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Research Article

VARCITIES Pilot Characterisation: Research Findings of the Environmental Conditions and Health-related Risks in Gżira.

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Abstract. Gżira is a small, highly densely populated town in the Maltese Islands measuring just 0.6 km^2 in surface area, that is facing many ecological and environmental challenges. The Horizon 2020 project, VARCITIES, aims to co-create visionary solutions (VS) with the Gżira community and various stakeholders to address these problems. A characterisation study was carried out as the first step in the processes needed to develop these solutions. This report shows data gathered by the Research Innovation Unit of the Gżira Local Council and University of Malta, with VSs being suggested involving micro-greening and citizen engagement activities to address the lack of green public spaces and health related risks currently perceptible in its geographical location, climate, and infrastructure. Following a series of ethnographic field observations, air quality measurements, academic research and consultations with expert stakeholders three visionary solutions were carefully co-created in order to devise the main Nature-based Solutions (NBS) to be implemented in the pilot city. This article discusses the present situation in Gżira and identifies the challenges of the context, and describes the ways in which VARCITIES attempts to address such problems and how NBS can be of benefit to the Gżira locality and users of space. The main challenges identified about the pilot sites are linked to deprivation of green infrastructure, high levels of air and noise pollution, the Urban Heat Island effect and improper disposal of waste. Visionary Solutions were proposed for these challenges in the form of infrastructural implementation and sociocultural events. These include; the micro-greening of a bus stop area and pop-up activities in Rue d'Argens, a citizen science activity involving residents in conducting air pollution measurements to increase awareness and a green outdoor learning space at St. Clare Gżira Primary School.

Keywords: Air Pollution, Noise Pollution, Nature-based Solutions, Urban Greening, Urban Heat Island effect, Health and Wellbeing, Visionary Solutions.

1 Introduction

Sustainable development of cities is becoming increasingly important, owing to an unprecedented level of urbanisation. Today, more than half of the world's population (55%) live in cities, a number forecast to increase to 68% by 2050 (UN, 2018). In some cases, urban population increase can also affect social services and health facilities in negative ways (Shao et al., 2022), leaving an impact on the health and wellbeing of residents, although further research is needed on this matter (ibid.). Urbanisation is linked to problems such as air pollution, the urban heat island (UHI) effect, decreased mobility, and other negat-

VS—Visionary Solutions
NBS—Nature-based Solutions
UHI—Urban Heat Island
UN—United Nations
SDG—Social Development Goal
IoT—Internet of Things
PESTLE—Political, Economic, Sociological, Technological, Legal, and Environmental
SWOT—Strengths, Weaknesses, Opportunities, and Threats
IR—Infrared
WHO—World Health Organisation

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ive outcomes that degrades the health and wellbeing of residents (WHO, 2016), which we outline below.

Air pollution is a well-known cause of various health related issues including respiratory diseases thus leading to reduced well-being in general (Dasom et al., 2018). Major pollutants found in the built environment include NOx's which are usually generated from internal combustion engines and particulate matter produced, for example, from building and construction activities (Dheeraj & Nagendra, 2022). Pollution in any given area varies spatiotemporally because of the varying sources (such as traffic) and environmental conditions including wind flow magnitude and direction (Youngkook & Guldmann, 2011). The monitoring of air pollution in rapidly changing urban environments, such as Gżira, provides significant data about the health risks that citizens are exposed to on a daily basis.

Urbanisation brings several environmental and social challenges (European Environment Agency, 2008). One main issue is the UHI effect (Revi et al., 2014). This phenomenon occurs when urban natural land cover is replaced by pavements and buildings that maintain heat in an area that then leads to detrimental problems, such as air pollution, heat-related illnesses, increasing electricity demand, thermal stress on low-income dwellings, and other long-term problems (EPA, 2020; Lin et al., 2015; Sakka et al., 2012; Santamouris, 2014). UHI increases the ecological footprint of cities exacerbating the climate crises (Santamouris, 2007). In order to mitigate the effects of this negative development, sustainable urban development or re-development strategies should be adopted with citizens and users in mind (Vandecasteele et al., 2019). In this respect, nature-based solutions (NBS) and visionary solutions (VS) play an indispensable role (European Commission, 2015). It is important to note that in cases where trees and vegetation are planted next to busy roads, the greenery could act as a canopy instead of a buffer, meaning that air pollution becomes trapped by obstructing dispersion of airborne pollutants (Jin et al., 2014). Proper optimisation and management of urban greenery can avoid this counter effective situation (WHO, 2016).

