

**ANNUAL CONFERENCE OF THE NATIONAL ASSOCIATION FOR
CLEAN AIR**

2024

AIR QUALITY EVOLUTION:

REFLECTING ON

**20 YEARS OF PROGRESS AND CHARTING FUTURE
PATHS**

ANNUAL CONFERENCE PROCEEDINGS

4 – 6 SEPTEMBER | GAUTENG

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PROCEEDINGS OF THE Annual Conference of the National Association for Clean Air

Air Quality Evolution: Reflecting on 20 Years of Progress and Charting Future Paths

4 – 6 September 2024

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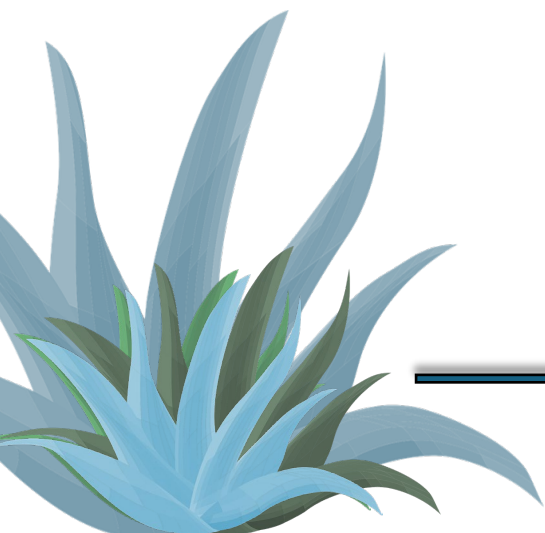
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TABLE OF CONTENTS

TABLE OF CONTENTS.....	II
SPONSORSHIPS.....	III
EXHIBITORS.....	IV
WELCOME MESSAGE.....	V
COMMITTEES.....	V
SCIENTIFIC REVIEW.....	VI
SCIENTIFIC PROGRAMME.....	VII
KEYNOTES SPEAKERS.....	XI
SCIENTIFIC PAPERS.....	1
POSTER EXHIBITIONS.....	128
3-MINUTE RESEARCH TALKS.....	145



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The organising committee sincerely thanks our sponsors for their generous support, which was vital to the success of the 2024 National Association for Clean Air Conference. Your contributions enabled informative sessions, meaningful discussions, and valuable networking among air quality professionals.

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WELCOME MESSAGE

The 2024 Annual NACA Conference, held in collaboration with the Department of Forestry, Fisheries, and the Environment's (DFFE) Air Quality Governance Lekgotla, was a highly significant event. This year, the conference focused on "Air Quality Evolution: Reflecting on 20 Years of Progress and Charting Future Paths."

This theme emphasised South Africa's transformative journey in air quality management following the enactment of the National Environmental Management: Air Quality Act (Act 39 of 2004). This landmark legislation aimed to protect the environment by establishing strong measures to prevent pollution, ensure ecological sustainability, and promote responsible economic and social development. It set national norms and standards to regulate air quality monitoring, management, and control across all levels of government.

The conference provided a unique platform to reflect on the achievements of the past two decades, analyse ongoing challenges, and gather key insights that will shape the future. Attendees anticipated a rich program featuring technical sessions, expert presentations, and research contributions that addressed the evolution of air quality management. The event also showcased cutting-edge strategies and technologies for advancing cleaner air in South Africa.

NACA remains dedicated to fostering collaboration among academia, industry, government, and civil society. By bringing together diverse perspectives, the conference aimed to spark dialogue, inspire innovative solutions, and drive collective efforts toward a cleaner, healthier, and more sustainable future.

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SCIENTIFIC REVIEW

The 2024 National Association for Clean Air (NACA) annual conference proceedings include peer-reviewed publications that underwent a rigorous review process.

A total of forty-three abstracts were submitted for initial screening. Among these, seventeen were poster submissions, including four three-minute research talks.

A total of twenty-three full papers were submitted, of which:

- One was withdrawn by the author, opting to submit only the abstract due to prior publication elsewhere.
- One was withdrawn for other reasons.
- Twenty-one manuscripts were sent for peer review.

Each of the 21 manuscripts underwent a blind review by two to three independent reviewers. The initial review outcomes were as follows:

- 2 papers were accepted as-is.
- 12 papers required minor revisions.
- 7 papers required major revisions.

Authors were required to address reviewer comments, and corrected versions were resubmitted for confirmation. Dr. Brigitte Language, who served as chair, oversaw the review process.

Following the review process, the documents included in the proceedings span three categories: Full Papers, Posters, and 3-MRT.

Among the Full Papers (16):

- Air Resource Management (1)
- CSIR (2)
- Mintek (1)
- North-West University (6)
- Nova Institute (1)
- University of Cape Town (1)
- University of Limpopo (2)
- University of Pretoria (2)

For the Poster category (17):

- Air Resource Management (1)
- Department of Economic Development, University of Cape Town (1)
- National Metrology Institute (1)
- North-West University (4),
- Sol Plaatje University (1)
- South African Medical Research Council (1)
- Stellenbosch University (3)
- University of Cape Town (2)
- University of Johannesburg (2)
- University of Pretoria (1)

In the 3MRT category (4),

- National Research Foundation (1)
- North-West University (1)
- Stellenbosch University (1)
- University of Johannesburg (1)
- In addition, 9 posters were also presented as 3-MRT.

The NACA LOC, chaired by Dr. Brigitte Language, managed the online review process through an online management system. A full archive of the review history was maintained.

SCIENTIFIC PROGRAMME

WEDNESDAY, 4 SEPTEMBER (FULL DAY)

