OLS regression is a widely employed linear regression technique that allows for the estimation of relationships between dependent and independent variables, enabling the identification and quantification of significant associations (Esri, 2023a; Cao, Chen, Imura & Higashi, 2009; Lo, 2008; Cepeda-Carrion, Cegarra-Navarro & Cillo, 2018; Marvuglia, Cellura & Heijungs, 2010). OLS regression analysis provides a single set of estimated coefficients that represents the average relationship between the dependent variable and the explanatory variables across the entire study area. It assumes a constant relationship that is applicable to all locations. By employing the OLS regression analysis, the study aims to assess the overall relationship between green space and school performances across the entire study area, while considering the influence of other covariates.

OLS regression analysis makes several assumptions about the data and the model. These assumptions are important to ensure the validity and reliability of the regression results (De Vocht, 2019; Esri, 2023b). The assumptions for a multiple regression analysis are that the observations are independent, that the dependent variable is an interval or ratio variable and that the explanatory variables are interval, ratio, or dichotomous, that a causality theoretically exists between the variables, that a linear link exists between the variables, that the residuals are normally distributed, and that the residuals are homoscedastic, meaning that they have a constant variance (De Vocht, 2019). The data used in this study shows independent variables, with the dependent and explanatory variables being interval or ratio. The literature has indicated a causality between the dependent and explanatory variables. The assumptions on linearity, normality of residuals, and homoscedasticity are assessed through statistical diagnostics.

A scatterplot of the observed versus the predicted residual values is provides insight if there is a linear link between the explanatory variables and the dependent variable. Furthermore, the Jarque-Bara statistic provides insight in the normality of the distribution of the residuals. The null hypothesis for this test is that the residuals are normally distributed. When this test is statistically significant, model predictions are biased (Esri, 2023b). A Koenker Breusch Pagan statistic assesses the homoscedasticity of the residuals. The null hypothesis for the Koenker Breusch Pagan test is that the explanatory variables in the model are not effective. When the Koenker Breusch Pagan test is statistically significant, the relationships modeled are not consistent, and the analysis should rely on the Robust Probabilities to determine coefficient significance and on the Wald Statistic to determine overall model significance (Esri, 2023b). Lastly, a global Moran's I spatial autocorrelation tool measures the spatial autocorrelation based on both feature locations and feature values simultaneously (Esri, 2023c).

The global Moran's I spatial autocorrelation tool evaluates if the pattern is clustered, dispersed, or random. It provides a robust and systematic way to examine spatial autocorrelation and detect spatial patterns in the data. For the global Moran's I statistic, the null hypothesis states that the attribute being analyzed is randomly distributed among the features in the study area. The spatial relationship among features is defined as *inverse distance*, with nearby features having a larger influence on the computations for a target feature than features farther away, since it is expected that the association between variables is less but not insignificant the farther away features are from the target feature (Browning & Rigolon, 2019). A *Euclidean* distance method is selected because the Euclidean distance is more suitable for this study than the use of city blocks (*Manhattan*). Lastly, the default standardization of *Row* is applied.

The R-Squared value in the OLS regression analysis, also known as the coefficient of determination, provides insights into the goodness of fit or the proportion of variation explained by the independent variables within the study area (Esri, 2023b). It represents the amount of variability in the dependent variable that is accounted for by the explanatory variables. It measures the strength and quality of the relationship between independent and explanatory variables in a global context. It ranges from 0 to 1, where 0 indicates no variation explained and 1 indicates perfect explanation.

The Variance Inflation Factor (VIF) values are analyzed to assess covariable correlations in the study, and explanatory variables associated with VIF values larger than about 7,5 should be removed from the regression model (Esri, 2023b). The OLS regression analysis examines the global associations at play.

The standardized residual provides insights into the difference between the observed values of the dependent variable and the predicted values from the OLS regression model (Esri, 2023b). The standardized residuals are the residuals scaled by their standard deviation. It helps assess the quality of the OLS regression model by indicating how well the model fits the data. By examining the standardized residual, patterns or deviations in the residuals can be identified and the model's assumptions and potential issues can be assessed.

3.5.3 Geographically Weighted Regression (GWR) analysis

In addition to the global OLS regression analysis, a Geographically Weighted Regression (GWR) analysis is employed to explore the spatial heterogeneity of the association between green space and school performances. Where the OLS regression analysis treats the relationships between variables as constant, disregarding potential spatial variations or heterogeneity in these relationships, the GWR analysis is a spatial regression technique that recognizes the spatial non-stationarity of relationships. It acknowledges that the association between variables may vary across different locations or neighborhoods (Fotheringham, Charlton & Brunsdon, 1998). GWR constructs a separate equation for every feature in the dataset incorporating the dependent and explanatory variables of features within the bandwidth of each target feature (Esri, 2023d; Lo, 2008). It allows for the examination of local effects, considering the unique characteristics and dynamics of each neighborhood, in contrast to the OLS regression analysis, that examines global effects.

The dependent variable of average CITO-test scores per neighborhood in the Netherlands is considered as a continuous (*Gaussian*) variable, since the numeric values in the data range from 501 to 550 and include up to two decimals, meaning that the dependent variable is continuous. (De Vocht, 2019). The neighborhood type (or bandwidth) that is selected in the analysis is *distance band*, since the neighborhoods in the dataset are irregularly shaped. A *golden search* is selected as neighborhood selection method, to identify an optimal number of neighbors based on the characteristics of the data (Esri, 2023d). *Golden search* determines the number of neighbors with the lowest Akaike Information Criterion (AICc) as the neighborhood size (Esri, 2023d).

GWR empowers the analysis by incorporating a geographical weighting scheme for the features involved in each local regression equation (Esri, 2023e). The determination of weights is facilitated by a kernel, and a Gaussian kernel is selected, because it is expected that the association between variables is less but not insignificant the farther away features are from the regression point (Browning & Rigolon, 2019). The Gaussian kernel weighting approach assigns lower weights to features located farther away from the regression point, thereby reducing their influence on the regression results for the target feature. By employing a Gaussian weighting scheme in Geographically Weighted Regression, a higher number of neighbors are considered for each regression feature.

The local R-Squared value provides insights into the goodness of fit or the proportion of variation explained by the independent variables at each specific location within the study area, since the R-Squared value in the OLS regression analysis only examined the global association (Esrib, 2023d; Esri, 2023e). It represents the amount of variability in the dependent variable that is accounted for by the explanatory variables at each location. It measures the strength and quality of the relationship between independent and explanatory variables in a local context.

Values close to zero indicate that the explanatory variables do not explain any variation in the dependent variable at that specific location. Conversely, values close to one indicate that the explanatory variables perfectly explain all the variation observed in the dependent variable at that location. Interpreting the local R-Squared values allows to understand the spatial variability in the performance of the GWR model. Higher local R-Squared values indicate that the explanatory variables have a stronger influence and explain a larger proportion of the variation in the dependent variable at those specific locations. Lower local R-Squared values suggest a weaker relationship or less variability explained by the explanatory variables. Analyzing the distribution and patterns of local R-Squared values helps to identify areas where the GWR model performs well or poorly in capturing the spatially varying relationships between the variables. It helps to understand the heterogeneity in the strength of the relationships and identify locations where the model provides a better or worse fit to the data.

The Pseudo-T and significance variables are important to assess the overall model fit and whether the coefficient is statistically significant. A significant coefficient indicates that there is a meaningful constant association with the average CITO-test scores that should be considered even when the percentage of green space, the average socio-economic status, the average household size, and the level of urbanicity are accounted for.

The Corrected Akaike Information Criterion (AICc) is a statistical measure used in model selection and comparison in regression analyses (Esri, 2023b). It evaluates the relative quality or fir of different models, where lower AICc values indicate a better fit. It considers the trade-off between the goodness of fit and the complexity of the model. In GWR, the goal is to identify the neighborhood size or bandwidth that minimizes the AICc, indicating the best-fitting model for each location (Esri, 2023e). This selection helps determine the optimal spatial scale or neighborhood distance at which the relationship between variables is best represented. The AICc values of both regression analysis will be assessed to compare both models and see which model provides a better fit with the observed data. The model with the smaller AICc value is the better model.

4 Results

4.1 Descriptives

4.1.1 CITO-test scores

The dataset containing the data on average CITO-test scores per neighborhood in the Netherlands, shows that there are 2.089 neighborhoods in the Netherlands with an average CITO-test score. There are 6.426 primary schools in the Netherlands, of which 2.868 had their students undertake the CITO-test, and with some primary schools being situated in the same neighborhood. The average CITO-test scores per neighborhood in the Netherlands range from 506,93 to 548,60. The mean CITO-test score per neighborhood in the Netherlands is 534,60 which corresponds with the average CITO-test score since 2006 as stated by CBS (2018). The data shows a standard deviation of 4,3, which means that the CITO-test scores are relatively close to the mean. Table 1 shows a summary of the statistics, and figure 1 shows a map of the spatial distribution of the average CITO-test score per neighborhood in the Netherlands.

