ParagraphS
Paragraphs Environmental Design

Original Research

DOI: 10.5281/zenodo.24161798

OPEN ACCESS

***CORRESPONDENCE**
Jonas Spence-Sales
jonasspence568@outlook.com

RECEIVED: May 2025
ACCEPTED: May 2025
PUBLISHED: July 2025

ISSN-L 2960-2874

VOLUME 3, ISSUE 3
2025

MANUSCRIPT INFORMATION
Main text: 8,550 words | Evidence cutoff: 31 December 2024

CITATION
Spence-Sales J. (2025). Park and Open-Space Provision in Relation to Population Growth in Singapore: An Analysis of Official Statistics. Paragraphs Environmental Design, 3(3), 79-97. DOI: 10.5281/zenodo.24161798.

COPYRIGHT
© 2025 Spence-Sales J. This is an open-access article distributed under the terms of the Creative Commons Attribution License (CC BY). The use, distribution or reproduction in other forums is permitted, provided the original author(s) and the copyright owner(s) are credited and that the original publication in this journal is cited, in accordance with accepted academic practice. No use, distribution or reproduction is permitted which does not comply with these terms.

Park and Open-Space Provision in Relation to Population Growth in Singapore: An Analysis of Official Statistics

Jonas Spence-Sales*

Professor of Architectural Science,
Toronto Metropolitan University, formerly Ryerson

Abstract

Singapore's reputation for urban greening raises an empirical question: has the provision of parks and open space kept pace with population growth? This article examines seven paired observations of National Parks Board maintained park and recreational open-space area and official population estimates for 2010, 2015, and 2020-2024. It distinguishes an operational land-maintenance series from the broader park provision indicator used in national planning. Between the first and last observations, reported maintained area increased from 2,236.00 to 3,326.02 hectares, while total population increased from 5.077 million to 6.037 million. The resulting ratio rose from 0.440 to 0.551 hectares per 1,000 people, an increase of 25.09%. This overall improvement conceals a 2.54% decline between 2010 and 2015. Moreover, most of the ratio's improvement between 2020 and 2021 arose arithmetically from population contraction rather than additional maintained area. Resident-only denominators produce higher provision levels and reverse the direction of the early-period finding. These results establish an expansion of reported administered provision relative to population over the full period; they cannot establish equivalent improvements in local accessibility, recreational capacity, environmental quality, or equity. A review of Singapore scholarship explains why those outcomes require different measures and sometimes yield different assessments. The article proposes a reporting framework that retains transparent area-to-population accounting while adding consistent land classifications, pedestrian access, usable capacity, and distributional evidence. Singapore's experience supports a conditional conclusion: aggregate provision improved over the selected period, but a defensible assessment of adequacy requires explicit decisions about which land, which people, which dates, and which public benefits are being measured.

Keywords: Singapore; parks; open space; population growth; official statistics; accessibility; spatial equity

Introduction

Population growth creates a continuing obligation to examine whether urban public resources expand with the people they serve. Parks are especially useful for investigating this relationship because their area can be measured, their provision involves deliberate land allocation, and their benefits extend beyond a single municipal function. Nevertheless, a larger park estate does not automatically mean more space per person, while a larger per-capita estate does not guarantee that a nearby park is usable when needed. These distinctions matter in Singapore, where land-intensive public amenities coexist with dense development. The appropriate research problem is therefore more specific than whether Singapore is becoming greener. It concerns whether a clearly defined component of park and open-space provision has grown faster than a clearly defined population, and how far that arithmetic can support judgments about urban well-being. Establishing this narrower relationship is a necessary foundation for broader assessment, even though it cannot complete that assessment alone.

The historical scholarship provides a reason to investigate rather than presume success. P. Y. Tan et al. (2013) found that increasing park land could coexist with pressures on per-capita provision and differences between planning areas. Their account is relevant because it identifies a mechanism through which an expanding green estate can still fall behind demand. However, its findings describe an earlier period and cannot determine the position at the end of 2024. Repeating the earlier conclusion without updating the evidence would obscure subsequent changes, just as invoking Singapore's greening reputation would prejudge the outcome in the opposite direction. This article consequently treats the historical study as a question-generating baseline. It asks whether a later, explicitly documented sequence of official observations supports the same relationship, and whether the answer remains stable when the denominator and observation window change.

The title's reference to open space requires a deliberate boundary. An analysis could include recreation grounds, nature reserves, roadside planting, private gardens, vacant vegetated land, or building greenery, depending on the purpose of the inquiry. These categories can contribute to urban environmental conditions, but they have different ownership, accessibility, permanence, and recreational functions. Combining them into one total would give an apparently comprehensive result while weakening its meaning. The principal empirical series used here is therefore the National Parks Board's category covering maintained parks, playgrounds, open spaces, fitness corners, and park connectors, excluding the separately reported nature reserves. This is a substantive part of Singapore's provision, rather than a census of every open space in the country. The broader subject is addressed by explaining how that measured component relates to other forms of provision and why these forms cannot be substituted without qualification.

Three research questions organize the analysis. First, how did the reported maintained area change relative to total and resident population across the selected observations? Second, how sensitive are conclusions to the period examined, population composition, and timing of measurement? Third, what do the resulting ratios establish about adequacy when considered alongside Singapore's research on accessibility, quality, and equity? The questions are related, but they require different kinds of evidence. Official aggregate statistics can answer the first and illuminate the second, whereas the third requires interpretation informed by studies that observe spatial or experiential conditions directly. Keeping these evidentiary roles separate prevents national totals from being used to assert outcomes they do not measure. It also allows the article to extract useful findings from aggregate records without presenting their limitations as a reason to disregard them.

The article's contribution is a reproducible, definition-conscious reassessment using material published by 31 December 2024. Its originality lies in the integration of official stock accounting, alternative population denominators, period comparisons, and a critical reading of what these indicators signify. It does not claim to introduce a new spatial dataset or estimate the causal effect of a particular programme. Such claims would require information and research designs beyond the assembled records. The analysis instead shows that several apparently conflicting accounts can each be correct within their stated scope:

maintained area can rise, total-population provision can temporarily fall, resident-population provision can rise, and local inequality can remain unresolved. The value of the comparison is to make these relationships explicit and to identify the additional evidence required for decisions about future provision.

Literature and analytical framework

The distinction between aggregate expansion and per-capita provision is established in Singapore's urban greening literature. P. Y. Tan et al. (2013) examined the development and distribution of greenery over several decades and drew attention to pressures associated with increasing density. Their findings justify evaluating the denominator rather than treating hectares added as sufficient evidence of improved provision. Yet a historical relationship between density and green-space ratios does not establish an immutable constraint: institutions can allocate additional land, alter its management, or connect existing spaces. The analytical implication is to test whether area growth exceeded population growth in specified intervals, without assuming that either growth process determines the other. This formulation makes the proposition falsifiable through arithmetic while reserving explanations of policy effectiveness for evidence capable of identifying them.

Spatial scale is another source of disagreement in assessments of provision. P. Y. Tan and Samsudin (2017) showed that evaluations of park equity changed with the geographic units used, with population-based indicators particularly sensitive to smaller-scale differences. This challenges an interpretation in which a favourable national ratio demonstrates fair distribution. It does not, however, make the national ratio meaningless: the total stock still constrains what can be distributed, and national planning can influence local opportunities. The two scales answer different questions. National accounting establishes the aggregate resource relative to potential demand, while neighbourhood analysis examines the pattern of access to that resource. A sound evaluation therefore preserves both levels rather than expecting one measure to resolve the other, and it interprets any local conclusion at the geographic scale actually investigated.