NBS have been construed as "actions to protect, sustainably use, manage and restore natural or modified ecosystems, which address societal challenges, effectively and adaptively, providing human well-being and biodiversity benefits" (IUCN, 2020). Due to the multiple benefits which directly or indirectly affect stakeholders, such as the provision of ecosystem services and promoting solutions to local climate drivers, there is a growing interest in the implementation of NBS (Balzan et al., 2022) which should be assessed from a holistic point of view to gather information about the different aspects which are affecting the health and wellbeing of citizens. NBS implementation contributes to the UN's Social Development Goals (SGDs) framework in various ways depending on the social and environmental predicaments affecting specific contexts (ibid,). For this reason, it is necessary to carry out preliminary research prior to the selection of NBS to identify which of these can be more effective in mitigating or addressing challenges in the target locality.

As the most densely populated country in the EU (Eurostat, 2019), Malta is a highly urbanised small island state with a major deprivation of green public spaces (Scheiber, 2020) and has several of the above-mentioned challenges. The EU has been encouraging the uptake of Nature-based Solutions as a way to mitigate the negative impact of climate change and urbanisation (O'Sullivan et al., 2020). For the above reasons, the authors of this paper joined a consortium that successfully applied for an H2020 call leading to the EU funded project VARCITIES (H2020-SC5-2019-2; grant agreement ID: 869505). The target site chosen in Malta was Rue d'Argens, the main thoroughfare of Gżira. The location is a highly trafficked road packed with residential and office buildings. It has very little to no greenery. It has also been earmarked for high-rise buildings, including 21-storey blocks (Borg, 2021). These factors make it an ideal site to benefit from NBS. This pilot characterisation study shows that the area needs a larger surface area dedicated to greenery to mitigate the negative impact of climate change and improve the health and wellbeing of its various communities; residents, local employees, commuters and other users of space. VARCITIES will collect through key performance indicators (KPIs) that will be measured before and after the implementation of the VSs to evaluate their impact. To inform which NBS can and will be introduced, an observational analysis of the area was carried out, coupled to a stakeholder engagement study, and the monitoring of air pollution data in Rue d'Argens and surrounding streets. Based on these findings, citizens, users and experts are being engaged at different stages of the project to identify which NBS should be introduced in the area and encourage collaboration to improve public spaces and people's health and wellbeing. These stakeholders will also be involved in the research process. This research paper describes the status and challenges of Gżira in detail based on the results obtained from the pilot characterisation process, the process implemented by VARCITIES and relevant literature related to this research.

Being a VS project, the main objective of VARCITIES is to enact real, innovative ideas and add value by establishing durable models for improving health and wellbeing of citizens who are exposed to various climatic conditions and challenges across Europe (Tsekeri et al., 2021). The intention of VARCITIES is to put these en-

visaged solutions into practice in the redesign of urban spaces, and test the effectiveness of these innovative solutions. These VSs are encompassed into four typologies; Nature-Based Solutions, Energy IoT, Mobility and Knowledge/Awareness. The focus of the Gżira VS implementation is to improve ecosystem services in the area to improve the health and wellbeing of citizens using a co-creation process, which includes; a co-identification, co-design and other participatory processes with citizens and key stakeholders. The infrastructural and socio-cultural implementations include the micro-greening of a bus stop in Rue d'Argens and organising pop-up events in Rue d'Argens, installing a community garden playscape at St. Clare Primary School and conducting research on air pollution with Gżira residents.

2 Visionary Solutions for Gżira

The VARCITIES project is and will be engaging citizens to develop a sense of ownership of the community and a desire for change towards a green-friendly environment and healthier livelihood for their benefit. A set of three VSs was originally drafted as ideas for NBS implementation to be proposed to stakeholders from the information collected in the pilot characterisation study. Stakeholders were able to provide feedback during the first co-creation workshop with experts, the local community and the users of space. This feedback was then integrated in the VSs and any changes made were presented to stakeholders during the second workshop, and provided reasons in cases where their feedback was not feasible to implement.

The project has three VSs for the Gżira locality. VS one is focused on implementation in Rue d'Argens through a participatory design process; the infrastructural implementation includes the micro-greening of a bus-stop with increased shade for bus users, and pop-up parks with temporary greening are being organised, focusing on cultural as well as educational activities. Within the framework of this visionary solution, businesses and residents in Rue d'Argens will be encouraged to contribute to their spaces. Their main contribution could be the greening of balconies, facades, and interiors of their households to further increase vegetation, embellish the streetscape and help biodiversity to thrive. This implementation process depends on the level of participation of various stakeholders. Local community members will be involved and consulted through focus groups to understand the needs and wants of the locality, centred around the possibility of improving health and wellbeing in the area through NBS.