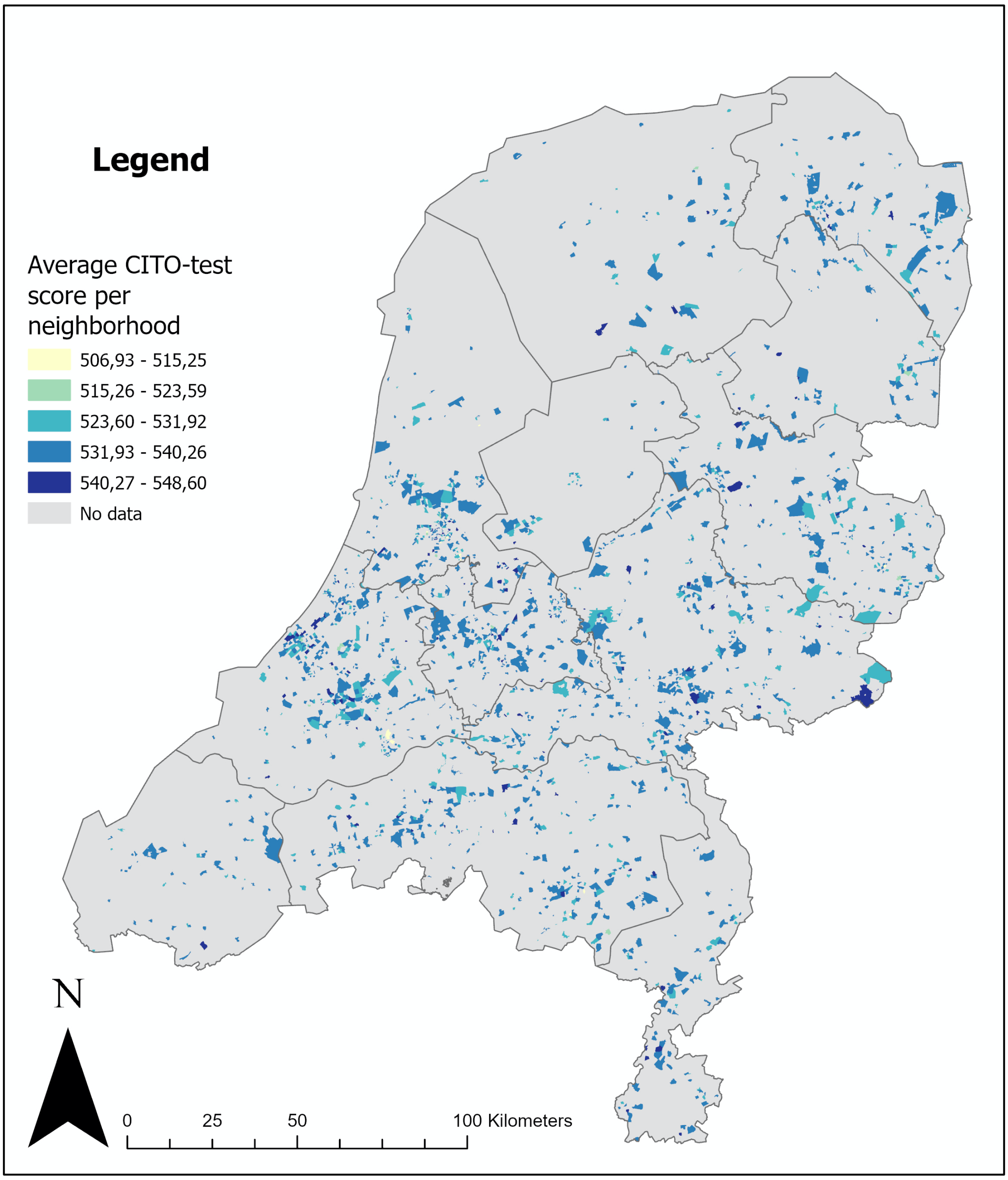

Figure 1: Map of the average CITO-test score per neighborhood in the Netherlands for the year 2022. Source: own work, 2023

4.1.2 Green space

The dataset containing the percentage of green space per neighborhood shows that there are 14.159 neighborhoods in the Netherlands with a percentage of green space. Of the 14.175 neighborhoods in the Netherlands, 16 neighborhoods do not have data on the percentage of green space. The percentages of green space on the map range from 0% to 96,247%. The mean percentage of green space per neighborhood in the Netherlands is 58,7%, with a standard deviation of 16,7 which means that the percentage of green space is relatively far from the mean. Table 1 shows a summary of the statistics, and figure 2 shows a map of the Netherlands with the percentage of green space per neighborhood.

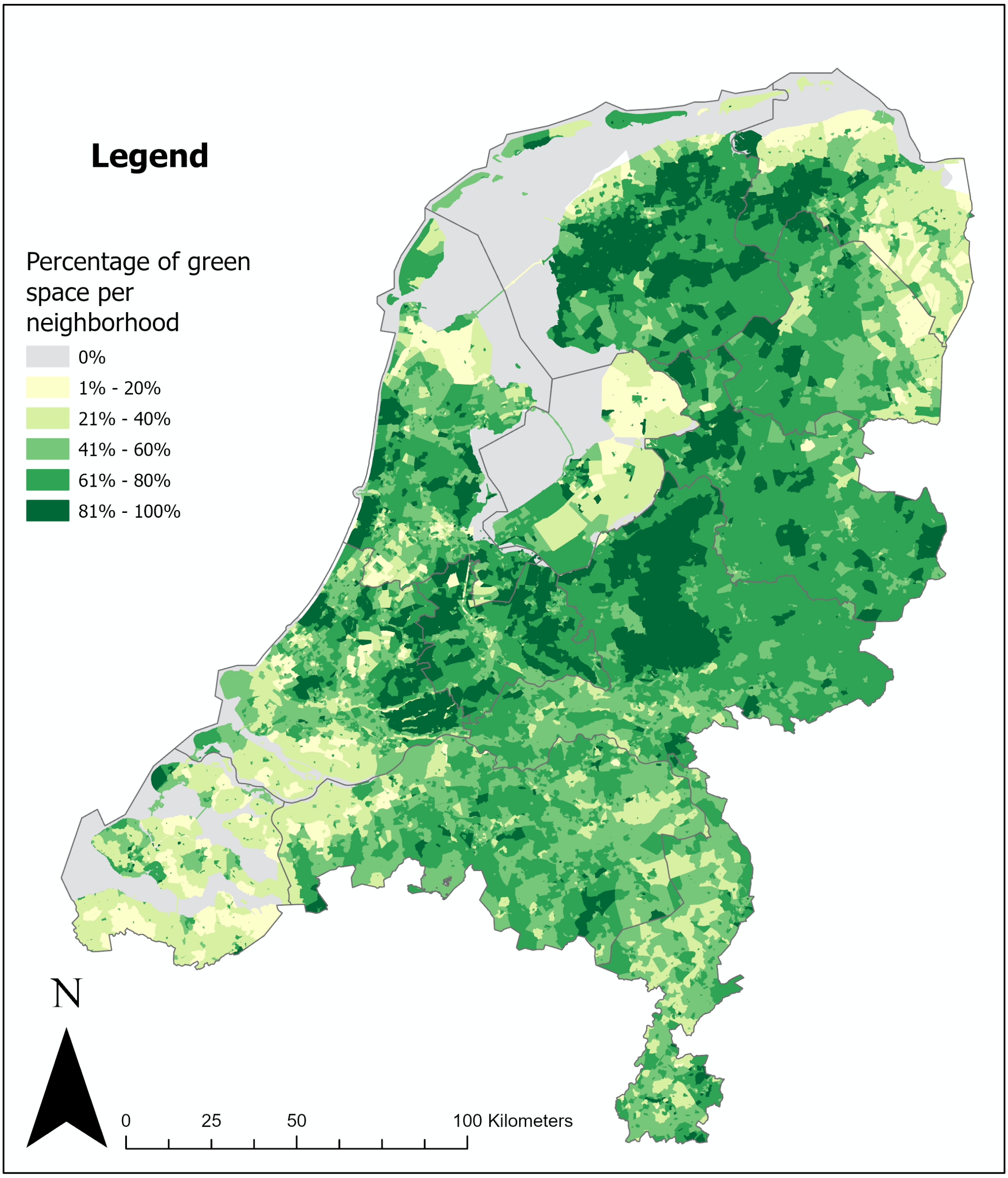

Figure 2: Map of the percentage of green space per neighborhood in the Netherlands for the year 2021. Source: own work, 2023

4.1.3 Covariates

4.1.3.1 Socio-economic status

The dataset containing the average socio-economic status score per neighborhood shows that there are 9.707 neighborhoods in the Netherlands with an average score. Of the 14.175 neighborhoods in the Netherlands, 4.468 neighborhoods do not have data on the socio-economic status. The socio-economic status scores on the map range from -1,784 to +0,793. The mean socio-economic score per neighborhood in the Netherlands is 0,087, with a standard deviation of 0,295 which means that the socio-economic status scores are relatively close to the mean. Appendix 2.1 contains a map that shows the average socio-economic status score per neighborhood in the Netherlands.

4.1.3.2 Household size

The dataset containing the average household size per neighborhood shows that there are 13.723 neighborhoods in the Netherlands that have data on the household size. The household sizes range from 1 to 6 persons per household (CBS, 2022). The mean household size per neighborhood in the Netherlands is 2,3, with a standard deviation of 0,45, which means that the household sizes are relatively close to the mean. Appendix 2.2 contains a map that shows the average household size per neighborhood in the Netherlands.