The type of space also changes the distributional result. Nghiem et al. (2021) distinguished managed vegetation, natural vegetation, and blue space around homes, examining availability at several distances. They found that equity depended on both spatial scale and environmental category. Their work supports caution about translating the availability of any vegetation into the availability of a public recreational park. Equally, household surroundings can offer useful environmental benefits without being formally classified as parkland, so an exclusive focus on parks can omit part of people's exposure to nature. The synthesis is functional: classification should follow the outcome under examination. An official park-area series is appropriate for administered provision, whereas assessments of everyday environmental exposure require a broader but carefully specified inventory. A single green-space total cannot perform both tasks reliably.

Evidence about ecosystem services prevents an automatic inference that uneven land distribution produces identical social inequalities in every environmental benefit. Law et al. (2022) found little evidence of socioeconomic inequity in modelled supplies of five regulatory ecosystem services in Singapore, despite substantial geographic variation. That finding complicates a blanket claim that urban greening necessarily privileges affluent households. It also has limits: modelled service supply differs from experienced exposure, service demand, and observed health outcomes. Read alongside the park-equity studies, the result indicates that the distribution of hectares, the distribution of recreational opportunities, and the distribution of regulatory services need not coincide. This article therefore treats equity as an empirical question whose answer depends on the benefit and population being assessed, rather than as a property that can be inferred from greenery alone.

Research on recreational opportunity further distinguishes proximity from the conditions encountered after arrival. Guo et al. (2024) evaluated park equity in Singapore through opportunities and environmental quality within a ten-minute walking framework, identifying an important role for community parks. This supports attention to the composition of the park network,

especially spaces serving routine neighbourhood use. Nevertheless, a finding favouring community parks for one distributional objective does not establish that regional parks are dispensable; different spaces accommodate different activities and ecological functions. The implication is to assess a portfolio of provision. Local parks can serve frequent short visits, while larger sites can support activities or habitats requiring more extensive areas. Aggregate land expansion becomes more informative when accompanied by evidence about which part of that portfolio expanded and whose opportunities changed.

The health literature reinforces the importance of choosing a measure suited to the claimed outcome. Zhang and Tan (2019) found that associations between urban green space and health depended on analytical scale and the way greenery was measured. Zhang et al. (2021), using a survey of 1,000 people, found that canopy cover and perceived usage quality at a 400-metre scale were associated with mental health; none of the tested green-space indicators was significantly associated with general health. These observational findings do not permit the conversion of an additional hectare into a predictable health improvement. They do indicate why a national park-area ratio is an incomplete exposure measure: canopy, perceived usability, and the environment close to home can matter differently from nominal acreage. The appropriate inference is therefore conditional. Additional provision creates potential opportunities for beneficial experience, but the realization of those opportunities must be investigated rather than presumed.

Land-cover research offers another necessary qualification. Gaw et al. (2019) developed a detailed map of Singapore's terrestrial ecosystems, distinguishing ecological types rather than merely reproducing administrative park categories. Such mapping can reveal vegetation that an agency maintenance inventory excludes and can differentiate environments within a single park. However, the use of imagery from 2003-2018, reported overall classification accuracy of 79%, and absence of direct access information prevent its straightforward substitution for an annual public-park stock. The two approaches should be related through an explicit classification crosswalk. Administrative records identify responsibility and reported area; remotely sensed land cover identifies physical surfaces and vegetation types. Their combination could substantially improve evaluation, but adding their totals without checking overlap would create double counting and obscure the particular resource available to the public.

Networks and cultural values explain why equal areas can have unequal practical significance. K. W. Tan (2006) described the development of Singapore's greenway network and the coordination involved in using linear corridors. Thiagarajah et al. (2015) examined changing cultural ecosystem-service values, showing that relationships to environmental places evolve historically. A connector that makes an existing park easier to reach or a familiar landscape that retains cultural meaning can therefore matter without producing a large change in total hectares. Conversely, neither connectivity nor attachment can be assumed simply because a space is designated. The analytical framework adopted here consequently separates stock, access, experience, and distribution. Area-to-population accounting addresses the first relationship; the literature supplies reasons to investigate the others through suitable evidence. This preserves a measurable national question while avoiding an unjustified claim that all relevant benefits are interchangeable.

Institutional context and the meaning of provision

Singapore's planning documents recognize that park provision has several dimensions. The Sustainable Singapore Blueprint 2015 reported 4,040 hectares of park space for 2013 and set a 2030 park provision target of 0.8 hectares per 1,000 population; it also specified a household walking-access target and a park connector target (Ministry of the Environment and Water Resources & Ministry of National Development, 2014). These indicators suggest that official policy itself extends beyond land totals. Nevertheless, their coexistence can generate confusion if figures with different definitions are treated as parts of one homogeneous series. The appropriate interpretation is that they describe complementary planning objectives. A park-area indicator

addresses aggregate supply, a walking indicator addresses proximity, and a connector indicator addresses a component of the network. Evidence of achievement in one dimension cannot settle performance in another.

The operational statistics require particular care because the word provision can conceal the difference between an estate maintained by an agency and a broader planning inventory. The former is suitable for examining recorded responsibilities and their evolution. The latter may include a different set of publicly accessible spaces and is the relevant basis for evaluating its own planning target. A numerical comparison between the operational ratio calculated here and the 0.8-hectare target would therefore be invalid without a documented reconciliation. This is not a minor technical reservation: a change of numerator can alter the apparent verdict even when the population denominator is unchanged. The article accordingly retains the operational series under its own name and presents official planning achievements separately where available, rather than manufacturing a national deficit from incompatible quantities.

Nature reserves present a related distinction. Their protection, habitat functions, and opportunities for selected forms of recreation make them important to Singapore's wider open-space system. However, counting an entire reserve as freely usable recreational surface would ignore conservation objectives, access restrictions, and the fact that only part of a site may be appropriate for intensive use. The maintained-area category in the principal analysis excludes the reserves reported separately by NParks. This exclusion should not be interpreted as a judgment that reserves have no public value. It is a decision to avoid treating different forms of environmental provision as equivalent units of recreational capacity. Any combined total would therefore have a changed meaning and would require its own justification, rather than serving as a corrected version of the principal series.

Linear spaces further complicate intuitive interpretations of area. Park connectors may occupy relatively little land while making a larger network reachable, and their inclusion in the maintained-area category captures part of that physical estate. Yet additional kilometres cannot simply be converted into equivalent hectares of parkland without information about widths, surfaces, access, and overlap with the recorded area. Nor does a longer network necessarily eliminate missing crossings or difficult junctions. For these reasons, the length of connectors is treated as complementary descriptive evidence. Its significance lies in the possibility of improving movement between places, which must be evaluated through actual routes. The inclusion of both area and length in a reporting system is therefore useful provided that each retains its unit and its distinct interpretation.

The population side of the comparison also involves institutional definitions. Official resident population comprises citizens and permanent residents, whereas total population additionally includes non-residents such as foreign workers, dependants, and students (National Population and Talent Division et al., 2024). Resident counts are valuable for demographic and household planning, but public parks can also serve people outside that administrative category. Conversely, the total count still does not measure actual park users or include every temporary visitor. The principal denominator is consequently total population, interpreted as a broad measure of potential demand from people ordinarily living in Singapore. Resident population is retained as a sensitivity comparison. This arrangement makes the inclusion decision visible and prevents administrative categories from silently becoming assumptions about who needs access to public space.