07:30 - 08:30	Registrations Refreshments Exhibit
08:40 - 09:00	Welcome and Opening Prof Roelof Burger NACA President (NWU)
09:00 - 11:00	Session 1 Multi-stakeholder Workshop HYBRID Dr Patience Gwaze (DFFE) Development of the National Nonindustrial Emission inventory <i>Mr Maluta Mbedzi (DFFE)</i> Present progress and status of the non-industrial inventory - Overview <i>Dr Anja van Basten (Gondwana Env. Solutions)</i> National on-road Transport Module Development Status <i>Mr Prince Chidhindi (North-West University)</i> Residential Fuel Burning Module of the National Inventory
11:00 - 11:30	Mid-morning Refreshments Poster Viewing Exhibit
11:30 - 12:30	Session 2 Keynote Prof Stuart Piketh (NWU) <i>Mr Peter Lukey (DFFE)</i> The Birth of the NEM: AQA – A patchy tale of the transition to objectives-based air quality governance in South Africa
12:30 - 13:30	Lunch Poster Viewing Exhibit
13:30 - 14:00	Session 3 Keynote Mr Siya Mkhize (S&W Attorneys) <i>Dr Patience Gwaze (DFFE)</i> The Future Direction of Air Quality Management in South Africa
14:00 - 15:00	Session 4 Oral Monitoring, Measurement and Analysis Dr Gerrit Kornelius (UP) <i>Ms Nomsa Muthelo (University of Pretoria)</i> A nationwide assessment of nitrogen pollutants and related species using the CAMx model [Paper] <i>Ms Tamryn Hamilton (North-West University)</i> High-Resolution Temporal Trends of Near Surface NO ₂ : Insight into Deposition Dynamics at a South African Background Site [Paper] <i>Mr Pfano Makhokha (University of Limpopo)</i> Evaluation of Simulated Planetary Boundary Layer Heights Against Radiosonde Derived Estimates for Locations across South Africa [Paper] <i>Mrs Sarah Dikgale (Council for Scientific and Industrial Research)</i> Validation Of CSIR Wind Tunnel Calibration Data Under Different Barometric Conditions Using Comparisons with A Reference Laboratory [Paper]
15:00 - 15:30	Mid-afternoon Refreshments Poster Viewing Exhibit
15:30 - 16:30	Session 5 Technical HYBRID Dr Phathutshedzo Mukwevho (NWU) <i>Dr Montagu Murray - NOVA Institute</i> <i>Prof Stuart Piketh - North-West University</i>

Prof Kristy Langerman - University of Johannesburg

Dr Herman van der Walt - Sasol

Mr Brian McCourt – Eskom

Air quality Offsets as an instrument for Air Quality Management in South Africa - Follow-up from Working Group

16:30 - 17:15

Session 6 | Oral | Policy, Regulation and Urban Planning | Dr Hasheel Tularam (SRK)

Dr Niké Jacobs (North-West University)

Lost in Integration: Spatial Planning and Air Quality Management in South Africa [Paper]

Ms Oarabile Masekwameng (North-West University)

The Importance of Climate Variables in Spatial Planning: A Comparative Study of North-West Province Planners' Decision-Making Processes [Paper]

Dr Phathutshedzo Mukwevho (North-West University)

20 years of AQ monitoring in South Africa: What have we learned? [Paper]

17:15 - 17:25

Closing of Day | Conference Chair

THURSDAY, 5 SEPTEMBER (FULL DAY)

07:00 - 08:00

Registration | Refreshments | Poster Viewing | Exhibit

08:00 - 08:15

Welcome and Arrangement | Conference Chair

08:15 - 09:00

Session 7 | Keynote | Mr Grant Ravenscroft (Argos Scientific)

Dr Hanlie Liebenberg-Enslin (Airshed Planning Professionals)

Air Quality Evolution in South Africa over the past 20 years: A Constants' Journey

09:00 -10:00

Session 8 | Oral | Community Impacts | Dr Mbalenhle Mpanza (UJ)

Mr Avishkar Ramandh (Air Resource Management)

The Improvement in Air Quality Due To A Waste Offset Program in Sharpeville [Paper]

Ms Sonja de Beer (North-West University)

Urban Trees and Air Quality and Climate Regulation: Perceptions from a Rural Informal Settlement in South Africa [Paper]

Dr Montagu Murray (Nova Institute)

Towards a better understanding of the impact of demographic and services trends on air quality in low-income settlements: a case study of eMbalenhle and Lebohang [Paper]

Mr Thato Phala (North-West University)

Investigating the contribution of open waste burning to air pollution in Oranjeville, South Africa

10:00 - 10:30

Mid-morning Refreshments | Poster Viewing | Exhibit

10:30 - 11:15

Session 9 | Technical | HYBRID | Prof Roelof Burger (NWU)

Mr Ngongang Wandji Danube Kirt - Stockholm Environment Institute (SEI) Kenya, Africa

Dr Chris Malley - SEI York, United Kingdom

Dr Kevin Hicks - SEI York, United Kingdom

Dr Charlie Heaps - SEI United States

Dr Aderiana Mbandi - United Nations Environment Programme (UNEP), Africa

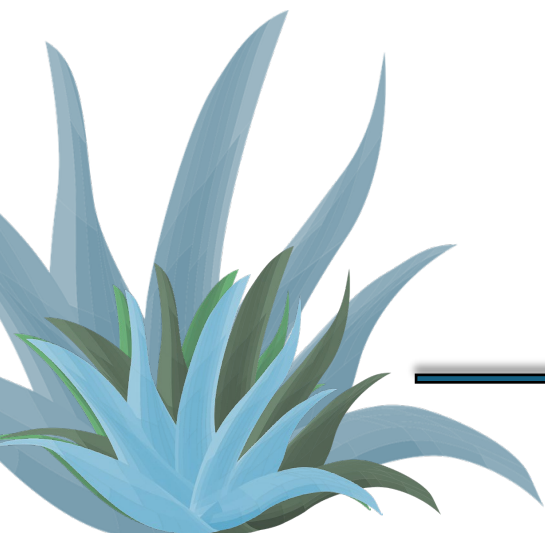
International Day of Clean Air (UNEP) - Beyond Monitoring: Using the Low Emissions Analysis Platform (LEAP) for examining Air Quality Futures