4.1.3.3 Urbanicity

The dataset containing the level of urbanicity per neighborhood shows that there are 14.009 neighborhoods in the Netherlands that have been ranked by their level of urbanicity. The levels of urbanicity range from 1 to 5 (CBS, 2023). An urbanicity level of 1 means that the area is extremely urbanized, 2 means strongly urbanized, 3 moderately urbanized, 4 hardly urbanized, and 5 not urbanized. The mode level of urbanicity is 5, meaning that most neighborhoods in the Netherlands are classified as not urbanized. Table 1 shows a summary of the statistics. Appendix 2.3 contains a map that shows the average level of urbanicity per neighborhood in the Netherlands.

Table 1: Statistics on average CITO-test scores, percentage of green space, average socio-economic status, household size, and level of urbanicity. Source: own work, 2023

	CITO-test score	**Percentage of green space**	**Socio-economic status score**	**Household size**	**Urbanicity**
Mean	534,6	58,7	0,087	2,3	-
Median	535	61,2	0,13	2,3	-
Standard deviation	4,3	16,7	0,295	0,45	-
N	2089	14.159	9707	13.723	14.009

4.2 OLS results

4.2.1 OLS assumptions

The assumptions on linearity, normality of residuals, and homoscedasticity are assessed through statistical diagnostics. Figure 3 shows a scatterplot of the observed versus the predicted residuals, indicating linearity in the model. Appendix 3.1 shows a figure of the distribution of the residual, indicating a normally distribution which supports the assumption on the normality of the residuals and appendix 3.2 shows a map of the spatial distribution of the standardized residual value per neighborhood. However, the Jarque-Bera statistic shows a significant value of 0 ($p < 0,01$) (see table 3), meaning that the model predictions are biased and that the residuals are not normally distributed. The scatterplot of figure 3 can also indicate if the residuals are homoscedastic or heteroscedastic, but the plot does not show a clear pattern. The Koenker Breusch Pagan test assesses the homoscedasticity of the residuals and shows a significant value of 0 ($p < 0,01$), meaning that the residuals are heteroscedastic (see table 3). The relationships modeled are not consistent and the Robust probabilities value should be used to determine coefficient significance and the Wald statistic should be used to determine overall model significance.

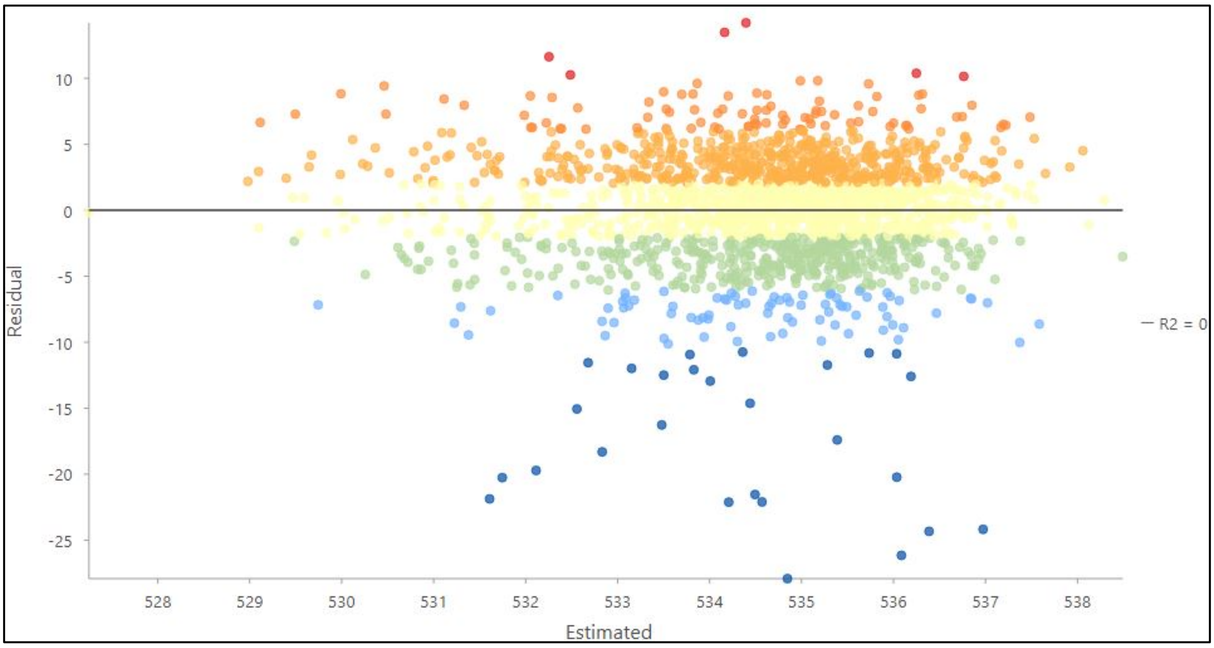

Figure 3: Scatterplot of the observed residual versus the estimated values. Source: own work, 2023

Table 2: Summary of OLS results. Source: own work, 2023

Variable	Coefficient	Std. Error	t-Statistic	Probability	Robust_SE	Robust_t	Robust_Pr	VIF
Intercept	539,173417	0,777962	693,058865	0,0	0,797562	676,026809	0,0	-
Green space	-0,021558	0,008215	-2,624031	0,008749	0,008548	-2,521902	0,011737	1,386020
SES	6,124140	0,420776	14,554393	0,0	0,464407	13,187000	0,0	1,614617
Household size	-1,859786	0,376540	-4,939150	0,000001	0,380345	-4,889731	0,000002	1,910766
Urbanicity	0,186151	0,076400	2,436524	0,014901	0,075406	2,468640	0,013632	1,492800

The Variance Inflation Factors (VIFs) in the analysis do not exceed the value of 1,91, which indicates that no explanatory variables tell the same story (see table 2) (Esri, 2023b).

Table 3: OLS diagnostics. Source: own work, 2023

Number of observations	2040	**AICc**	11510,786152
Multiple R-Squared	0,114154	**Adjusted R-Squared**	0,112412
Joint F-Statistic	65,559440	Prob(>F), (4,2035) degrees of freedom	0,000000*
Joint Wald-Statistic	231,483043	Prob(>chi-squared), (4) degrees of freedom	0,000000*
Koenker (BP) Statistic	25,922742	Prob(>chi-squared), (4) degrees of freedom	0,000033*
Jarque-Bera Statistic	3173,272254	Prob(>chi-squared), (2) degrees of freedom	0,000000*

*Indicates a statistically significant p-value ($p < 0,01$).

4.2.2 Moran's I

The global Moran's I spatial autocorrelation shows a positive Moran's Index value of 0,038451 (see table 4), which indicates a presence of positive spatial autocorrelation. This means that similar values tend to cluster together, and neighboring locations have similar values. Table 4 shows a statistically significant P-value of 0 and a positive Z-score of 6,681133, meaning that the null hypothesis for Moran's I can be rejected. The spatial distribution of high values and/or low values in the dataset is more spatially clustered than would be expected if underlying spatial processes were random. The results indicate that there is a significant positive spatial autocorrelation.

Table 4: Summary of the global Moran's I spatial analysis. Source: own work, 2023

Moran's Index	0,038451
Expected Index	-0,000490
Variance	0,000034
Z-score	6,681133
P-value	0,000000

4.2.3 Joint Wald statistic and Robust Probability

The Joint Wald statistic value 231,483043 with 4 degrees of freedom indicates a very high chi-square value, which suggests strong evidence against the null hypothesis that the coefficients of the explanatory variables is equal to zero. This means that there is a significant relationship between the average CITO-test score and the explanatory variables. The Prob(>chi-squared) value of 0 ($p < 0,01$) indicates that the probability of obtaining such a large chi-square value by chance alone is essentially zero. The Joint Wald statistic is highly statistically significant.

The Robust Probability value of the association between the average CITO-test score and the percentage of green space is 0,011737 and is statistically significant ($p < 0,01$). The Robust Probability values of the association between the average CITO-test score and the other explanatory variables are in table 2.

4.3 GWR results

4.3.1 Local R-Squared

The local R-Squared values per neighborhood in this study range from 0,072 to 0,174. The mean value of the local R-Squared per neighborhood in the Netherlands is 0,132, with a standard deviation of 0,024, which means that the local R-Squared values are relatively close to the mean. The mean local R-Squared value of 0,132 suggests that the explanatory variables explain approximately 13% of the variation in the dependent variable for the specific data point or neighborhood being considered. The remaining 87% of the variation is not accounted for by the explanatory variables included in the model.

Figure 4 shows a map of the Netherlands with the local R-Squared per neighborhood. Areas in the southeastern part of the Netherlands show the lowest local R-Squared values, with values as low as 0,072423, meaning that in these areas the explanatory variables only explain 7% of the variation in the dependent variable. Areas in the center of the Netherlands show the highest local R-Squared values, with values as high as 0,174099, meaning that in these areas the explanatory variables explain up to 17% of the variation in the dependent variable.