Policy targets also evolve, making the publication date part of the indicator's meaning. NParks' 2020/2021 report presented a 2030 aspiration of full household coverage within a ten-minute walk of a park, compared with the earlier blueprint's 90% target (National Parks Board, 2021). An assessment that mixes these targets could misleadingly describe either an improvement or a missed commitment. The relevant comparison must identify the target version, reference year, denominator, and method. This article restricts its documentary evidence to publications available by the end of 2024 and distinguishes reported achievements from future commitments. That boundary permits a historically coherent assessment while recognizing

that policy ambition is itself a changing object of analysis rather than a timeless standard against which every earlier observation should be judged.

Data and methods

The study is a descriptive secondary analysis of official publications, supported by a focused review of Singapore scholarship. The documentary cutoff applies to both statistical reports and literature: publications after 31 December 2024 are excluded from the evidence base. This restriction does not require every underlying observation to come from 2024; historical observations are necessary to examine change. Conversely, a current website displaying an older year is not automatically an acceptable historical source if its dataset has subsequently been revised. The analysis therefore prioritizes dated annual reports and population publications. This choice supplies a traceable record of the figures actually used, while acknowledging that later revisions could be relevant to a different study. The result is an assessment bounded by the selected publications rather than a claim to reconstruct every statistic available at every earlier moment.

Seven paired observations are assembled for 2010, 2015, and each year from 2020 through 2024. These provide two longer intervals and a closer view of the pandemic and subsequent population recovery. The selection is not a complete annual series, and the five-year gaps must not be interpreted as periods of uninterrupted change. Its advantage is a compact set of individually verifiable observations; its cost is the inability to locate fluctuations within the longer intervals. Accordingly, comparisons describe endpoint changes, and any connecting lines in a figure indicate the order of observations rather than estimated annual values. No missing year is interpolated. This design is sufficient to test whether endpoint provision ratios rose or fell, although a claim about the timing of a turning point would require a more continuous, harmonized record.

For each observation, the numerator is NParks' reported area of maintained parks, playgrounds, open spaces, fitness corners, and park connectors. The corresponding annual reports are those for 2009/2010, 2014/2015, and 2019/2020 through 2023/2024 (National Parks Board, 2010, 2015, 2020, 2021, 2022, 2023, 2024). The category remains recognizable across the reports, but this continuity does not guarantee unchanged site boundaries, classification, or management responsibility. Earlier footnotes also specify components of reserve exclusions differently. The observations are consequently treated as comparable published administrative stocks with a residual harmonization limitation, rather than as a surveyed constant-boundary land-cover series. Growth means growth in reported maintained area; it is not automatically the amount of newly created physical parkland. This distinction is carried into the interpretation of every change estimate.

Population observations come from the 2015, 2021, 2022, and 2024 editions of Population in Brief, which reproduce official demographic statistics and distinguish total from resident population (National Population and Talent Division et al., 2015, 2021, 2022, 2024). These publications report the required figures in thousands, usually to one decimal place. That rounding is retained in the input data rather than replaced by invented precision. The numerator is a stock at 31 March, whereas population is measured at end-June of the same calendar year. For example, March 2024 is three months from June 2024, compared with nine months from June 2023; the same-calendar-year pairing reduces but does not remove the timing difference. The calculated ratios are therefore paired annual indicators, not exact simultaneous observations. In rapidly changing years, especially around the pandemic, that qualification becomes substantively important.

The principal provision indicator is maintained area divided by population expressed in thousands. If A denotes hectares and P denotes persons, the ratio q equals 1,000 multiplied by A divided by P. Multiplying q by ten expresses the same quantity in square metres per person. A resident-based ratio replaces P with the resident count R. These are simple transformations, but they prevent two common mistakes: confusing hectares per thousand with square metres per person, and switching population definitions without changing the interpretation. They also reveal why the resident-based ratio must be larger

10.5281/zenodo.24161798

whenever non-residents are present. The difference is mathematical and does not demonstrate better provision for residents in practice. Both groups may use the same estate, so the alternative denominator is an analytical scenario rather than an observed allocation of land.

$$q(T,t) = 1{,}000\ A(t) / P(t);\ q(R,t) = 1{,}000\ A(t) / R(t)$$

$$m^2 \text{ per person} = 10\ q(T,t)$$

$$q(T,1) / q(T,0) = [A(1) / A(0)] / [P(1) / P(0)]$$

$$\ln[q(T,1) / q(T,0)] = \ln[A(1) / A(0)] - \ln[P(1) / P(0)]$$

$$A^*(1) = A(0)\ P(1) / P(0)$$

Here A is area in hectares; P and R are total and resident population in persons; T and R identify the denominator; and A* is the constant-baseline comparison. When population is entered in thousands as in Table 1, divide hectares directly by that published population figure.

Percentage changes are calculated from unrounded ratios. To assess whether provision kept pace, the ratio change is compared with the relative growth of area and population: a positive change occurs when the area's proportional growth exceeds the population's proportional growth. Absolute additions are also reported because the same percentage can represent very different amounts of land. For selected periods, the accounting identity linking logarithmic changes separates the contribution of the numerator from that of the denominator. This is a decomposition of a quotient, not an estimate of causal influence. A fall in population can raise the ratio mechanically without a corresponding improvement in the park experience. Interpreting the identity in this restricted way makes it useful for identifying misleading narratives while avoiding the stronger claim that demographic change alone explains how people actually use parks.

A constant-baseline comparison supplies a further interpretation of the full-period change. The 2010 ratio is multiplied by the 2024 population to calculate how much maintained area would have been required to preserve that initial ratio. The difference from reported 2024 area is a benchmark comparison, not a measure of excess or disposable land. Its purpose is to distinguish the area associated arithmetically with population growth from the amount above the initial per-capita level. This benchmark also has a normative limitation: the initial ratio may have been inadequate, unevenly distributed, or poorly matched to user needs. The calculation consequently answers whether the reported estate outgrew one historical baseline. It cannot establish that the additional area meets a socially desirable standard or that further provision is unnecessary.

No regression, significance test, or causal policy model is fitted to the seven observations. A small aggregate sequence with shared time trends, irregular intervals, and administrative classification uncertainty would not justify causal interpretation, even if a fitted relationship appeared strong. The official counts are also not a random sample for which conventional sampling confidence intervals would resolve the main uncertainty. Relevant uncertainty instead concerns definitions, dates, population coverage, and the relationship between recorded area and usable capacity. The study addresses those issues through transparent source tables, alternative denominators, period comparisons, and explicit limitations. This approach sacrifices a superficially elaborate statistical model in favour of results whose meaning follows directly from the observations and whose restrictions remain visible to the reader.

Results

Table 1 presents the seven observations and derived ratios. The reported maintained area increased from 2,236.00 hectares in March 2010 to 3,326.02 hectares in March 2024. Total population increased from 5,076.7 thousand to 6,036.9 thousand, yielding 4.404 and 5.509 square metres per person respectively. These endpoint values support an improvement in reported aggregate provision relative to total population. However, the conclusion applies to the specified maintained category and paired dates; it does not describe every public green space or an individual's accessible share. The meaningful empirical finding is therefore bounded but clear: the administered estate represented in this series expanded proportionately faster than the total

population between the first and last observations. Questions about the practical distribution of that gain require further evidence.