VS two is focused on citizen science, aimed at increasing awareness about air pollutants (ibid.). Three areas, namely the Council of Europe Gardens, Rue d'Argens, and the University of Malta have been selected as a reference point where sensors will be installed to measure the amount of air and noise pollution, identify various pollutants, and create models of the flow of pollutants to inform which forms of greening infrastructure would benefit the community the most. Citizens who are interested in being part of the data collection will be provided with sensors to measure pollutants. Other relevant engagement activities, such as giving access to the health and wellbeing information through a platform will be considered to engage citizens. These suggestions were provided by stakeholders during the co-creation workshops. Furthermore, the team intends to collect data from participants using a gamified approach. Citizens will have the opportunity to engage in the project using an interactive digital platform developed by Darttek, a local partner in the VARCITIES Consortium.

Visionary Solution three is called "urban biodiversity, education and engagement through a co-created community garden project" (ibid.) and aims to focus on working with St. Clare primary school to implement NBS and citizen engagement activities in the process. The intention is to integrate greenery in educational and cultural settings. In this regard, green walls with particular plants will be installed at the primary school to attract various biodiverse organisms, create a harmony between urban life and nature, and raise children's awareness of ecology, the initiative is in line with the United Nations Sustainable Development Goals 2030, namely goals 11 and 13 (UN, 2015). Another participatory activity will be organised at the Gżira Gardens in collaboration with the Gżira municipality to invite various stakeholders in a transdisciplinary and multicultural event.

3 Methodology

This study uses a mixed methodology research design that has enabled us to understand underlying urban complexities within the Gżira pilot site. The content analysis method was applied to analyse quantitative and qualitative research material, while minimising the limitations of both techniques (Creswell & Creswell, 2018). The inductive approach of content analysis proved to be of significant help to study the locally underexplored research problems (Vourvachis & Woodward, 2015), as a way of combining existing statistics at the local level with international standard on air pollution, and data collected from stakeholders while exploring consistencies and environmental patterns from existing sources to correlate the data and devise Visionary Solutions to mitigate the challenges of the locality. In the data collection stage, an in-depth literature review was performed by analysing existing articles, reports, statistics and grey literature, other research and later compared the data with quantitative data from vari-

ous sensors; namely air quality, sound and heat sensors.

3.1 Methodology: community engagement approach

In VARCITIES, public spaces are considered as places of social interaction with various opportunities for community inclusion and engagement (Tsekeri et al., 2021). The co-creation strategy is being adopted in order to exploit these opportunities by involving stakeholders with different expertise, experiences and social backgrounds to support creativity, inclusivity, health and happiness for the citizens (ibid.). Several workshops were held in the early stages of the project to collect data from the participants, using both online and in-person formats. The first co-creation process was held online and had participants representing different fields and backgrounds; 4 cultural practitioners (one was a Gżira resident), 3 administrative staff and academics in educational institutions, 2 architects and a founding member of the student association of Architecture and Civil Engineering Society (SACES) at University of Malta, 2 local suppliers of green infrastructure, 2 experts on environmental management from the private and public sector and a Gżira resident. The workshop was structured in two parts. During the first hour the VARCITIES research team introduced and collected information about the proposed VSs, which at the time were drafted based on the pilot characterisation, field observations and internal discussions. The second part of the session focused on conducting a PESTLE (or also referred to as PESTEL) and SWOT Analysis with attendees in relation to the VARCITIES VSs, to have a more holistic approach in our VSs. The intention of a PESTLE Analysis is to collect information related to the political, economic, socio-cultural, technological, legal and environmental key external factors. Originally, the PESTLE Analysis was implemented in businesses to examine the environmental external factors which could affect the performance of an implementation strategy (Siobhan, Benedict et al., 2021). In this context, the PESTLE Analysis was directly used to capture relevant information on the local environment and microclimate to devise a way forward. In addition, attendees were also invited to participate in a SWOT Analysis, which is aimed at identifying the strengths, weaknesses, opportunities and threats which the research team can exploit and mitigate based on the data collected during the session. This sort of approach has recently started to be implemented in environmental management projects to assess factors which contribute to the successfulness of the project (Bull et al., 2016). The ideas which came out of the first workshop fed into the designs of the infrastructural and cultural NBS. Once the feedback was integrated in the VSs, the designs for implementation were redrafted and presented to stakeholders in the co-design workshop. Due to the lack of citizen involvement in the online workshop, the research team also organised preliminary on-site workshops, called 'pop-up parks', at various locations and times in streets in Gżira around Rue D'Argens to increase the level of engagement with users of space in general. This approach enabled the researchers to interact with residents, passers-by and employees in local businesses who have different subjective experiences in the area. In these workshops participants were asked to comment about their daily environment in Gżira and provide suggestions on how the situation can be improved by giving feedback about the proposed VSs.