11:15 - 12:00	Session 10 Oral Industrial, Urban, and Rural Air Quality Prof Kristy Langerman (UJ) <i>Ms Meg Pettie (University of Cape Town)</i> Evaluating the Relationship Between Loadshedding and Air Pollution [Paper] <i>Ms Ncobile Nkosi (North-West University)</i> Intra-urban Variability of Non-exhaust Traffic PM ₁₀ Emissions from Limpopo Province Unpaved Residential Roads [Paper] <i>Dr Carla Grobler (MIT, now at the University of Pretoria)</i> Public Health Impacts of Residential Heating Electrification in the Contiguous US [Abstract]
12:00 - 13:30	Lunch Poster Viewing Exhibit
13:30 - 14:15	Session 11 Keynote Mr Mogesh Naidoo (CSIR) <i>Mr Siyabonga Mkhize (Shepstone & Wylie Attorneys)</i> Intersection between Climate Change and Air Quality – A look at the Climate Change Act 22 of 2024 and how it interconnects with existing Air Quality Legislation [Paper]
14:15 - 15:00	Session 12 Keynote HYBRID Dr Terri Bird (Airshed Planning Professionals) <i>Prof Jesse van Griensven Thé (Lakes Environmental Software)</i> Artificial Intelligence in Atmospheric Science: Transforming Environmental Modelling and Forecasting
15:00 - 15:15	Session 13 Oral Aerobiology Dr Nomfundo Mahlangeni (SA-MRC) <i>Prof Frank Neumann (North-West University)</i> Progresses in Aerobiology in South Africa and at NWU: Allergenic Pollen and Spores as a Health Risk of National Importance [Paper]
15:15 - 15:45	Mid-afternoon Refreshments Poster Viewing Exhibit
15:45 - 16:45	Session 14 Oral Technological Innovations Dr James Tshilongo (MINTEK) <i>Mr Keagan Velde (North-West University)</i> Biochar as a Sustainable Alternative to Anthracite in Metallurgical Smelting [Paper] <i>Ms Shimoné Bridges (North-West University)</i> Emission Performance of a Clean Cookstove and Oven Utilising Predominant South African Wood Species [Paper] <i>Dr Stephen Opiyo (North-West University)</i> Evaluation of aerial thermography as a tool for in-situ determination of the thermal insulation status of dwellings in large settlements in South Africa [Paper] <i>Dr Andile Mkhohlakali (MINTEK)</i> Volatile organic compounds sensing using CuO based nanocomposite: Addressing Structural and sensing characteristics [Paper]
16:45 - 17:00	Closing of Day Conference Chair
18:00 – 00:00	Social Evening

FRIDAY, 6 SEPTEMBER 2024 (HALF DAY)

07:15 - 08:00	Morning Welcome & Refreshments
08:00 - 08:15	Welcome and Arrangement
08:15 - 09:00	Session 15 Keynote Dr Johanna von Holdt (UCT)

	<i>Ms Deidre Herbst (Eskom)</i> The Nexus of Air Quality and Electricity in South Africa
09:00 - 10:00	Session 16 Technical Dr Johanna von Holdt (UCT) <i>Mr Brian McCourt (Eskom)</i> Eskom Minimum Emission Standards National Environmental Consultative and Advisory Forum Outcomes – an Eskom Perspective
10:00 - 10:45	Session 17 Oral Climate Change and Air Quality Dr Martin van Nierop (Gondwana) <i>Dr Gerrit Kornelius (University of Pretoria)</i> Tier 2 Greenhouse Gas Emission Factors for South African Solid Fuels <i>Mr Mogesh Naidoo (Council for Scientific and Industrial Research)</i> Investigating the Air Quality Co-Benefits of Transitioning to Net Zero in The South African Energy Sector [Paper] <i>Ms Karabo Makgaretse (University of Limpopo)</i> Influence of climate change on meteorological conditions affecting air pollution dispersion in South African Air Quality Priority Areas [Paper]
10:45 - 11:30	Session 18 3-Minute Research Talks Ms Happy Mabowa (MINTEK)
11:30 - 12:00	Mid-morning Refreshments
12:00 - 13:00	NACA Annual General Meeting Prof Roelof Burger (NWU)
13:00 - 13:30	NACA Awards
13:30 - 13:45	Closing Mr Siya Mkhize



Perceptions of Urban Trees in Air Quality and Climate Regulation: Insights from a Low-Income Settlement in South Africa

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Urban green spaces (UGS), such as parks, gardens, and trees, are essential in urban areas, providing ecosystem services (ES) that support human well-being and environmental health. Urban trees are particularly effective in improving air quality, regulating climate, and reducing dust, services that are especially critical in the Global South, where rapid urbanisation and pollution pose significant health risks. In South Africa, where urban growth and informal settlements are expanding, established UGS are scarce in low-income areas. Here, trees in private gardens and undeveloped spaces could play a pivotal role in improving the environment. This study examines the perceptions of residents in the small low-income community of Metsimaholo, South Africa, regarding the benefits and ecosystem disservices (EDS) of urban trees, such as maintenance needs, which can influence community support for existing and future municipal and community-led tree planting initiatives. Even though many residents value trees for their cooling, shade, and wind protection benefits, awareness of trees' roles in air purification appears limited, potentially reducing appreciation for their full range of ES. Although participants largely agree that trees improve quality of life, some express concerns over the costs and labour associated with tree upkeep. To foster greater community support for urban tree projects, this study suggests that raising awareness of trees' environmental benefits, particularly for air quality, and providing maintenance support could help mitigate concerns over EDS, making existing and future municipal and community-led tree planting initiatives more appealing and sustainable in low-income communities.

Keywords: Urban Trees, Urban Green Spaces, Ecosystem Services, Air Purification, Community Perceptions.

1. Introduction

Urban green spaces (UGS), including gardens, parks, and trees, are essential components of urban environments, providing crucial Ecosystem Services (ES) that enhance urban ecosystems and human well-being (Young, 2010, M'ikiugu *et al.*, 2012, Bertram and Rehdanz, 2015). UGS have been integral to urban

planning and design since the industrial revolution, comprising areas of vegetation within city settings such as parks, gardens, street and urban trees, and undeveloped margins (Breuste *et al.*, 2013, Woolley, 2003, Loughran, 2018). Urban trees, in particular, are vital in delivering a range of ES, including air purification, dust reduction, noise reduction, water regulation, climate regulation, carbon sequestration, and supporting

biodiversity ([Salmond et al., 2016](#), [Livesley et al., 2016](#), [Mullaney et al., 2015](#), [Pretzsch et al., 2023](#), [Elmqvist et al., 2013](#)). However, urban trees could play a particularly significant role in aiding both adaptation and mitigation efforts related to air quality and climate change ([Fryd et al., 2012](#), [Hoppa et al., 2022](#)).

Air purification is one of the most noteworthy ES provided by urban trees, capturing pollutants such as particulate matter (PM), nitrogen dioxide (NO₂), and sulphur dioxide (SO₂) ([Manes and Salvatori, 2014](#), [Mandal et al., 2023](#), [Eisenman et al., 2019](#), [Yao et al., 2022](#)). This function is critical in the Global South, where PM pollution has become a severe health threat due to rapid urbanisation and the high dependence on solid fuel burning for heating and cooking ([Mannucci and Franchini, 2017](#), [Pauw et al., 2022](#), [Chafe et al., 2014](#), [Language et al., 2016](#)). Urban tree foliage has the ability to reduce suspended dust in the surrounding atmosphere. However, only certain tree species have this ability and accumulated dust could have potential negative effects on trees ([Chaudhary and Rathore, 2019](#)). Urban trees also reduce dust by acting as wind barriers, and have often been used in urban areas for this purpose ([Taleb and Kayed, 2021](#)). Lastly, urban trees also reduce dust producing surfaces by enforcing soil stabilisation and reducing erosion ([Beckett et al., 1998](#)).