Table 1. Maintained area and population at selected observations

Year	Maintained area (ha)	Total population (thousands)	Resident population (thousands)	Ha per 1,000 total population	Ha per 1,000 residents
2010	2,236.00	5,076.7	3,771.7	0.4404	0.5928
2015	2,376.00	5,535.0	3,902.7	0.4293	0.6088
2020	2,774.35	5,685.8	4,044.2	0.4879	0.6860
2021	2,794.33	5,453.6	3,986.8	0.5124	0.7009
2022	2,935.66	5,637.0	4,073.2	0.5208	0.7207
2023	3,235.62	5,917.6	4,149.3	0.5468	0.7798
2024	3,326.02	6,036.9	4,180.9	0.5509	0.7955

Note. Area is measured at 31 March and population at end-June of the stated year. Maintained area includes parks, playgrounds, open spaces, fitness corners, and park connectors, excluding separately reported nature reserves. Population figures retain published rounding. Sources: National Parks Board (2010, 2015, 2020, 2021, 2022, 2023, 2024); National Population and Talent Division et al. (2015, 2021, 2022, 2024). Ratios are calculated for this article. See Appendix A for source locations.

Over the full interval, reported area grew by 48.75%, total population by 18.91%, and the total-population provision ratio by 25.09%. The proportional difference is large enough to reject the proposition that this series merely kept pace with the denominator at its 2010 level. Nonetheless, the unequal growth rates should not be read as an estimate of policy efficiency or as proof that population growth caused additional provision. Both could reflect multiple planning, demographic, and administrative processes. The constant-baseline calculation clarifies the narrower result: maintaining the 2010 ratio for the 2024 population would require 2,658.91 hectares, compared with the reported 3,326.02 hectares. The 667.11-hectare difference indicates provision above that historical accounting baseline. It is not a surplus available for redevelopment, because neither the adequacy nor the distribution of the baseline has been established.

The earlier subperiod yields a different finding. From 2010 to 2015, maintained area rose by 140 hectares, or 6.26%, while total population grew by 9.03%. Consequently, the ratio fell from 0.4404 to 0.4293 hectares per thousand, a decline of 2.54%. An account based solely on hectares added would miss this deterioration in the population-adjusted indicator. Yet the decline cannot establish worsening access or crowding in every neighbourhood; new sites could have improved provision for particular communities even while the national ratio fell. The appropriate synthesis is a period-specific one: reported stock expansion did not keep pace with total population over these endpoints, and that finding is compatible with localized improvements. It also demonstrates why the longer-period result should not be described as continuous progress since 2010.

The following five-year interval reverses that relationship. Between 2015 and 2020, maintained area increased by 16.77%, while total population increased by 2.72%, producing a 13.67% rise in the ratio. This improvement exceeds the preceding interval's decline, explaining why the 2020 ratio stood above its 2010 value. Nevertheless, two endpoints cannot reveal whether additions were evenly distributed across the five years or concentrated near one endpoint. Nor do they identify how much of the increase came from new facilities, expanded boundaries, or responsibility transfers. The result establishes that reported area growth overtook population growth over this particular interval. Its explanatory value lies in identifying when the endpoint relationship

changed, while its limits prevent the assignment of that change to a specific project or administrative decision without additional records.

The 2020-2021 comparison illustrates the danger of interpreting a ratio as a direct measure of investment. Maintained area increased by only 19.98 hectares, or 0.72%, while total population fell by 4.08%; the ratio nevertheless rose by 5.01%. Holding area at the 2020 level while using the 2021 population would produce 0.5087 hectares per thousand, close to the observed 0.5124. Expressed as 100 times the logarithmic change, the ratio improvement comprises approximately 0.718 log-percentage points from area growth and 4.170 from population contraction; their sum differs from ordinary percentage growth because the transformation differs. Official demographic reporting relates the population decline to pandemic-era conditions (National Population and Talent Division et al., 2021). The arithmetic therefore identifies a predominantly denominator-driven improvement in this indicator. It does not establish an equivalent improvement in park access, particularly when travel conditions and the organization of everyday activity were also changing.

Population recovery did not erase all of the subsequent gain. Between 2021 and 2024, total population increased by 10.70% and maintained area by 19.03%, leaving the ratio 7.53% higher. This matters because an improvement caused only by a temporary population fall would be vulnerable to reversal as the denominator recovered. The observed endpoint pattern instead includes further expansion of the reported estate. However, its pace varied: between 2023 and 2024, area growth of 2.79% only moderately exceeded population growth of 2.02%, producing a ratio increase of 0.76%. These comparisons support a sustained net improvement across the selected recent observations, while showing that the margin over population growth can narrow. They offer no basis for assuming that the same margin will persist under future demographic or land-allocation conditions.

Table 2. Changes in maintained area, total population, and provision

Interval	Area change (%)	Total population change (%)	Provision ratio change (%)
2010-2015	+6.26	+9.03	-2.54
2015-2020	+16.77	+2.72	+13.67
2020-2021	+0.72	-4.08	+5.01
2021-2022	+5.06	+3.36	+1.64
2022-2023	+10.22	+4.98	+4.99
2023-2024	+2.79	+2.02	+0.76
2010-2024	+48.75	+18.91	+25.09

Note. Changes are cumulative over each interval, not annualized. Provision uses total population. Calculations use the unrounded ratios derived from Table 1; the final row is the full-period comparison.

Resident-only denominators alter both the magnitude and, in the earliest interval, the direction of the result. The resident-based ratio increased from 0.5928 hectares per thousand in 2010 to 0.7955 in 2024, a rise of 34.19%. During 2010-2015 it increased by 2.69%, even though the total-population ratio declined by 2.54%. This is not a contradiction: resident population grew more slowly than total population. It is nevertheless consequential because an unannounced denominator choice could reverse the answer to whether provision kept pace. The 2024 resident-based figure also happens to approach the numerical value of the 0.8 planning target. That proximity does not validate a target-compliance claim, since neither the numerator's coverage nor the target denominator has been reconciled. The comparison demonstrates sensitivity to population

inclusion rather than evidence of a separate resident entitlement.

The official planning indicator reinforces the importance of keeping inventories distinct. NParks reported a park provision ratio of 0.81 hectares per thousand as a 2022 achievement, alongside 94% of households within a ten-minute walk of a park (National Parks Board, 2023, pp. 54-55). The operational ratio calculated here for the March/June 2022 pairing is approximately 0.521. Different reference dates may contribute to differences, but the two values should not be treated as alternative calculations of a known identical inventory. The official 0.81 exceeds the stated 0.8 target numerically under that indicator's own reporting framework; it does not establish that every neighbourhood is adequately served. Equally, the lower operational ratio cannot establish a national policy shortfall. The defensible conclusion is to report both with their own labels and require an explicit inventory reconciliation before comparing them.

Figure 1 summarizes the divergence between stock growth and population growth without converting the selected observations into an annual series. The indexed estate rises more rapidly than total population over the complete interval, while the early relative decline remains apparent in the ratio panel. The visual comparison is useful because absolute hectares and population cannot share a meaningful numerical scale without transformation. Its limitation is that an index removes the absolute size of the quantities and can make differently defined series look more comparable than they are. The figure is therefore read alongside Table 1, which retains the original units and denominators. Together they show a measurable aggregate improvement and its period sensitivity, rather than a comprehensive performance score for Singapore's entire open-space system.