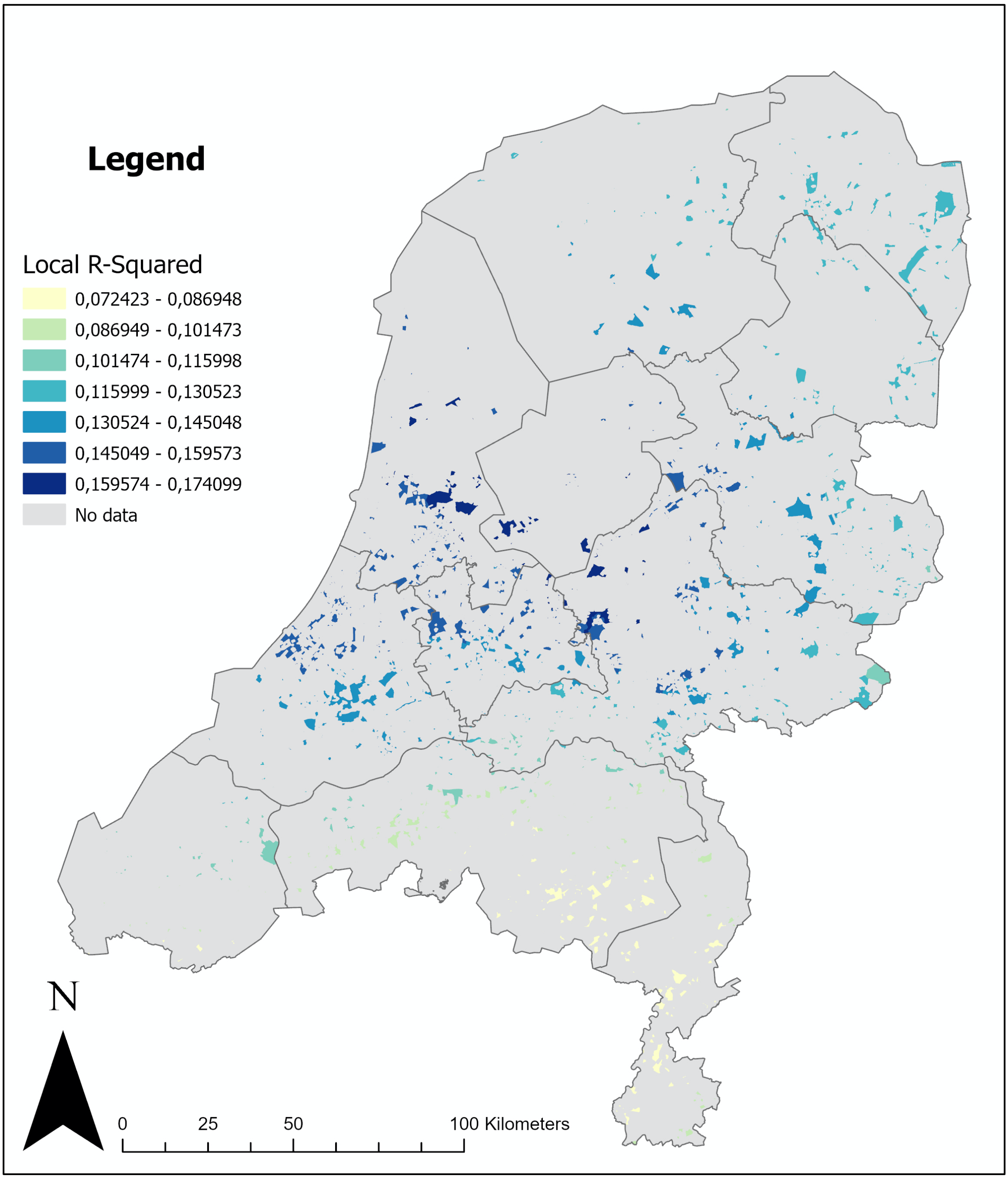

Figure 4: Map of the distribution of the local R-Squared values per neighborhood in the Netherlands. Source: own work, 2023

4.3.2 Pseudo-T

4.3.2.1 Pseudo-T (intercept)

A mean Pseudo-T value of 456,4 suggests that the intercept is highly statistically significant. The magnitude of the Pseudo-T value indicates a strong level of significance, indicating that the intercept is highly likely to be different from zero. This indicates that there is a meaningful constant association with the average CITO-test scores that should be considered even when the explanatory variables are accounted for. It emphasizes the importance of including the intercept in the model and considering its association with the overall model fit. Table 5 shows a summary of the statistics of the average Pseudo-T values.

Table 5: Statistics on the average Pseudo-T values for the intercept, percentage of green space, average socio-economic status score, average household size, and level of urbanicity. Source: own work, 2023

	Pseudo-T (intercept)	Pseudo-T (green space)	Pseudo-T (SES)	Pseudo-T (household size)	Pseudo-T (urbanicity)
Mean	456,4	-1,55	10,1	-2,9	1,05
Median	497,3	-1,67	10,5	-2,94	0,92
Standard deviation	75,6	0,88	1,83	0,9	0,81
N	2040	2040	2040	2040	2040

Figure 5 shows a map that projects the Pseudo-T value of the intercept per neighborhood in the Netherlands. Neighborhoods in the central and western part of the Netherlands show the highest Pseudo-T values, meaning that the intercept is most significant in these areas. Neighborhoods in the north- and southeastern parts of the Netherlands show the lowest Pseudo-T values, meaning that the intercept is least significant in these areas.

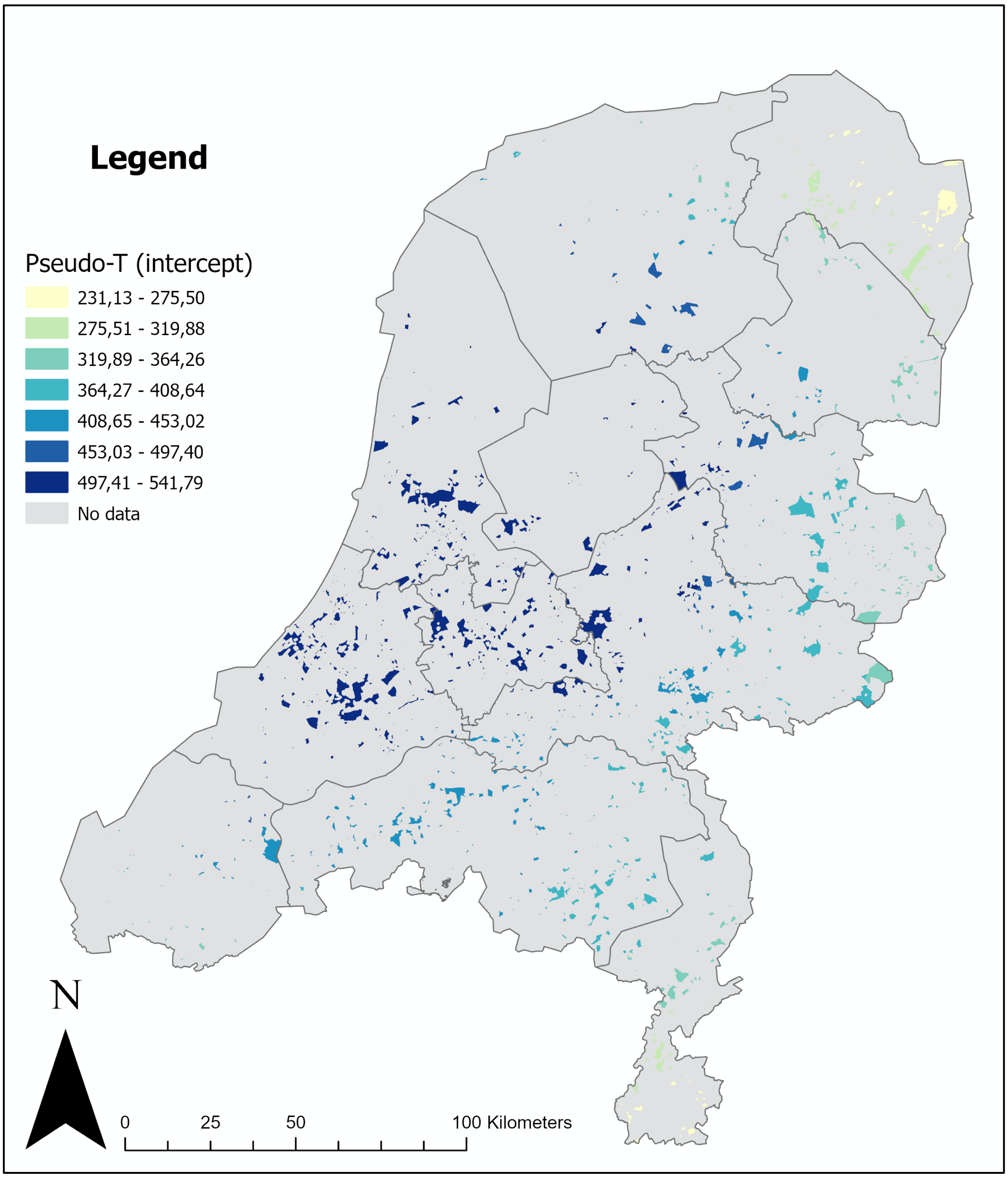

Figure 5: Map of the distribution of the Pseudo-T value for the intercept per neighborhood in the Netherlands. Source: own work, 2023

4.3.2.2 Pseudo-T (covariates)

The mean Pseudo-T values in table 5 for socio-economic and household size indicate that these variables are statistically insignificant. The socio-economic status and household size variables do not show any significant Pseudo-T values, indicating that no neighborhood shows a statistical significance for the socio-economic status and household size variables.