Alternatively urbanisation, combined with global warming, exacerbates the urban heat island effect ([Sachindra et al., 2016](#), [Li et al., 2018](#)). Urban trees can reduce these effects through their cooling and shading abilities ([Fryd et al., 2012](#), [Schwaab et al., 2021](#)). In South Africa, like many other countries in the Global South, drastic urbanisation intensifies poverty and expands low-income settlements, established UGS are rare due to historically political planning regimes ([Arndt et al., 2018](#), [Lemon, 2021](#), [Bakker et al., 2020](#), [Gwedla and Shackleton, 2017](#)). Due to mobility constraints, as well as the cost of maintenance, higher income neighbourhoods often have more and better access to UGS than low-income settlements ([Cilliers et al., 2013](#), [Davoren et al., 2015](#), [Lategan et al., 2022](#), [Reuther and Dewar, 2006](#), [Rigolon et al., 2018](#)). Therefore, urban trees, found in private gardens and undeveloped margins could play a fundamental role in delivering ES in relation to air quality and climate change in these low-income settlements.

Despite their benefits, urban trees can emit biogenic volatile organic compounds (BVOCs), which contribute to fine particulate matter (PM_{2.5}) and ground-level ozone (O₃) formation, posing significant threats to air quality and human health. These emissions are particularly pronounced in urban areas, where the high density of vegetation and pollution sources create complex interactions ([Calfapietra et al., 2013](#), [Ren et al., 2017](#), [Eisenman et al., 2019](#)). This must be an important consideration in municipal and community-led tree

planting initiatives and accompanying risks and benefits must be managed appropriately in low-income settlements. Additionally, in low-income settlements, urban trees are often relied upon as a fuel source ([Nkosi et al., 2021](#)). Poverty and the current energy crisis in South Africa are intensifying this reliance on solid fuels, which has detrimental effects on the residents' exposure to air pollution in low-income settlements ([Language et al., 2016](#), [Langerman et al., 2023](#), [Jafta et al., 2017](#)). This emphasises the need to balance the ES provided by trees with the immediate needs and health of these communities.

Appropriate management and awareness are essential to maximising the net positive impact of urban trees on air quality in low-income settlements. In low-income settlements, the perception of urban trees by inhabitants critically influences their support for existing and future municipal and community-led tree planting initiatives ([Balram and Dragičević, 2005](#), [Gwedla and Shackleton, 2019](#)). Understanding how residents perceive the benefits (ES) and obstacles (ecosystem disservices, EDS) of urban trees is vital for urban planning and environmental management. Positive perceptions can foster community support for tree planting initiatives, enhancing ES provision. On the contrary, perceived EDS, such as allergies, maintenance burdens, and safety concerns, can discourage support for these initiatives. [

Therefore, this study examines the perceptions of the low-income community of Metsimaholo, South Africa, regarding the usefulness of trees and whether perceived EDS might discourage support for urban tree projects. Additionally, it aims to analyse whether improved air quality and cooling are perceived as ES provided by urban trees. Semi-structured interviews were employed to capture community perceptions on urban green, accompanied by a brief remote analysis assessing changes over time in urban tree and UGS coverage in Metsimaholo and contrasting it with the neighbouring higher-income town of Oranjeville. The primary objective of the study was. This study offers a potentially novel perspective by focusing on the unique perceptions of residents in a low-income community regarding the balance of advantages and disadvantages associated with urban trees and UGS, providing critical insights for existing and future municipal and community-led tree planting initiatives aimed at enhancing air quality and climate resilience in rapidly urbanising regions.

2. Methods

This study used semi-structured interviews to explore community perceptions of urban trees and green spaces in Metsimaholo, focusing on their benefits and drawbacks. A remote analysis of urban tree and UGS coverage changes, comparing Metsimaholo with Oranjeville, supplemented the findings.

2.1. Study Area

This study was conducted in Metsimaholo, a small town located in the Free State province of South Africa. It is located on the southern shore of the Vaal Dam in the Metsimaholo Local Municipality [Fig.1]. Furthermore, the town is located in the Vaal Triangle Air Pollution Priority Area, which is known for its severe air pollution and associated negative health impacts on inhabitants (Mwase, 2022) [Fig 1].

Metsimaholo is a low-income settlement, primarily residential with a mix of formal and informal housing. It is characterised by a semi-arid climate, with hot summers and cool winters. The area forms part of the grassland biome, meaning very few trees naturally occur. Thus, most trees are found in residential or developed areas

where they were purposefully planted. The semi-arid climate and grassland ecosystem contribute various elements to the air quality challenges in the region. Dust pollution and bio allergens, such as grass pollen, are noted as factors affecting air pollution here (Neumann *et al.*, 2024, Zhao *et al.*, 2014). The area features both natural and altered landscapes, with nearby agricultural activities that can further elevate dust pollution levels. The town has limited formal UGS, with most vegetation found in private gardens and undeveloped open margins. The absence of well-developed UGS also suggests a shortage of urban trees that could offer ecosystem services like air purification.