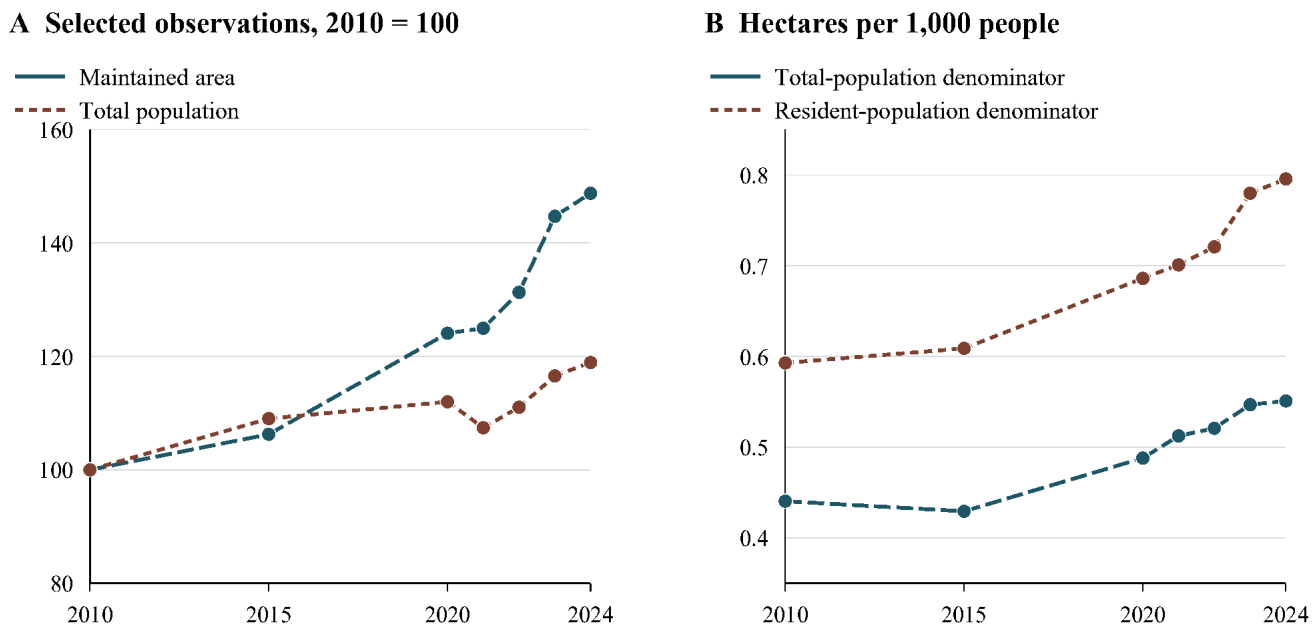


Figure 1. Maintained area, population, and denominator-sensitive provision

Note. Dots represent the seven observed pairs in Table 1. Segments only connect those observations; no annual values are interpolated. Panel A indexes area and total population to 2010 = 100. Panel B compares provision ratios using the same area and alternative population denominators. Source: calculations from Table 1.

The magnitude of denominator sensitivity can also be expressed without making assumptions about visitor behaviour. In 2024, dividing the same maintained area by resident population rather than total population raises the reported ratio by approximately 44.39%. That difference follows from the ratio between the two population counts, not from an improvement in the land or preferential access for one group. It would therefore be misleading to describe the higher value as evidence that residents enjoy 44.39% better provision. Its analytical value is to quantify

how much an inclusion decision changes the headline. Reporting the two values together makes the consequence visible and invites a substantive justification of the denominator. It also demonstrates why comparisons between cities or studies require aligned population definitions before their numerical rankings can be interpreted.

Interpreting aggregate improvement

The full-period result supports the proposition that demographic growth need not mechanically reduce the reported stock of park space per person. Singapore's maintained estate expanded sufficiently to exceed its initial total-population ratio by the final observation. Nevertheless, this descriptive success does not establish which institutional arrangements produced it, or whether similar growth could be achieved at the same cost elsewhere. Land availability, administrative responsibilities, development sequencing, and the composition of the estate could all affect the observed outcome. The transferable lesson is therefore methodological and conditional: population pressure should be evaluated against observed supply responses, rather than treated as an inevitable cause of deterioration. Singapore provides evidence that administered provision can outgrow population over a specified period, while leaving the causal explanation and comparative efficiency of that response open to further investigation.

The coexistence of national improvement and unresolved local access is a matter of aggregation rather than a paradox. Consider a hypothetical addition situated far from a rapidly growing residential area. It would raise the national ratio even if residents of that area experienced no improvement in their ordinary walking opportunities. Conversely, a small local park could improve daily access substantially while barely changing the national indicator. Neither example describes a documented Singapore project; together they show why the geographical placement of additions matters. The scale-sensitive findings in the literature make this more than an abstract concern, but they do not supply a current map of the gains measured here. The appropriate next analytical step is to locate additions and relate them to population change in their catchments, retaining the national account as a control total rather than using it as a proxy for every locality.

Spatial adequacy also depends on competition for the same accessible space. A park can lie within walking distance of many households while offering limited capacity for the activities they wish to undertake at the same time. A proximity indicator would register those households as served, even though queues, conflicts between uses, or crowding could remain. Yet a simple division of local hectares by neighbouring population would also be imperfect because visitors travel across catchment boundaries and activities occupy different amounts of space. The implication is to distinguish access opportunity from service capacity. A future assessment could combine entrances and pedestrian routes with usable recreation areas and time-specific visitor observations. Such a design would investigate whether a nominally accessible park can accommodate routine demand, rather than assuming that distance or area alone resolves the question.

Population composition complicates that demand assessment. The difference between total and resident ratios demonstrates that administrative inclusion changes the national result, but it does not show how frequently any group visits a park. Non-residents include people with varied employment conditions, housing locations, schedules, and household circumstances. Treating them as a single observed demand category would therefore be as unwarranted as omitting them entirely. A useful planning principle is to begin with an inclusive potential-demand denominator and then investigate actual patterns without assuming uniform behaviour. The proposed extension would sample people across relevant living and working arrangements and times of use. This would allow provision to be evaluated against experienced opportunities while preserving the distinction between a statistical population category and evidence about the needs of the people within it.

Age structure adds a separate dimension that population totals cannot express. Population in Brief 2024 reports that 19.9% of citizens were aged 65 or above, compared with 12.4% in 2014 (National Population and Talent Division et al., 2024). This does not imply that all older people

have the same mobility or recreational preferences, and the figures concern citizens rather than the total population used in the main ratio. They nevertheless provide a reason to examine the suitability of nearby routes and facilities alongside aggregate hectares. Resting opportunities, gradients, shade, and crossing conditions are plausible dimensions for an accessibility audit, rather than benefits demonstrated by the current dataset. The inference is that demographic change can alter the specification of adequate provision even when the per-capita stock improves; a planning framework should therefore examine who can use a space as well as how many people are counted.

Environmental quality changes the practical meaning of time and distance. A route that is short on a map may still be uncomfortable or difficult to use under particular weather or surface conditions, while a shaded route may make an existing destination more usable without increasing park area. These possibilities are consistent with the measurement-sensitive findings of Zhang and Tan (2019) and Zhang et al. (2021), but the present records contain no route-level observations from which to quantify them. The appropriate conclusion is consequently a specification for measurement rather than an asserted effect size. Walking access should be documented through actual entrances, route continuity, and relevant physical conditions, with results reported for distinct user needs where possible. Doing so would explain why equal nominal proximity can produce unequal practical opportunities without discarding the value of a transparent walking-distance indicator.