4.3.3 Coefficients

4.3.3.1 Coefficient for green space

The coefficient for the green space variable indicates the estimated effect of the percentage of green space on the average CITO-test score per neighborhood in the Netherlands, while controlling for the other covariates. The coefficient shows a normal distribution. The mean coefficient for the green space variable is -0,02045, which suggests that, on average, for every unit increase in the percentage of green space, the average CITO-test score decreases by 0,02045 units. This implies that higher percentages of green space in a neighborhood are associated with slightly lower average CITO-test scores. Table 6 shows statistics on the coefficients for the different explanatory variables in this study.

Table 6: Statistics on the coefficients for green space, socio-economic status, household size, and urbanicity. Source: own work, 2023

	Coefficient for green space	Coefficient for socio-economic status	Coefficient for household size	Coefficient for urbanicity
Mean	-0,02045	6,45197	-1,74266	0,13503
Median	-0,0196	6,5	-1,84	0,111
Standard deviation	0,0125	0,48	0,67	0,106
N	2040	2040	2040	2040

A mean Pseudo-T value of -1,55 suggests that the percentage of green space is statistically significant (see table 5). Most neighborhoods in the Netherlands show Pseudo-T values less than 1,96 and more than -1,96, meaning that the percentage of green space is significant in these areas. The coefficient values in these neighborhoods range from -0,038157 to 0,015053. Table 7 shows statistics on the coefficient of green space for the neighborhoods that are statistically significant ($p < 0,05$).

Table 7: Statistics on the coefficient for green space for neighborhoods that are statistically significant ($p < 0,05$). Source: own work, 2023

	Coefficient for green space ($p < 0,05$)
Mean	-0,0138
Median	-0,015
Standard deviation	0,009
N	1296

Figure 6 shows a map that projects the spatial distribution of the coefficient for green space per neighborhood in the Netherlands that is statistically significant ($p < 0,05$), and it shows a spatial heterogeneous distribution of the coefficient. Most neighborhoods in this area show a negative coefficient, indicating a negative association between the two variables, and only some neighborhoods show positive coefficients with values up to 0,015053, meaning that for every unit increase in the percentage of green space, the average CITO-test score also increases with up to 0,015053 units.

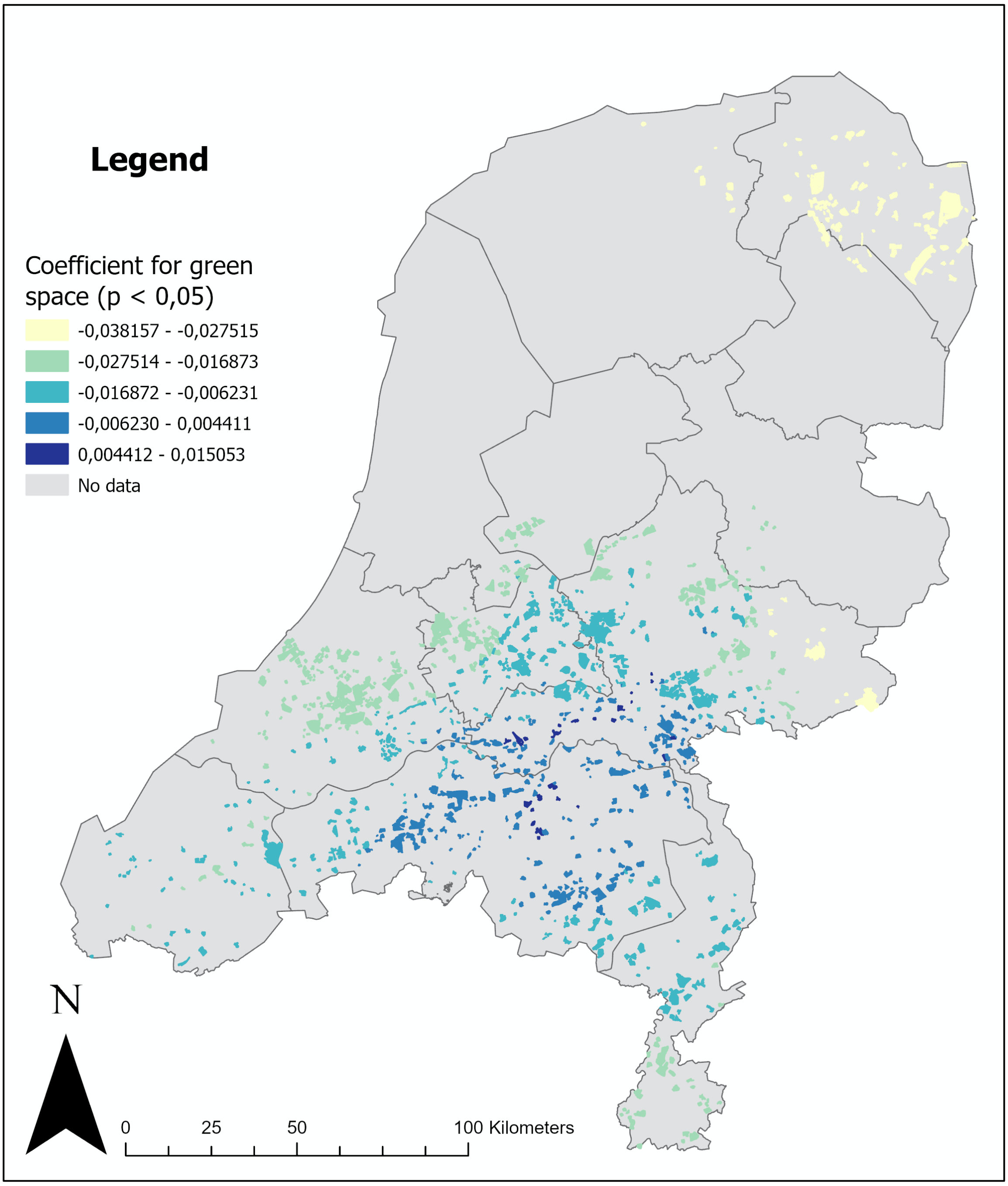

Figure 6: Map of the distribution of the coefficient for green space in neighborhoods where the coefficient is statistically significant (p < 0,05). Source: own work, 2023

5 Discussion

5.1 Main findings

This study used data on the average CITO-test score per neighborhood and the percentage of land use per neighborhood, along with some covariates in OLS and GWR analyses to investigate to what extend school performances are associated with green space exposure in the surroundings of primary schools in the Netherlands. The Joint Wald statistic and the Robust probability value of the OLS analysis have indicated that there is a significant association between the average CITO-test score and the percentage of green space per neighborhood in the Netherlands. The Local R-Squared values per neighborhood of the GWR analysis indicate that up to 17% of the variation in the average CITO-test score per neighborhood is explained by the explanatory variables in this study, and the mean Pseudo-T value indicates that a meaningful constant association with the average CITO-test score exists, even when the explanatory variables are accounted for. The mean coefficient in the GWR analysis for the whole study area for the green space variable implies, in contrast to the OLS analysis, that higher percentages of green space in a neighborhood are associated with slightly lower average CITO-test scores. However locally, the GWR indicates that statistically significant negative, but also positive associations between the percentage of green space, and the average CITO-test score per neighborhood in the Netherlands exist.

5.2 Results in the context of the existing literature

The findings of this study align with this study's hypothesis and are mostly in line with findings in the literature. Extensive research has been conducted on the association between school performances and green space exposure. Studies by Fägerstam & Blom (2013), Mousel, Moser & Schacht (2006), Greene & Byler (2004), Lavie Alon & Tal (2015), Lekies, Yost & Rode (2015), and Stern, Powell & Hill (2014) have indicated a positive association between green space and school performance through enhanced learning environments. Chawla, Keena, Pevec & Stanley (2014), and Li & Sullivan (2016) indicated a positive association through stress reduction. Kuo (2015), James, Banay, Hart & Laden (2015), Dadvand et al. (2012), and Rook (2013) indicated a positive association through physical health and fitness, and Becker, Lauterbach, Spengler, Dettweiler & Mess (2017) indicated a positive association through social interactions and collaborations. The OLS regression analysis and GWR analysis of this study have also found positive statistically significant associations between green space and school performances which complies with the findings of previous studies.

Interestingly, studies by Beere & Kingham (2017), Browning, Kuo, Sachdeva, Lee & Westphal (2018), Hodson & Sander (2017), Kuo, Browning, Sachdeva, Lee & Westphal (2018), Matsuoka (2010), Sivarajah, Smith & Thomas (2018), Tallis, Bratman, Samhouri & Fargione (2018) and Wu, McNeely, Cedeño-Laurent, Pan, Adamkiewicz, Dominici & Spengler (2014) have indicated a negative association. This study has also found the existence of a negative association between green space and school performance in some neighborhoods in the country.