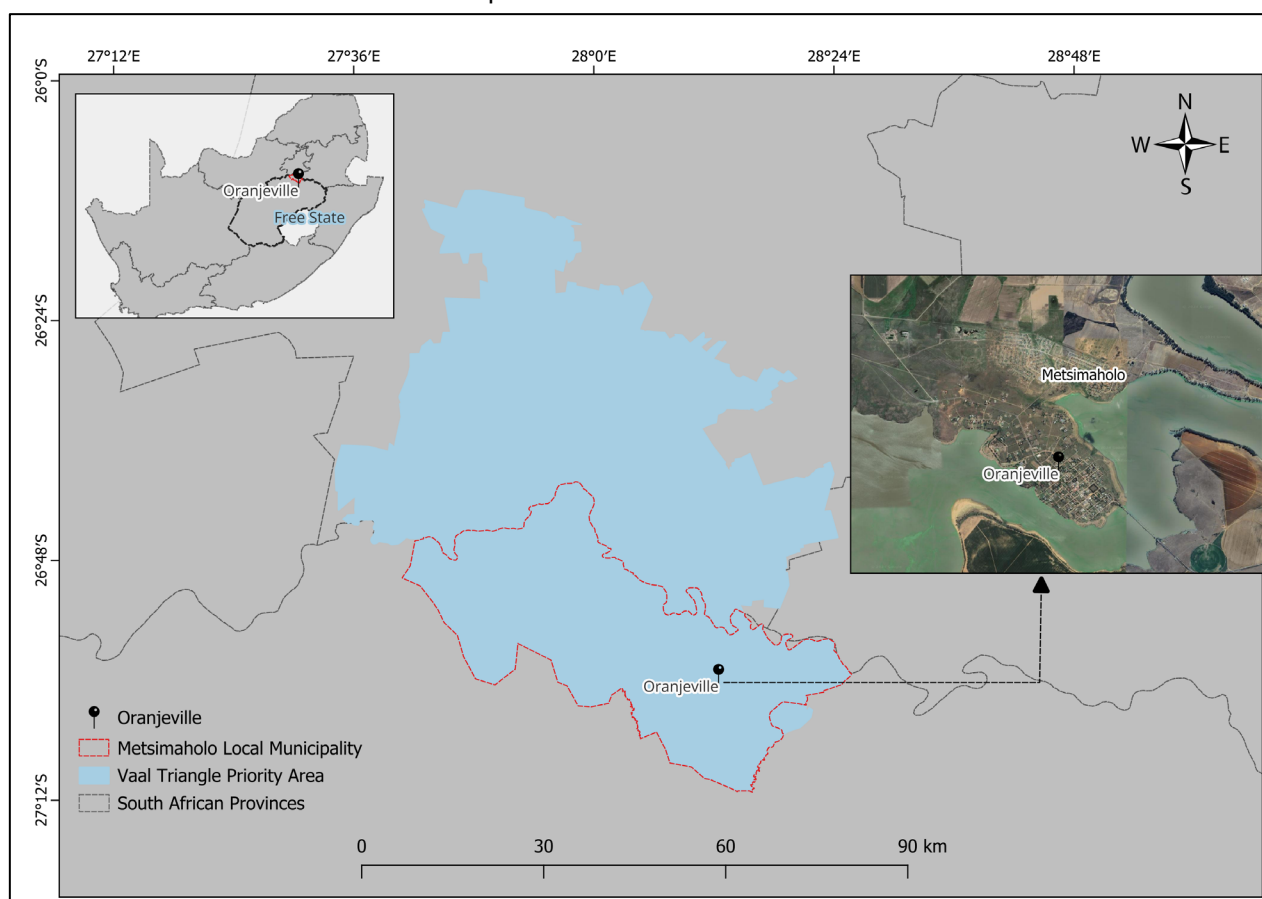


Figure 7: Locality Map of Metsimaholo Low-Income Settlement (GoogleEarth, 2024).

2.2. Demographics

The town has a diverse population, with many residents relying on local resources and services for their livelihood. Economic activities are limited, with employment opportunities mainly in agriculture, small businesses, and informal sectors. The community faces challenges such as unemployment, limited infrastructure, and access to services. The predominant language

amongst the participating households is Sesotho (78%). The remaining languages (isiZulu, isiXhosa, Xitsonga, and Sepedi) were only spoken by a minority of households (22%). Household sizes were predominantly between 4 to 6 people, which is more than the average household size of the district, being 3 people per household. Of the people in the community aged 20 and older, 36% have some form of secondary schooling, and only 30% have matric. In the municipality, 6% of people

have no schooling and 12% have some form of primary schooling ([Statistics South Africa, 2022](#)).

Table 1. Age distribution of Metsimaholo household members

Age Grouping	Age (yrs)	Number of Household members
Infants	< 1	0
Children	1 -12	21
Adolescents	13 -17	9
Adults	18 -64	63
Elderly	>65	7

In Table 1, the number of household members per age grouping in Metsimaholo is displayed. Most household members consist of adolescents, with the second largest group being children.

2.3. Research Design

A simple remote analysis was done using Google Earth, Landsat data acquired via, EarthExplorer's USGS, and QGIS ([GoogleEarth, 2024](#), [QGIS, 2024](#), [EarthExplorer, 2024](#)). Firstly, using a Google Earth satellite images from 2004 and 2024 from the month of July. This is because a satellite image from the summer of 2004 was not available, with the winter image being the earliest accessible for Metsimaholo. Since the satellite imagery was captured during the winter season, the visual assessment reflects only evergreen trees and shrubs. A visual comparison of the two images was conducted to established if there has been any increase or decrease of trees and UGS in Metsimaholo ([GoogleEarth, 2024](#)).

Secondly, using a Google Earth satellite image of Oranjeville from 2024, also for the month of July, another visual analysis was completed. A comparison was made between the satellite images of Metsimaholo and Oranjeville for the same year. This was done to evaluate the differences in the presence and distribution of trees in Metsimaholo and its more formal and middle income neighbouring town, Oranjeville.

Thirdly, Google Earth Pro Street View, was used to get a perspective on the presence of trees on the town margins. This was conducted to evaluate the argument made earlier, that unused and underdeveloped town margins and private yards might represent untapped resources suitable for the establishment and implementation of UGS and urban trees.

Lastly, in order to gain a better understanding of the possible changes in vegetation and trees in general, over time, of Metsimaholo, a comparison of the Normalised Difference Vegetation Index (NDVI) of 2014 and 2024 was made. To ensure that the study also pertains to trees, shrubs, and other types of vegetation that are not

evergreen or are primarily growing during the summer season, this analysis was carried out in the summer months of both years. NDVI is effective in identifying vegetation density and is calculated using this formula:

$$NDVI = \frac{(NIR-VIS)}{(NIR+VIS)} \quad (\text{Equation 1})$$

Where NIR represents the near-infrared reflectance, and VIS represents the visible red reflectance. NDVI values range from -1.0 to 1.0. Negative NDVI values generally indicate clouds or water, values close to zero indicate bare soil, and increasingly positive values reflect vegetation density, ranging from sparse vegetation (0.1 to 0.5) to dense green vegetation (0.6 and above). In this study, Landsat 8 Level 2 satellite imagery, specifically the atmospherically corrected spectral reflectance measurements from Bands 4 (Visible red) and 5 (near-infrared), was used to calculate NDVI for Metsimaholo.