The estate's internal composition also matters for ecological and recreational objectives. A hectare of intensively used open recreation space and a hectare of habitat managed with limited disturbance can both have public value, yet they are not interchangeable for every purpose. Increasing access to a sensitive site could improve one recreational measure while undermining another objective that justified protection. Conversely, safeguarding habitat can benefit the wider environmental system without expanding the surface available for active recreation. The reported area increase therefore cannot be converted into a uniform increment of recreational capacity or biodiversity value. A more informative account would preserve separate functional categories and record how management changes affect each. This permits a principled assessment of tradeoffs rather than treating every unvisited part of a green estate as underused or every newly accessible part as an unqualified improvement.

The difference between physical creation and administrative recognition deserves equal attention. Transferring an existing open space into NParks maintenance could improve stewardship, establish responsibility, or stabilize access even if no new land is created. Such a transfer is therefore not necessarily an artificial gain with no public benefit. At the same time, it would be misleading to describe the entire increase in a maintenance inventory as newly supplied physical space. This distinction suggests a stock-reconciliation account in which openings, expansions, closures, transfers, and measurement revisions are recorded separately. The current reports provide endpoint stocks, so this article cannot allocate the observed increase among those mechanisms. The defensible synthesis is that growth in administered provision is meaningful, but its physical and institutional components should be documented before it is interpreted as a specific amount of new recreational land.

The results also caution against treating a favourable ratio as evidence that development choices have become costless. An aggregate gain can coexist with the loss of a particular landscape, because a replacement elsewhere may differ in accessibility, habitat, history, or attachment. Thiagarajah et al. (2015) provides a basis for taking the changing cultural significance of places seriously, although it does not quantify the value of any site affected during this study period. The policy implication is to avoid assuming automatic compensation between equal areas. Where development changes the estate, assessment should document which functions are lost, which are added, and which populations experience the change. This does not establish that every loss is unacceptable. It establishes that a positive national balance in hectares is insufficient evidence that the affected benefits have been replaced.

Household coverage and population coverage are also distinct measures of access. A percentage of households weights a small household and a

large one equally, whereas a percentage of persons would weight them according to the people represented. Either measure can be useful, but they need not produce the same estimate. Moreover, the treatment of people living outside conventional households, including dormitory populations, requires explicit metadata before their inclusion can be assumed. This article has not verified the full household-access methodology and therefore does not assert that any particular group is excluded from the official indicator. It identifies a question that matters because the population denominator materially changes the national provision finding. A transparent access report could publish both household and person coverage where feasible and specify how collective living arrangements are represented, allowing its inclusion boundaries to be assessed directly.

The aggregate accounting can be made more informative without constructing a composite index. For example, a proposed local evaluation could separately report the number of people able to reach an entrance, the usable area available within that network, and the observed concentration of visits at busy times. A location might perform well on the first measure and poorly on the second, indicating a capacity issue; another might have ample space but a difficult approach, indicating a route issue. These are diagnostic possibilities rather than findings about particular Singapore neighbourhoods. Their advantage is that each points toward a different intervention, while their limitation is the additional data required to distinguish them. The synthesis is a decision-oriented measurement framework in which each indicator identifies a specific condition that planning can address, rather than merely adding another number to a performance dashboard.

The population represented in research samples requires a similar audit. Nghiem et al. (2021) based their household analysis on citizens and permanent residents, with 1,513 usable survey responses. That design can illuminate differences among the sampled population, but it cannot independently resolve the experiences of non-residents included in the principal denominator of this article. This is a boundary on inference rather than a defect in a study addressing a different question. Connecting the two analyses therefore requires additional evidence rather than an assumption that one population's access pattern applies universally. A subsequent survey could explicitly include groups absent from the earlier sampling frame and investigate whether location, working schedules, or housing arrangements affect opportunities. Such work would test the practical significance of the denominator sensitivity identified here while preserving the validity of findings within each study's original population.

Implications for planning and public reporting

The first reporting priority is a published reconciliation between the maintained-area inventory and the national planning measure. Each should identify eligible spaces, responsible agencies, treatment of connectors and reserves, and the date to which the inventory applies. A reconciliation would explain why two official-looking ratios differ and allow researchers to assess the planning target using its intended numerator. However, the objective should not be to force all environmental land into one definition. Different inventories legitimately serve different purposes. The improvement would be a transparent relationship between them: which categories overlap, which are exclusive, and which are omitted from each total. This would preserve institutional usefulness while preventing analysts from assembling incompatible figures into a misleading time series or interpreting the smaller inventory as proof of failure against the larger inventory's benchmark.

A second priority is to distinguish net stock change from the processes that produce it. An annual account could start with the previous stock, add new openings and boundary expansions, subtract closures or conversions, and identify transfers and measurement revisions separately. The resulting closing stock should reconcile to the published total. Such reporting would make the interpretation of growth more precise and help distinguish physical supply from changes in responsibility. Nevertheless, a reconciliation table alone would not assess the quality of additions or the consequences of losses. It should therefore be accompanied by a site register with stable identifiers and concise functional classifications.

The gain would be practical: readers could reproduce the national total and then examine whether the mechanisms behind it are relevant to the particular outcome they wish to evaluate.

A third priority is to publish synchronized population-adjusted indicators while retaining demographic alternatives. A common reference date would reduce the ambiguity created by March land stocks and June population counts. Where synchronization is infeasible, both dates should be displayed, and the consequences of unusually rapid demographic change should be discussed. Total and resident population ratios can then be reported side by side rather than selected opportunistically according to which produces the more favourable result. This does not imply that every policy must use the same denominator; neighbourhood household access and national potential demand are different questions. It does require an explicit justification for the people included. A stable reporting convention would make changes over time easier to interpret and prevent compositional shifts from being mistaken for changes in the physical resource.

Planning should also make the implications of population scenarios numerically explicit. At the calculated 2024 operational ratio, each additional 100,000 people would require approximately 55.09 hectares in the same maintained category to preserve that ratio. Increases of 250,000 and 500,000 would correspond to approximately 137.74 and 275.47 hectares respectively. These are conditional arithmetic scenarios, not population forecasts or recommendations to allocate those exact amounts. They hold the current ratio, classification, and assumed demand relationship constant, while real planning must also consider location and changing needs. Their value is to expose the scale of a chosen maintenance objective before decisions are made. If planners seek a different level or a different mix of provision, that objective can be stated openly and its land implications calculated on a consistent basis.

Table 3. Illustrative requirements to preserve the 2024 operational ratio

Hypothetical additional population (persons)	Additional maintained area required (ha)	Resulting maintained stock (ha)
100,000	55.09	3,381.11
250,000	137.74	3,463.76
500,000	275.47	3,601.49

Note. Illustrative scenarios hold the 2024 operational ratio constant at its unrounded value, 0.550948 hectares per 1,000 total population. These are neither forecasts nor assessments against the separate national planning target.

Headline accessibility reporting should be accompanied by a stable, readily accessible technical specification of how coverage is measured. Relevant metadata include the definition of a household, the location used to represent it, qualifying park entrances, the pedestrian network, walking-time assumptions, and the treatment of barriers. These details matter because the same ten-minute label can describe different models. At the same time, excessive methodological detail in a public headline can reduce readability. A practical solution is a simple published indicator linked to a stable technical specification and disaggregated results. The headline would remain legible, while independent users could examine how the estimate was produced and which areas or populations remained underserved. Such a system would strengthen the interpretation of reported progress without implying that proximity alone captures capacity or experience.