The contradicting results between the OLS regression analysis and the GWR analysis of this study, and the contradicting results of the GWR analysis itself are in line with previous studies. Mixed results on the association between green space and school performance is highlighted by Browning & Rigolon (2019) in their systematic literature review. Studies by Markevych, Feng, Astell-Burt, Stanld, Sugiri, Schikowski & Heinrich (2019) have indicated that there are non-significant associations between green space and school performances. Findings by both this study and previous studies indicate that the association between green space and school performance is not undoubtedly clear.

5.3 Strengths and limitations of this study

5.3.1 Strengths

The design of this study of a literature review to form a contextual basis for statistical analyses to be executed using datasets from different sources has proven to be effective in assessing the association between green space and school performance. The data used in this study was of good quality. Data was retrieved from renowned and trustworthy sources, such as CBS, DUO, and LGN.

This study tried to address the existing research gap and add to the existing findings on the association between green space and school performances by assessing OLS and GWR analyses. Previous studies had not assessed the association between green space and school performance for the Dutch case. The statistically significant associations that have been found by this study, add to the existing knowledge.

The different regression analyses used in this study have shown adequate outcomes. No errors or significant deviations in the analyses and results have occurred. The OLS and GWR analyses in this study have indicated statistically significant associations which aligns with findings from previous studies. Therefore, it can carefully be stated that the selection of these statistical regression analyses was well executed.

The research of this study has not conflicted with research ethics. All the data that was used in this study has been retrieved from trustworthy sources that have been correctly referenced. Nothing in this study has been used that would conflict with research ethics.

5.3.2 Limitations

Due to the lack of data on the average CITO-test scores and socio-economic status per neighborhood, only 2040 neighborhoods out of the existing 14.175 neighborhoods in the Netherlands could be used in the OLS and GWR analyses. This could possibly have affected the results of the analyses. The greater the number of values in the analyses, the more representative and accurate the results are. Even though the number of 2040 neighborhoods in the analyses is still large, it may not be sufficient to make general statements on the association between green space and school performance.

Additionally, the use of average CITO-test scores per neighborhood to measure school performances might have affected the results on the association between green space and school performance. The choice of a different measure for the dependent variable in this study might indicate a different outcome on the association studied in this study. As indicated by previous studies, green space might be stronger associated with individual performances on separate skills and subjects, rather than on a combined final test.

The variable used in this study to measure green space might also have affected the results. This study has reclassified several land-uses in the Netherland as one class of green space. Therefor this study does not consider the association between different sorts of green space and school performances. This makes it unclear which land-uses are stronger associated with school performances, which could have affected the results of the analyses in this study.

Furthermore, the selection of covariates in this study could have affected the outcomes. To study the association between green space and school performances, this study considered three different covariates for the OLS and GWR analyses. The selection of these covariates was done based on the literature, but the selection of more, or other covariates might change the outcomes of the analyses. The GWR analysis has indicated that only 17% of the variation in the average CITO-test score is explained by the explanatory variables used in this study. This indicates that quite some variation in the average CITO-test score is explained by other variables that have not been considered in this study.

Given the scope and time frame for the execution of this study, the study could have been more extensive and in-depth. These limitations may have impacted the comprehensiveness or completeness of this research.

5.4 Future research

The findings of this research indicate that more research must be done on the association between green space and school performance. Although findings of this study align with findings of previous studies, some discrepancies have been found that suggest the need for further investigation. The discrepancies in the findings of the association between green space and school performance between different neighborhoods in the Netherlands suggest that more research is needed. And although this study was able to investigate the association, the outcomes of the study are however not sufficient to make general statements on the association between school performance and green space. More research must be done, and future studies should consider the limitations and constraints that occurred in this study to be able to study the association between green space and school performance.

6 Conclusion

The Dutch system of education has been praised for its high quality for years (Scheerens, Luyten & Van Ravens, 2010), but the Netherlands' educational standing has been declining since 2006 and is now only slightly above average in comparison to other nations, according to the Programma for International Student Assessment (PISA) (OECD, 2018; CPB, 2022). School performance is a critical predictor of long-term success and well-being (Browning & Rigolon, 2019; Rauber, 2007; Feinstein & Duckworth, 2006; Ogbu & Simons, 1998; Pfeffer, 2008; Oberle, Schonert-Reichl & Zumbo, 2011), and the worrisome decline in school performances in the Netherlands makes it relevant to explore strategies that can potentially enhance academic outcomes, such as green space (Buckingham, 2000; Fröjd, Nissinen, Pelkonen, Marttunen, Koivisto & Kaltiala-Heino, 2008).

Green space has been associated with academic performance through enhancing learning environments (Fägerstam & Blom, 2013; Mousel, Moser & Schacht, 2006; Greene & Byler, 2004; Lavie Alon & Tal, 2015; Lekies, Yost & Rode, 2015; Stern, Powell & Hill, 2014), reducing stress (Chawla, Keena, Pevec & Stanley, 2014; Li & Sullivan, 2016), improving physical health and fitness (Kuo, 2015; James, Banay, Hart & Laden, 2015; Dadvand et al., 2012; Rook, 2013), and supporting social interactions and collaborations (Becker, Lauterbach, Spengler, Dettweiler & Mess, 2017).

While many studies have examined the relationship between green space and academic performances through a variety of different ways (Browning & Rigolon, 2019; McCormick, 2017; Kweon, Ellis, Lee & Jacobs, 2017; Hodson & Sander, 2017; Gilavand, Espidkar & Gilavand, 2016; Keniger, Gaston, Irvine & Fuller, 2013; Wu et al., 2014; Van Aart et al., 2018; Dadvand et al., 2015; Grahn, 1996; Wells, 2000), there is still a research gap regarding the specific association between green space exposure and school performances in the surroundings of primary schools in the Netherlands.

This study has tried to address the existing research gap on the association between school performances and green space to understand the localized dynamics, to harness the potential benefits of green space within urban environments, and to inform evidence-based policies and interventions to optimize school environments. It tried to investigate to what extend school performances are associated with green space exposure in the surroundings of primary schools in the Netherlands. This study used data on the average CITO-test score per neighborhood and the percentage of land use per neighborhood, along with some covariates in OLS and GWR analyses. The OLS analysis indicates that there is a significant association between the average CITO-test score and the percentage of green space per neighborhood in the Netherlands. The GWR analysis shows localized dynamics and indicates that statistically significant positive and negative associations between the percentage of green space, and the average CITO-test score per neighborhood in the Netherlands exist. The findings on the existence of a positive association between green space and school performance highlight the potential benefits of green space within urban environments to optimize school environments, by adding to the percentage of green space in the neighborhood. Part of the findings of this study align with this study's hypothesis. Optimizing Dutch school environments to improve school performance is imperative, since school performance is a critical predicter of long-term success and well-being. Although more research must be done on this topic, the findings of this study can provide valuable insights for educational policymakers, school administrators, and urban planners seeking to create conducive learning environments to improve the declining school performances in the Netherlands.

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Appendix

1 Table of the classification of land use in the Netherlands

Table 8: Old and new classification of land use in the Netherlands. Source: LGN, 2021

	LGN land-use category	New land-use category
1	Agrarisch gras	Green space
2	Maïs	-
3	Aardappelen	-
4	Bieten	-
5	Granen	-
6	Overige landbouwgewassen	-
8	Glastuinbouw	-
9	Boomgaarden	-
10	Bloembollen	-
11	Loofbos	Green space
12	Naaldbos	Green space
16	Zoet water	-
17	Zout water	-
18	Bebouwing in primair bebouwd gebied	-
19	Bebouwing in secundair bebouwd gebied	-
20	Bos in primair bebouwd gebied	Green space
22	Bos in secundair bebouwd gebied	Green space
23	Gras in primair bebouwd gebied	Green space
26	Bebouwing in buitengebied	-
27	Overig grondgebruik in buitengebied	-
28	Gras in secundair bebouwd gebied	Green space
29	Zonneparken	-
30	Kwelders	-
31	Open zand in kustgebied	-
32	Duinen met lage vegetatie	Green space
33	Duinen met hoge vegetatie	Green space
34	Duinheide	Green space
35	Open stuifzand en/of rivierzand	-
36	Heide	Green space
37	Matig vergraste heide	Green space
38	Sterk vergraste heide	Green space
39	Hoogveen	Green space
40	Bos in hoogveengebied	Green space
41	Overige moeras vegetatie	Green space
42	Rietvegetatie	Green space
43	Bos in moerasgebied	Green space
45	Natuurlijk beheerde agrarische graslanden	Green space
46	Gras in kustgebied	Green space
47	Overig gras	Green space
61	Boomkwekerijen	-
62	Fruitkwekerijen	-
251	Hoofdinfrastructuur en spoorbaanlichamen	-
252	Halfverharde wegen, infrastructuur langzaam verkeer en overige infrastructuur	-
253	Smalle wegen	-
321	Struikvegetatie in hoogveengebied (laag)	Green space
322	Struikvegetatie in moerasgebied (laag)	Green space
323	Overige struikvegetatie (laag)	Green space
331	Struikvegetatie in hoogveengebied (hoog)	Green space
332	Struikvegetatie in moerasgebied (hoog)	Green space
333	Overige struikvegetatie (hoog)	Green space