3.2 Methodology: air pollution monitoring

In this pilot study, a single sensor was installed on the roof of a building which currently houses the Gżira Local Council. The building is located in the middle of Rue d'Argens road and next to a very busy crossroad linking it to Sliema road. Further details regarding the location chosen are given in section 3. The sensor captures the concentration of several air pollutants which are discussed in Section 4. A thermal imaging camera was also installed at the site.

The data considered for the study was collected between the 29th of June and the 14th of August 2018 to capture baseline data to identify traffic flows during the summer period. The sensor (Model: AQM Id. no. 734150) was set to capture one reading per hour for every pollutant. In this way, daily means and standard deviations for each pollutant were computed.

These research findings were collected in order to identify the baseline of the current environmental conditions in Rue d'Argens. These results will be compared with findings that are going to be collected during the pre-implementation and post-implementation stages of the VARCITIES project. During these stages more sensors will be installed along the entire length of the road.

3.3 Methodology: Urban Heat Island identification

The UHI data presented in this paper is from the PHASE 1 (PH-1) project led by Fabian Borg (a paper author) of the Research Innovation Unit of the Gżira Local Council. Since 2017, PH-1 has developed the following UHI framework to determine UHI and its contributors within the locality of Gżira (Borg, 2021). The initial data collection by PH-1 focused on heat analyses utilising industry standard handheld thermocouples and thermopile IR sensors as well as portable and high-end, calibrated FLIR thermal instruments for visual heat analyses of the excess waste heat trapped within the Atmospheric Boundary Layer of the locality. The portable FLIR One Pro performs auto

calibration of its thermal sensors (Borg, 2020).

These research findings were collected from various sources in order to identify the baseline of the current environmental conditions in Gżira, which will be compared with findings collected during the pre-implementation intervention and post-implementation intervention stages of the VARCITIES project. More details of the findings are provided in the following chapters.

4 Overview of the Gżira Locality

Located in the North Harbour Area of Malta, Gżira forms part of the central region with 13,000 residents that make up 2.69% of the total Maltese population (NSO, 2020). Gżira has several narrow roads, heavy traffic with a main thoroughfare and is in the process of becoming a future hub for high-rise development. It has a high level of commercial activity due to bars, restaurants and ethnic shops within it that conflict with its residential status. On top of this, its green public space is under dire threat due to the unprecedented urban development (Borg, 2020; Delia, 2020).

Malta has a Mediterranean climate with mild winters and hot summers (The World Factbook, 2021). Gżira is one of the warmest regions in Malta with an average daily high temperature of 23°C where temperature can sometimes continuously reach as high as 40°C degrees during certain months due to its infrastructure and lack of urban greening (ibid). This warrants a call for new technological, environmental and social solutions to create better living conditions and experiences.

Studies have identified the following major concerns for Gżira: the Urban Heat Island (UHI) effect, heavy traffic, real estate development, deficiency of sustainable development, heavy fuel oil pollutants from sea vessels, volatile organic compounds, and other pollutants emitted from yacht yards, as well as the old wastewater pumping station (Mercieca, 2021; Scicluna, 2016).

In terms of environmental concerns, the geographic location of Gżira results in manifold challenges. One of the authors (Fabian Borg who has been employed with the Gżira Local Council for 28 years) describes Gżira in the following manner: It is in a basin type area with its neighbourhoods set at a higher altitude than the locality itself. This results in rainwater run-offs from the surrounding areas that lead to flooding. The problem is exacerbated by increasing sea-levels due to climate change which seems to be increasing over time as stated in the European Environment Agency (2022a) report. Another problem is the overloading of main sewers due to intense downpours that is further aggravated by rainwater run-offs. In addition, air pollution caused by the excessive traffic and waste heat from the densely-built urban zones are of main concern. Noise pollution is pervasive, and a major issue not only inside urban areas like Gżira, but Malta in general, which is considered to be the noisiest country in the European Union until 2020 (Eurostat, 2023). Traffic and construction are considered to be the main sources of noise pollution (ibid). Urban noise, typically that generated by high traffic intensity is a predominant cause of stress, sleep deprivation, and annoyance in people's everyday lives (European Environment Agency, 2022a), disrupting the residents' time to rest in their own private spaces (Calleja, 2018). In Sliema, the neighbouring locality of Gżira, constant urban changes seem to be a cause for social alienation, individualisation, and exclusion for people with restricted mobility as well as a lack of sense of belonging among the residents—especially natives (ibid.). Rhythm of life is a health factor which should be taken into consideration when examining the links between noise pollution, psychological health and mental wellbeing. Quieter and calmer environments, such as parks, are often considered as therapeutic spaces with psychological benefits, while busy urban streets can be overstimulating, causing stress to people who are exposed to them on a daily basis (ibid.).