Investment choices should be informed by the relationship between local need and the functions supplied by different spaces. Evidence from Guo et al. (2024) supports examining community parks within an equity assessment, while the wider literature shows that environmental benefits vary with scale and type. This suggests evaluating improvements to small parks, entrances, connecting routes, and facilities alongside additions of extensive sites. It does not establish that small projects always deliver better outcomes

or that major parks should receive lower priority. A defensible allocation process would compare alternatives using explicit objectives: who gains routine access, which activities become possible, and which ecological functions are maintained. The national area account would then provide a resource constraint and long-term trajectory, while local evidence would guide the placement and character of interventions.

Maintenance deserves a visible place in that allocation process because a recorded hectare can persist while its usability changes. Surface condition, planting management, facilities, and temporary closures can affect the opportunities an existing estate provides without altering its boundaries. Conversely, substantial expenditure may protect current service rather than create new acreage. The present data cannot compare maintenance effectiveness or costs, so they should not be used to infer either declining quality or efficient management. A reporting extension could combine the area inventory with condition audits and availability records, keeping financial inputs separate from service outcomes. This would make it possible to assess whether growth in the estate is accompanied by resources sufficient to maintain its intended functions. It would also avoid rewarding expansion in a performance system that ignores the condition of what already exists.

Distributional reporting should also describe who has participated in defining adequate provision. Technical measures can identify distances and quantities, but they cannot independently determine whether the selected activities, opening conditions, or facilities meet a community's priorities. Consultation offers evidence about those priorities, yet participation can be uneven and should not be treated as a representative survey without an appropriate design. A defensible approach would combine accessible engagement with systematic sampling and publish where the two sources agree or differ. This recommendation follows from the distinction between measured opportunities and experienced needs; it is not an empirical claim that current consultation is deficient. It would enable planning to preserve transparent quantitative standards while testing whether those standards address the practical conditions that different users consider important.

Limitations and further research

The principal limitation is the absence of a fully reconciled inventory with constant coverage across all observations. Category names and exclusion notes support a meaningful administrative comparison, but changes in boundaries or responsibilities could contribute to the recorded growth. This uncertainty does not justify treating the figures as unusable, nor does it permit assuming that all observed growth represents new land. Its appropriate consequence is a limit on the claim: the article establishes a change in reported maintained provision. A useful next study would audit the underlying site register and allocate changes among physical additions, losses, transfers, and revisions. That exercise could determine how much of the 1,090.02-hectare increase reflects each mechanism and whether the direction of the population-adjusted finding persists under a stricter constant-coverage definition.

Temporal alignment is a second limitation with a measurable illustration. Pairing the March 2024 stock with June 2023 population would yield approximately 0.5621 hectares per thousand, compared with 0.5509 using June 2024 population. The earlier denominator is not presented as a better estimate, and these two calculations do not establish bounds on the unknown March population. They show that an alternative date can change the level by more than the small measured increase between the latest two paired observations. The implication is to avoid overinterpreting short-period differences when the observations are not synchronized. A future release with common-date counts, or sufficiently frequent population estimates to support a documented timing adjustment, would strengthen short-run comparisons. The longer-period result remains a comparison of the published endpoints, subject to the same explicit timing convention.

The seven-observation design limits statistical and historical interpretation. It identifies endpoint relationships across the selected intervals but cannot demonstrate annual monotonicity before 2020, estimate a stable response of park supply to

population, or isolate the impact of a named policy. Adding more annual observations would improve temporal resolution, yet it would not solve causal identification by itself. A policy evaluation would need a plausible comparison design, information about project timing, and attention to other changes affecting outcomes. The present evidence is therefore best used to frame hypotheses for more detailed work. For example, researchers could investigate whether additions preceded population growth in developing areas or followed increased demand in established ones, while recognizing that a correlation between project openings and population change would still require careful interpretation.

Finally, the study does not directly measure visitors, accessibility, health, ecological outcomes, or distribution among demographic groups. The literature explains why these distinctions matter but cannot substitute for contemporaneous observations of the specific estate changes analyzed here. This limitation prevents both an unqualified success narrative and an unsupported claim of widespread inequity. It also defines a feasible research programme: connect stable park boundaries to pedestrian networks and disaggregated population data, then add observations of use and condition for selected sites. The objective should be to test whether aggregate gains translate into particular benefits for particular populations. Maintaining this link between the question and the evidence would extend the current analysis without pretending that more elaborate data automatically resolve the normative choices involved in defining adequate provision.

Cross-city comparison is a further application requiring caution. A ratio expressed in the familiar unit of square metres per person can appear ready for international ranking, but its numerator may cover maintained recreation land in one city, all designated parks in another, and vegetation of any ownership in a third. Population may likewise refer to municipal residents, a metropolitan area, or a daytime population. Standardizing the unit alone would leave those differences intact. A useful comparative study would first establish compatible inventories, access rules, geographic boundaries, and population definitions, then report residual differences explicitly. The Singapore figures assembled here could contribute to such work as a well-described component. They should not be presented as a universal green-space score or compared with an alleged international minimum whose provenance and applicability have not been verified.

Conclusion

Singapore's reported NParks-maintained park and recreational open-space estate grew faster than total population between the selected 2010 and 2024 observations. The resulting ratio rose by 25.09%, from approximately 4.40 to 5.51 square metres per person. That finding is substantial, but it describes a particular administrative inventory rather than every publicly accessible green space. It also contains contrasting periods: provision relative to total population declined between 2010 and 2015, while the 2021 improvement was predominantly associated with population contraction. The evidence therefore supports a qualified historical conclusion of aggregate improvement, accompanied by meaningful period and denominator sensitivity. It does not support a claim of uninterrupted progress, a causal attribution to a single programme, or a definitive judgment about experienced adequacy.

The comparison with official planning indicators shows why definitions are part of the substantive argument. A smaller maintenance inventory cannot be evaluated mechanically against a target calculated from a different land base, and a resident-only denominator cannot silently stand in for all potential users. At the same time, the limitations of aggregate statistics should not obscure what they reveal: the relative growth of a documented resource and a documented population can be calculated and checked. The productive synthesis is to retain that accountability while extending the evidence toward accessibility, usable capacity, quality, and distribution. Each addition should answer a defined question rather than contribute to an opaque composite judgment.

Future provision should consequently be evaluated through linked but distinct accounts. A reconciled stock record would explain what land is being counted and why it changed; population scenarios would reveal the requirements of maintaining a chosen level; spatial and observational evidence would show who can use

the resulting spaces and under what conditions. These accounts may yield different findings, and those differences are informative rather than inconvenient. They identify where an expanding estate is producing practical benefits and where additional intervention may be needed. Singapore's official statistics provide a defensible starting point for that inquiry. Their strongest use is to make claims about growth testable while directing attention to the specific evidence needed before growth can be equated with adequate, accessible, and equitable provision.