2 Descriptives of covariates

2.1 Socio-economic status

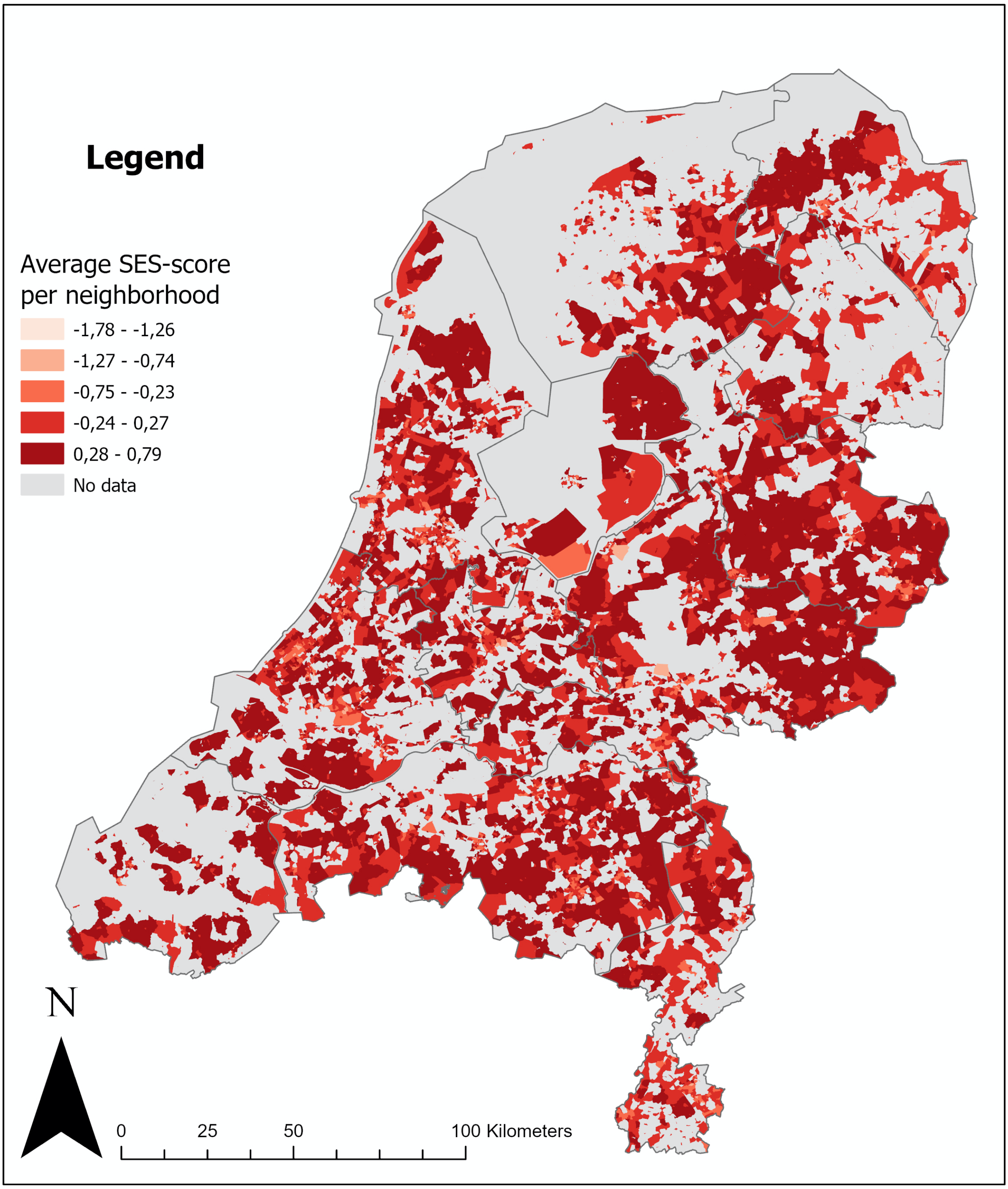

Figure 7: Map of the average socio-economic status score per neighborhood in the Netherlands for the year 2019. Source: own work, 2023

2.2 Household size

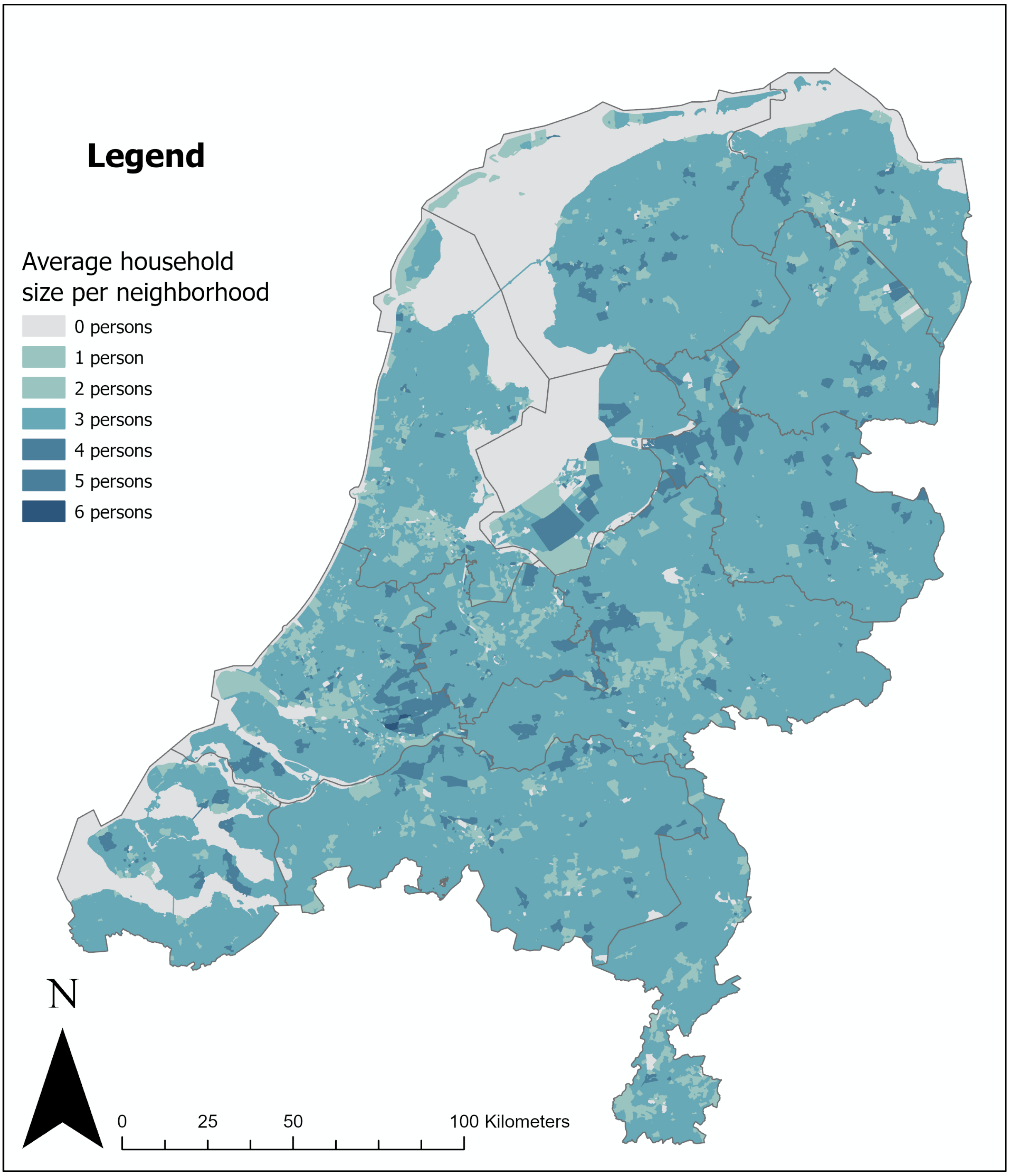

Figure 8: Map of the average household size per neighborhood in the Netherlands for the year 2021. Source: own work, 2023