The survey data used for this study was acquired during a larger research project. The research project aimed to evaluate the impact of semi-continuous coal stoves on air quality and quality of life in low-income households in Metsimaholo, South Africa, from January 2023 to October 2023. Initial engagement involved meetings with municipal officials and a community meeting attended by approximately 100 residents. Consent was obtained from political figures and community members, with a Community Liaison Officer (CLO) appointed to facilitate communication. Out of 100 residents that expressed interest, 50 households were selected based on having existing coal stoves and living in RDP houses, to ensure SANS compliance. Final selection was made after follow-up meetings and contract signing. Semi-structured in-person interviews were conducted with 70 households (50 participants and 20 non-participants to minimise bias) from May to October 2023. Surveys were conducted in Sesotho and Sepedi by trained junior researchers and students. Consent was obtained with assurances of anonymity and voluntary participation. The project was approved by a scientific committee and independent ethics review.

In these surveys, participants were asked among other aspects influencing quality of life to describe various factors of their natural capital. In terms of perceptions on trees, the semi-structured interview included the following themes:

- Satisfaction with tree coverage in Metsimaholo
- Perceived importance of trees and underlying reasons

The semi-structured interviews were recorded using mobile devices. Recordings were translated and transcribed to English. The digitalised semi-structured interviews were then analysed first using inductive coding to create an analysis framework, which was later used to perform deductive coding according to the nuances and novelties found within the qualitative dataset. This

analyses was done using the ATLAS.ti software ([ATLAS.ti, 2024](#)).

Data was anonymised with unique IDs and stored securely in a cloud repository. The research was coordinated by a multidisciplinary team from North-West University, including atmospheric scientists, chemical engineers, and social scientists.

3. Discussion

3.1. Remote analysis of UGS and urban trees in Metsimaholo

A simple analysis was done to compare the UGS and urban trees of Metsimaholo. The Satellite images of 2004 and 2024 the same seasons (winter) compared to one another [Fig.2].



Figure 8. Comparison of 2004 (top panel) to 2024 (lower panel) UGS and urban trees ([GoogleEarth, 2024](#)).

Metsimaholo expanded between 2004 and 2024, and consequently some UGS was lost due to development. In some areas the loss of urban trees can also be observed, as circled in red [Fig 2]. This could be due to development, the use of trees for fuel for heating and cooking, or possibly even the use of wood as building material. Interestingly, in some areas urban trees increased from 2004 to 2024, as marked in green [Fig 2]. Trees in private yards have also increased from 2004 to 2024. It is noteworthy that the larger agglomerations of

trees are found on the margins of Metsimaholo, rather than in the town itself.

When analysing the UGS and urban trees of the middle-income neighbouring town called Oranjeville, one can observe the difference caused by historical planning regimes and current economic dynamics [Fig.3].

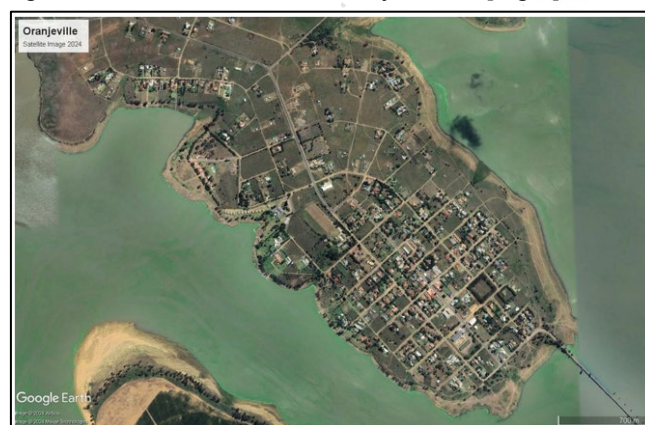


Figure 9. Oranjeville the neighbouring town of Metsimaholo ([GoogleEarth, 2024](#)).

Oranjeville have various street trees and open UGS. There are also more, and larger, older trees found in private and public yards. Although the Apartheid city model has been abolished after the 1994 democratic election, its impact on the current urban environment is still very evident ([Venter et al., 2020](#)). The inequality created by this planning regime is complex to address, as urban trees and UGS typically involve substantial maintenance costs and responsibilities that are increasingly being taken on by private stakeholders rather than the originally intended local municipalities. This adds further pressure on low-income communities such as Metsimaholo, which are already facing financial difficulties. Research shows that the lingering economic impacts of Apartheid continue to affect the development of children and adolescents in impoverished areas of South Africa. High levels of unemployment and rapid population growth place an immense burden on these low-income households, affecting their overall well-being ([Cameron, 2003](#)). Furthermore, studies suggests that the availability and utilisation of urban green spaces in the Global South declined during and following the COVID-19 pandemic ([Kleinschroth et al., 2024](#)).

Using Google Earth Pro Street View, it can be observed that there are indeed various UGS and urban trees in the town margins, being used for agriculture etc [Fig.4]. This substantiates the potential that these undeveloped town margins could have in serving as UGS and housing urban trees that could be managed to be utilised by the whole community.

To assess potential changes in vegetation in Metsimaholo, the NDVI was used as a proxy for vegetation density and change over time. To evaluate

changes in vegetation over the decade, a comparative analysis was conducted for the month of January (summer) in the years 2014 and 2024 [Fig 5].

It is important to note that while NDVI captures a broad range of vegetation types and not just trees, it effectively reflects any spatial changes in overall vegetation density over time. As shown in the figure above, there has been a notable increase in vegetation density in the area. It is also an indication that Metsimaholo's town margins have grown more vegetation over time, as well as the surrounding natural area. It can also be an indicator of more efficient agricultural practises or better rain over time from 2014 to 2024. Therefore, it might signify the potential for these town margins to be self-sustaining, which, if utilised and managed responsibly, could result in reduced maintenance requirements for community members.



Figure 10. Metsimaholo urban trees on town margins ([GoogleEarth, 2024](#)).

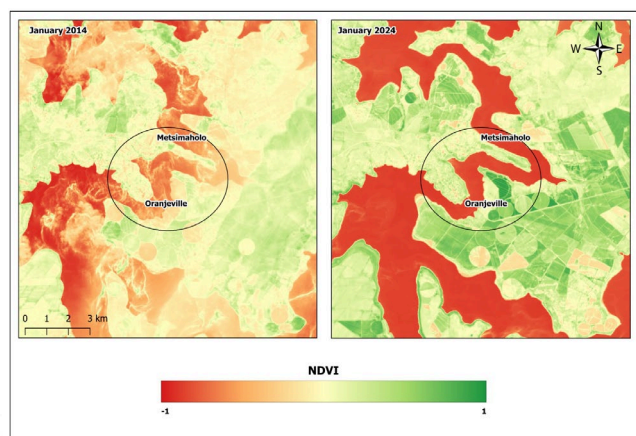


Figure 11: Comparison of NDVI for Metsimaholo in January 2014 and 2024.