References

Gaw, L. Y.-F., Yee, A. T. K., & Richards, D. R. (2019). A high-resolution map of Singapore's terrestrial ecosystems. Data, 4(3), Article 116. https://doi.org/10.3390/data4030116

Guo, R., Diehl, J. A., Zhang, R., & Wang, H. (2024). Spatial equity of urban parks from the perspective of recreational opportunities and recreational environment quality: A case study in Singapore. Landscape and Urban Planning, 247, Article 105065. https://doi.org/10.1016/j.landurbplan.2024.105065

Law, A., Carrasco, L. R., Richards, D. R., Shaikh, S. F. E. A., Tan, C. L. Y., & Nghiem, L. T. P. (2022). Leave no one behind: A case of ecosystem service supply equity in Singapore. Ambio, 51(10), 2118-2136. https://doi.org/10.1007/s13280-022-01735-x

Ministry of the Environment and Water Resources, & Ministry of National Development. (2014). Sustainable Singapore blueprint 2015. https://isomer-user-content.by.gov.sg/23/e3b18f21-1688-4e07-902a-1bc06517e8b0/ssb.pdf

National Parks Board. (2010). Annual report 2009/2010. https://www.nparks.gov.sg/-/media/nparks-real-content/about-us/annual-report/archive/2009-2010/nparks_ar0910_facts_figures.pdf

National Parks Board. (2015). Annual report 2014/2015. https://www.nparks.gov.sg/docs/default-source/resources/annual-report/ar-2014-2015/nparks-ar20142015.pdf

National Parks Board. (2020). Annual report 2019/2020. https://www.nparks.gov.sg/docs/default-source/resources/annual-report/ar-2019-2020/ar-2020.pdf

National Parks Board. (2021). Embracing nature: Annual report 2020/2021. https://www.nparks.gov.sg/docs/default-source/resources/annual-report/ar-2020-2021/nparks_annual_report_2020_21-annual-report-pdf_safe.pdf

National Parks Board. (2022). Annual report 2021/2022. https://www.nparks.gov.sg/docs/default-source/resources/annual-report/ar-2021-2022/nparks_ar-2021_fullfs-22-09-29v25lr.pdf

National Parks Board. (2023). A natural transformation: Annual report 2022-2023. https://www.nparks.gov.sg/docs/default-source/resources/annual-report/ar-2022-2023/nparks_ar23_230915_flattened_a.pdf

National Parks Board. (2024). Greening Singapore together: Annual report 2023-2024. https://www.nparks.gov.sg/portals/annualreport/pdfs/NParks-Annual-Report-2023-2024.pdf

National Population and Talent Division, Singapore Department of Statistics, Ministry of Home Affairs, & Immigration & Checkpoints Authority. (2015). Population in brief 2015. https://isomer-user-content.by.gov.sg/520/835e7297-25bc-479d-9492-4f430f8d878c/population-in-brief-2015.pdf

National Population and Talent Division, Singapore Department of Statistics, Ministry of Home Affairs, Immigration & Checkpoints Authority, & Ministry of Manpower. (2021). Population in brief 2021. https://isomer-user-content.by.gov.sg/520/1b525fdb-a2a8-4db8-bf6c-679df7c3eba5/population-in-brief-2021.pdf

National Population and Talent Division, Singapore Department of Statistics, Ministry of Home Affairs, Immigration & Checkpoints Authority, & Ministry of Manpower. (2022). Population in brief 2022. https://isomer-user-content.by.gov.sg/520/5bfee44a-ef96-412d-b873-cba846dabe70/population-in-brief-2022.pdf

National Population and Talent Division, Singapore Department of Statistics, Ministry of Home Affairs, Immigration & Checkpoints Authority, & Ministry of Manpower. (2024). Population in brief 2024. https://isomer-user-content.by.gov.sg/520/23344809-1aee-444b-9d46-df055aef2948/Population_in_Brief_2024.pdf

Nghiem, L. T. P., Zhang, Y., Oh, R. R. Y., Chang, C.-c., Tan, C. L. Y., Shannahan, D. F., Lin, B. B., Gaston, K. J., Fuller, R. A., & Carrasco, L. R. (2021). Equity in green and blue spaces availability in Singapore. Landscape and Urban Planning, 210, Article 104083. https://doi.org/10.1016/j.landurbplan.2021.104083

Tan, K. W. (2006). A greenway network for Singapore. Landscape and Urban Planning, 76(1-4),

45-66. https://doi.org/10.1016/j.landurbplan.2004.09.040

Tan, P. Y., & Samsudin, R. (2017). Effects of spatial scale on assessment of spatial equity of urban park provision. Landscape and Urban Planning, 158, 139-154. https://doi.org/10.1016/j.landurbplan.2016.11.001

Tan, P. Y., Wang, J., & Sia, A. (2013). Perspectives on five decades of the urban greening of Singapore. Cities, 32, 24-32. https://doi.org/10.1016/j.cities.2013.02.001

Thiagarajah, J., Wong, S. K. M., Richards, D. R., & Friess, D. A. (2015). Historical and contemporary cultural ecosystem service values in the rapidly urbanizing city state of Singapore. Ambio, 44(7), 666-677. https://doi.org/10.1007/s13280-015-0647-7

Zhang, L., & Tan, P. Y. (2019). Associations between urban green spaces and health are dependent on the analytical scale and how urban green spaces are measured. International Journal of Environmental Research and Public Health, 16(4), Article 578. https://doi.org/10.3390/ijerph16040578

Zhang, L., Tan, P. Y., & Richards, D. (2021). Relative importance of quantitative and qualitative aspects of urban green spaces in promoting health. Landscape and Urban Planning, 213, Article 104131. https://doi.org/10.1016/j.landurbplan.2021.104131

Appendix A Data provenance and reproducibility

The empirical analysis can be reproduced from Table 1 and the formulas in the methods section. The locations below refer to printed report pages, which may differ from PDF viewer page numbers because some reports use facing-page spreads. Full report URLs and bibliographic details appear in the references.

Table A1. Locations of the official input observations

Year	NParks area source and printed location	Population source and printed location
2010	Annual report 2009/2010, p. 43	Population in brief 2015, Table 1, p. 15
2015	Annual report 2014/2015, pp. 50-51	Population in brief 2015, pp. 4, 15
2020	Annual report 2019/2020, pp. 60-61	Population in brief 2021, p. 4
2021	Annual report 2020/2021, pp. 56-57	Population in brief 2021, p. 4
2022	Annual report 2021/2022, p. 59	Population in brief 2022, p. 4
2023	Annual report 2022-2023, pp. 64-65	Population in brief 2024, p. 5
2024	Annual report 2023-2024, p. 69	Population in brief 2024, p. 5

Note. The park stock date is 31 March and population date is end-June in each row. The 2022 area observation is on printed page 59 in the section headed Facts & Figures FY2021.

The principal numerator is the reported aggregate maintained category, not a sum of site-by-site regional park entries. The latter can include selected reserve areas that would be double counted if gazetted reserves were added. Roadside greenery, state land greenery, and the separate reserve totals are not included in the calculations.

The long-period comparison retains administrative category continuity rather than asserting constant site boundaries. Earlier reserve-exclusion notes specify 10 hectares from Labrador Nature Reserve, while later notes name the reserve without that qualification. This is one reason the estimated changes are described as changes in reported maintained area and are not treated as an audited measure of newly created land.

A worked example for 2024 is 3,326.02 / 6,036.9 = 0.550948 hectares per 1,000 people. Multiplication by ten gives 5.509483 square metres per person. The full-period ratio change is [(3,326.02 / 6,036.9) / (2,236.00 / 5,076.7) - 1] × 100 = 25.0894%. Rounding occurs only after calculation.

The constant-baseline area is 2,236.00 × (6,036.9 / 5,076.7) = 2,658.91394 hectares. Subtracting this from 3,326.02 gives 667.10606 hectares above the 2010-ratio benchmark. This is an accounting comparison, with no assumption that the starting ratio was adequate or that the difference is surplus land.

The scenario calculations use additional population divided by 1,000, multiplied by 0.5509483344. The national planning ratio of 0.8 is not used in those scenarios because its numerator has not been reconciled to the maintenance inventory. The 2022 official achievement of 0.81 and 94% household proximity is recorded separately in National Parks Board (2023), pp. 54-55.