2.3 Urbanicity

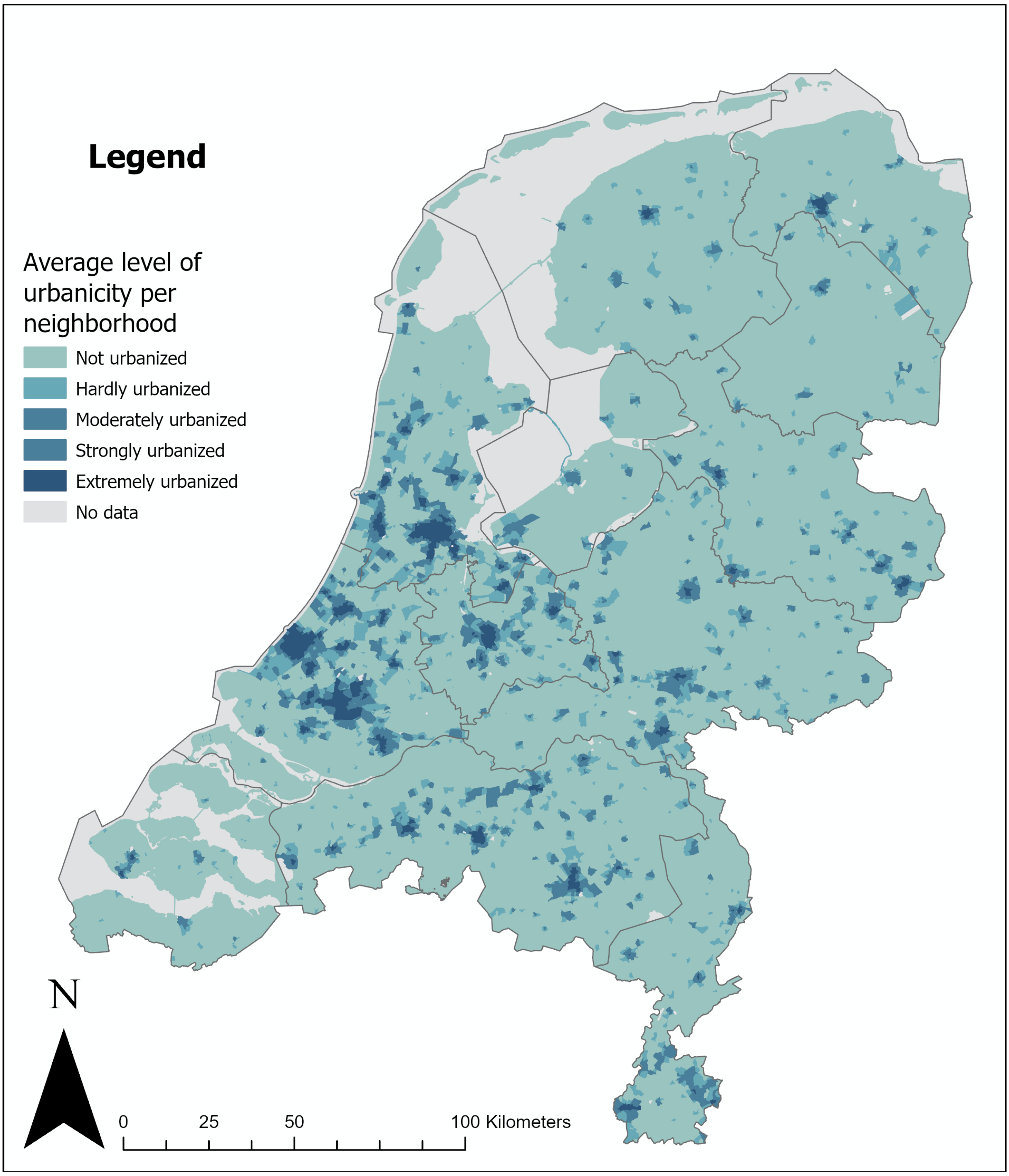

Figure 9: Map of the average level of urbanicity per neighborhood in the Netherlands for the year 2021. Source: own work, 2023

3 Global OLS regression analysis

3.1 Distribution of the residual

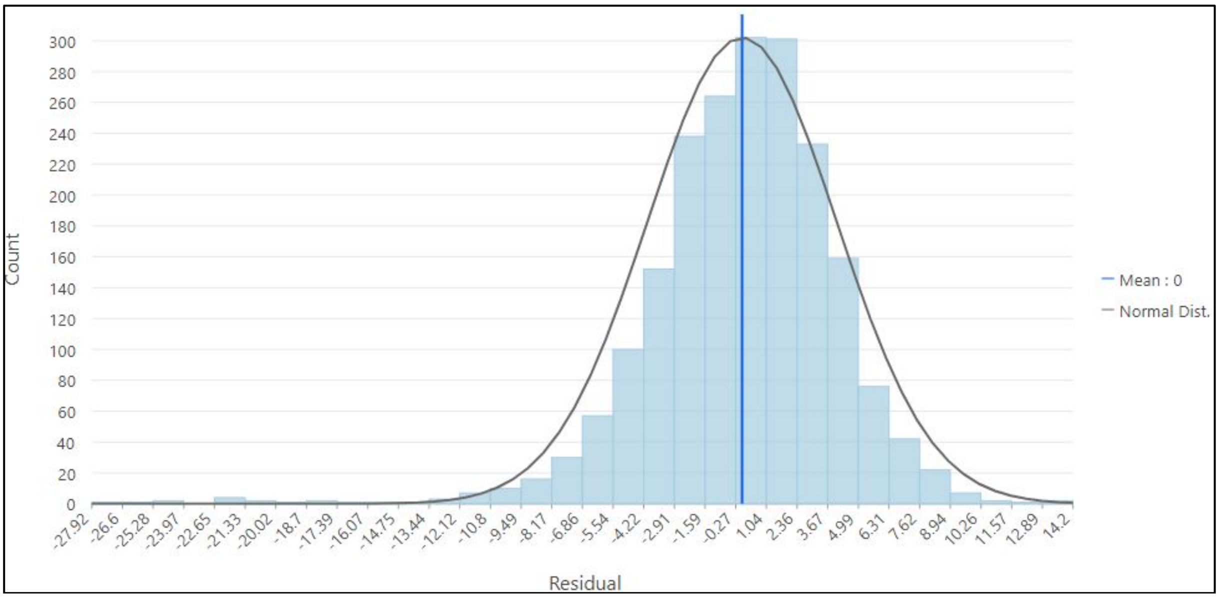

Figure 10: Distribution of the residual. Source: own work, 2023

3.2 Standardized residual

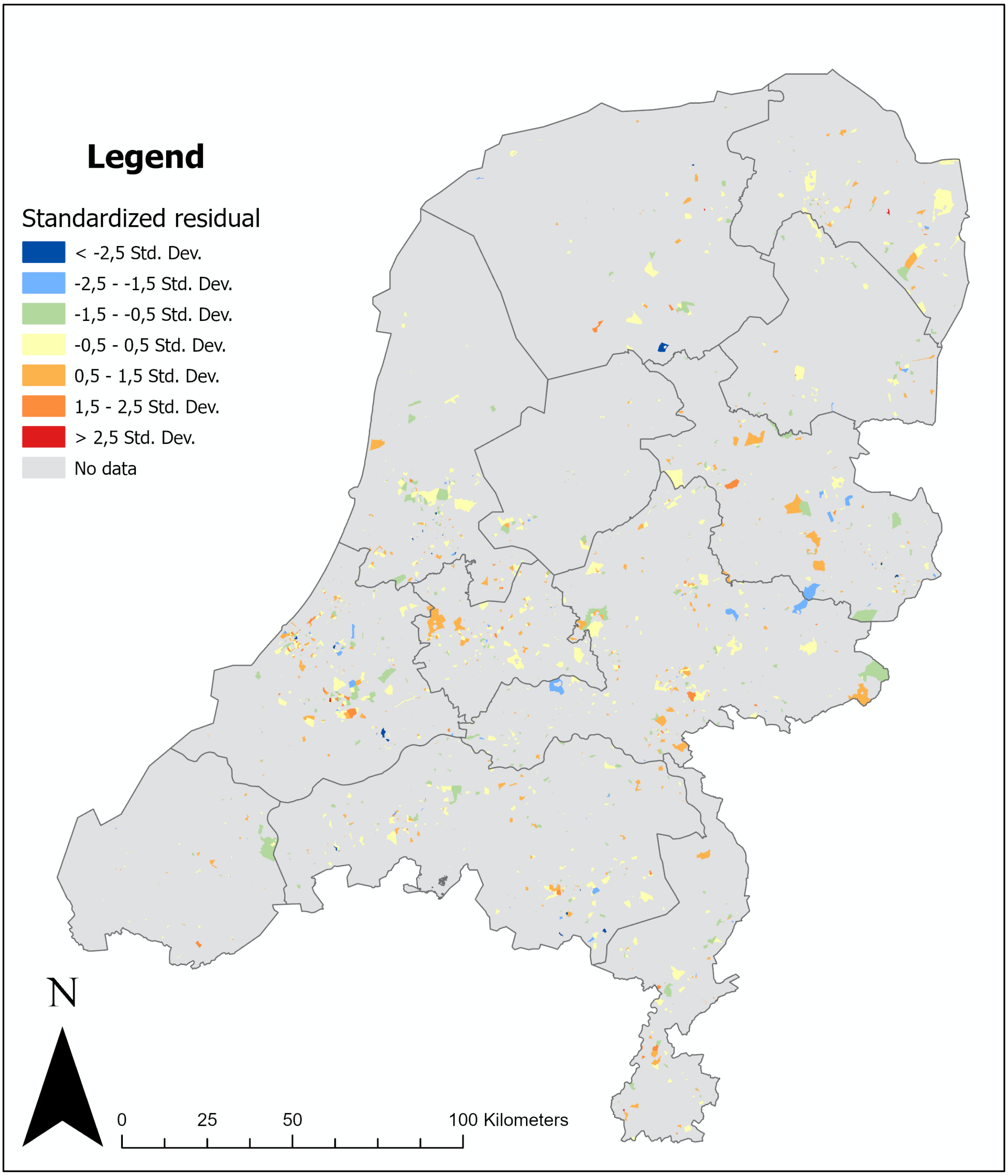

Figure 11: Map of the distribution of the standardized residual values per neighborhood in the Netherlands. Source: own work, 2023