3.2. Perception on trees and air quality

Many respondents associated trees with the provision of 'fresh air' and/or aiding in 'breathing', indicating a recognition of the trees' role in improving air quality. Of all participants interviewed 68 mentioned the specific ES that they associate with the importance of trees. These

participants mentioned 11 distinct benefits or advantages of trees, including wind protection, shade, food, fresh air, a place of rest/gathering, wood (fuel), flood control, water purification, aesthetics, habitat, medicinal purposes [Fig 6].

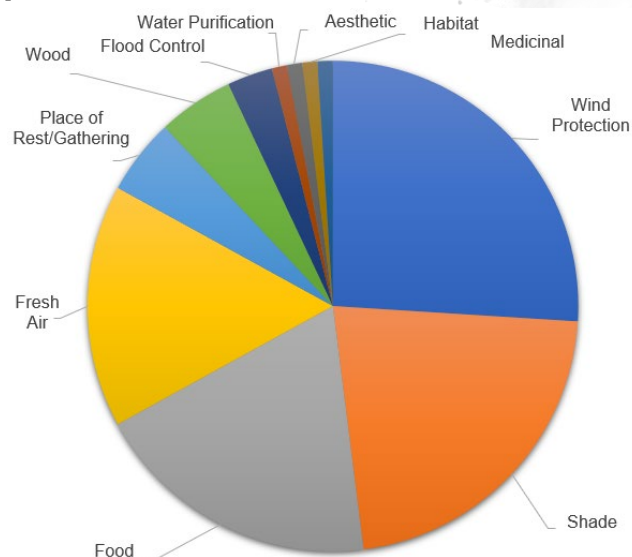


Figure 12. The ES of urban trees perceived by participants.

Approximately 16% of the participants mentioned that trees have some benefit with regards to better air quality. For example, one participant stated, 'Yeah, they're important because they can provide fresh air, they can get rid of dirty air...'. This understanding, albeit basic, shows an intuitive grasp of the benefits of trees in reducing pollutants from the air. Another participant added, 'Yes, they are very important because we obviously know where the carbon, we emit goes to...', suggesting some awareness of the carbon cycle and the role of trees in sequestering carbon dioxide.

However, it was also apparent that not all participants had a detailed understanding of the specific mechanisms through which trees improve air quality. 'Yes, trees are important because they help us to breathe'. Additionally mentioned, 'Yeah... Trees are very important, especially when it comes to the air that we breathe'. This possible gap in knowledge could influence how community members perceive the value of urban trees and their support for future municipal and community-led tree planting initiatives. Educational programs that enhance understanding of these ecological functions could potentially strengthen community support for these initiatives. This is especially important in the case of Metsimaholo, which is located in the VTAPA district known for its high levels of air pollution, ascribed to large industrial sources in the area. Additionally, when considering that low-income communities are experiencing comparatively high exposure to air pollution

due to domestic burning, the need for awareness and adaptation are essential in these communities ([Jafta et al., 2017](#), [Language et al., 2016](#), [Langerman et al., 2023](#)).

3.3. Perception on trees and cooling

Even though, cooling or climate regulation in itself was not mentioned by participants, provision of shade was perceived as an ES of trees by 22% of participants. Provision of shade was the second most commonly cited benefit by participants, while wind protection led with 26% as the most frequently mentioned service trees provide. Various participants mentioned using trees to shelter from sun and heat. Participants mentioned the following, '...if it's hot in the house, you know in summer it's too hot, you go and sit under the tree...'. Also, 'The shade, like when it's hot in summer then we sit under the shade...' and 'Yoh, on my side yes. As it's this hot, you can't sit in the house, you have to rest in the shade...'. Likewise, 'trees help...like when the sun is hot, we sit under the shade and also like if it's windy, it helps a lot for a lot of wind, it protects the house, yes'.

In addition to their significance for providing shade, 5% of participants highlighted the added benefit of trees being seen as spaces for relaxation and social gatherings. The recognised advantages by community members suggest that investing in UGS and developing urban trees in private gardens and properties could be highly advantageous. Participants noted it serves as an escape from the intense heat of their poorly insulated RDP houses. Coupled with the additional benefit of using it as a space for social gatherings and leisure, this indicates it could be a popular feature among community members. Trees have been known and described to provide significant cultural ES to various South Africans as they serve as a source of shade and consequently a gathering place for friends and family ([Shackleton et al., 2015](#)). It can therefore be argued that climate regulation, in the form of shade and wind protection, by trees can be used to support and motivate future municipal and community-led tree planting initiatives in low-income communities.

3.4. Perception of the number of trees

Participants in Metsimaholo generally feel that there are enough trees in their area. However, some believe there is a shortage of trees and express a desire to have more fruit trees, specifically. Various aspects of UGS, could provide solutions to the ever growing food insecurity ([Bhebhe et al., 2023](#), [Barthel and Isendahl, 2013](#), [Cilliers et al., 2018](#)). Even though a need for fruit trees was mentioned, some participants expressed satisfaction in the variety of tree species present. 'Ayy there are many, the trees here are a lot and they are of different kinds.' However, various participants want trees in their own yards. 'Yes, they're enough but they're not in the yard, they're over there, ...'. Similarly, 'Uh,

currently I don't have a tree in the yard, but I did have one. But I do love a place that has trees...a lot, I like it.' This supports the earlier observation that future municipal and community-driven tree planting projects in private yards could be well-received in low-income communities.

Even though most participants indicated the sufficiency of trees in Metsimaholo, many indicated insufficiency in the number of trees in the town. 'I am short of trees' and 'Trees, I have a shortage of trees, maybe you can bring me some...'. Also, 'No, there aren't many trees.' The shortage might exist on a personal level, but it can also relate to the town as a whole, suggesting that while residents favour more trees in their private gardens, they may also desire additional trees in public areas. Given the limited presence of formal UGS in low-income communities like Metsimaholo, adopting an unconventional approach by utilising undeveloped town edges and borders to plant more trees for community benefit could prove more advantageous.

Some participants provided insight into the reasons behind the perceived scarcity of trees reporting that trees have been removed or cut down. 'Uhh they're not enough in Orangeville..., you see inside there, over there... there were trees there and they cut them down'. Furthermore, 'No, they're not enough anymore because they cut them down, they used to be a lot'. Additionally, 'they're not enough, the ones we had were enough were around the river so they cut them down and they said the trees were depleting the water and that's something that I couldn't understand'. Trees being cut down could be a result of various activities such as development, agricultural practises etc. However, a large possibility is the use of wood for fuel.

South African low-income communities have a very high reliability on solid fuel burning ([Nkosi et al., 2021](#), [Language et al., 2016](#)). Future tree planting projects led by municipalities and communities need to carefully address and prioritise these essential and more urgent community needs, integrating them with long-term improvements to ensure their success and sustainability. On the other hand, one participant stated: 'There's a lot in town but in the township...'. Pre-1994, UGS was not included in South African low-income settlements, such as street trees and parks and some argue that the effects are still present in current planning efforts and corrective actions ([Venter et al., 2020](#)). This demonstrates that future initiatives driven by municipalities and communities need to be innovative and at times unconventional to navigate these seemingly insurmountable barriers and challenges.

3.5. Perception on trees ES and EDS

Overall, the consensus is that trees are important and have many benefits. Participants mentioned the importance of trees, as well as a variety of benefits

provided by trees [Fig 6]. Illustrating this general favourable perception of trees, a word cloud was created using ATLAS.ti, showing the most frequently used words when participants were asked to express the importance of trees, if applicable [Fig 7] ([ATLAS.ti, 2024](#)).

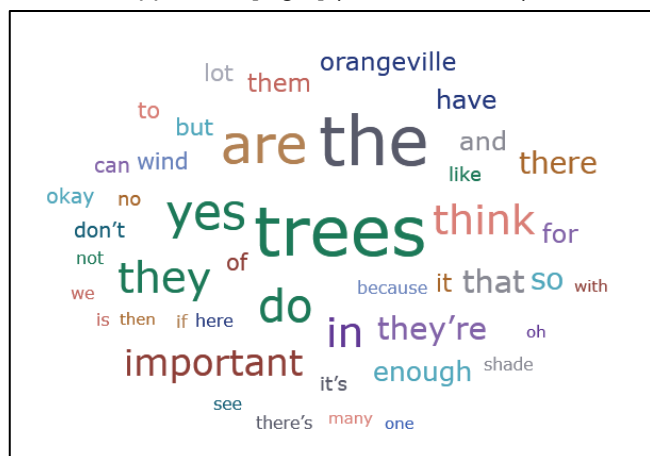


Figure 13. Frequent words are mentioned by participants when expressing their perception on trees (ATLAS.ti, 2024).

Figure 7 gives the impression that participants view trees primarily positively and associate them with various ES and benefits. [Gwedla and Shackleton \(2019\)](#) found very similar results when investigating the perception of trees in the Eastern Cape. The words 'wind' and 'shade' are some of the most frequently mentioned words when describing the importance of trees. This aligns with the findings presented in Figure 6, indicating that wind protection and shade were the most frequently cited advantages of trees by participants. Further detailing this, Table 2 lists the ES mentioned by participants, along with their types and any additional benefits they may provide ([Millennium Ecosystem Assessment, 2005](#)).

Table 2. ES mentioned by participants.

Perceived ES	Type of ES	Additional Benefits
Shade	Regulating Service	Climate Regulation, Sun Protection, Habitat Creation
Wind Protection	Regulating Service	Climate Regulation
Fruit	Provisional Service	Medicinal Remedies
Wood	Provisional Service	Building Material, Fuel
Place of rest and gathering	Cultural Service	Social Connection/Networking
Fresh Air	Supporting Service	Air purification. Oxygen Production, Carbon Cycling
Water Purify	Regulating Service	N/A

Aesthetic	Cultural Service	Mental Well-being
Flood Control	Regulating Service	Erosion Prevention
Medicinal	Provisional Service	Physical Well-being
Habitat	Supporting Service	Biodiversity, Habitat Creation

As mentioned before, trees have various cultural uses in South Africa. One participant mentioned, 'you'd say they're enough because you'd find everyone sitting under a tree like this'. The provision of shade and climate regulation that trees provide make them even more popular under the participants e.g., 'Yoh, on my side yes. As it's this hot, you can't sit in the house, you have to rest in the shade'. Even though, most participants indicated that trees are important, others had the opposite opinion. 'Eish, I don't know their importance, so I don't think they're important'. Additionally, "Ayy, when it comes to trees.... it's not something I like". The dislike or preference against trees might stem from a lack of knowledge about the exact ecosystem services (ES) that trees offer and a possible misunderstanding of how these services operate, which can make them appear more abstract and difficult to notice and perceive. It could also be that the perceived EDS outweigh the ES. For instance, a participant mentioned, 'yes, we're happy with them because it's only this time that we cut them down, we don't want them to grow too high because they will reach the electricity, we don't want that. We reduce them so that they don't bother with the electric poles. Future tree planting initiatives led by municipalities and communities must strategically address the challenges and drawbacks associated with trees (EDS). Proper maintenance and ongoing care are essential factors to consider, as low-income communities may lack the necessary resources, potentially turning trees into a burden rather than a benefit.

4. Conclusions

Metsimaholo experienced notable changes in urban tree and vegetation density over the past two decades as confirmed by NDVI analysis. An increase in vegetation density, especially in private yards and town margins, suggests that the community is actively planting trees, potentially aided by favourable weather conditions in recent years. These gains are counterbalanced by losses in tree cover, linked to urban expansion, and community practices.

Participants recognised the benefits of urban trees especially for air quality improvement, shade, wind protection. Some, however, raised concerns about the maintenance burden and felt that trees were not evenly distributed, particularly in public and private spaces. This

highlights the potential of undeveloped town margins as valuable areas that could offer ecological and social benefits, with reduced maintenance costs if managed sustainably.

Nevertheless, some UGS and trees have been diminished, possibly for building materials or fuel. Persistent challenges exist, however, in addressing historical inequalities in the distribution of urban green spaces and trees. Shifting maintenance responsibilities to private stakeholders rather than local government places additional pressure on low-income communities. This will require careful consideration in future municipal or community-directed efforts to ensure successful results.

To address historical inequalities and maintenance challenges, targeted educational programs could improve understanding and support for urban tree initiatives. Such efforts may mobilise community participation in tree-planting initiatives, enhancing air quality and overall quality of life in low-income communities. Future research could quantify how tree cover impacts air quality, providing clear guidelines on the number of trees needed for meaningful improvements.

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