Green urban areas available in Malta measure 181.1 ha according to the Environment and Resources Authority (ERA, 2019). ERA's analysis used the CORINE Land Cover (CLC) description (European Environment Agency, 2016). The smallest surface mapped when considering green infrastructure was 25 ha, and any land cover smaller than this was not plotted. Many of the gardens and areas identified in Malta were therefore too small to be recorded for the purpose of CORINE. For example, Gżira's Council of Europe Garden is less than 25 ha and a major green space for the area - as per measurements taken from Google Earth. This classification and calculation therefore do not take into account the smaller green infrastructure elements which may be found within the urban conurbation. Research conducted as part of the ReNature EU project has mapped out various NBS case-studies in the Mediterranean, with several solutions implemented in Malta (Sapundzhieva, Balzan et al., 2020). Apart from those NBS found in the map, it is worth mentioning here that smaller green infrastructure elements are mostly found within private spaces.

With respect to larger scale green infrastructure elements, nature sites and special areas of conservation and national importance, such as tree protection areas contribute to Malta's main green infrastructure elements, as well as natural valley systems (ERA, 2019). Of note in Gżira's urban locality, is Wied Għollieqa, a natural valley system which used to extend to the sea that acts as a vital habitat for various local species (Nature Trust, 2021).

Urban open spaces are an important element for urban areas since if planned and designed appropriately they can also act as green infrastructure (Hansen et al., 2017). They would then have the potential to contribute to addressing the climatic, environmental and health issues identified in the Gżira locality. Research specific to Malta has shown that currently urban open spaces in the Maltese conurbation are not functioning as green infrastructure, even though the potential does exist (Scheiber, 2022). As a result, they are lacking in their potential to address social and environmental challenges brought about by urbanisation and hence contribute to sustainable development (Scheiber, 2019, 2020).

The EEA's Urban Atlas Map of Malta illustrates that green urban areas are extremely limited within the Gżira locality (ERA, 2019); however, this does not take into account Malta's particular scale and thus the smaller scale green infrastructure elements which may be found. While accurate mapping of green infrastructure for the locality does not exist, Fig 9 identifies some of the key open spaces in Gżira and their connection to Wied Għollieqa and the University Campus grounds in the immediate vicinity. ERA (2019), lists the following elements as indicators of green infrastructure: trees along road verges and roundabouts, small gardens, afforested areas, recreational parks, valley system, green enclaves, areas of ecological importance, and sites for scientific importance (ibid). Applying this method, the main existing green infrastructure elements in Gżira can be listed as Council of Europe Garden (1), Wied Għollieqa (2), trees and vegetation clusters within urban open spaces, Manoel Island (3), and private internal gardens with significant vegetation and various trees. However, apart from existing elements, the opportunity to identify spaces which can be (re)developed as public green spaces still exist.

5 Results

This section outlines the various results emerging from this research, namely; air pollution, the UHI effect, health-related issues in Gżira and the outcomes of the PESTLE and SWOT analyses. The supplementary data presented in the Annex provides the reader with the context for these results. An annotated map found in the Annex section shows the status of existing green infrastructure in the area of interest to complement the results.

5.1 Results: Air pollution of the Gżira locality

To identify if air pollution in Gżira is within WHO recommendations, an air-quality sensor collected snapshot data throughout July and mid-August of 2018 in Rue D'Argens, Gżira. All plots within Figures 1 and 2 display the daily average (in blue) and the upper and lower bounds (in green). The latter consist of the daily average ± the standard deviation. The red line represents the WHO target concentration threshold limit of individual pollutants (the 99% percentile). Only those pollutants which cause serious health issues have a threshold limit. These limits can be obtained from the air quality guideline section of the WHO website (https://www.who.int/). We opted to consider WHO thresholds since these were comparable as 99th percentile thresholds. If concentrations of said pollutants exceed these threshold limits for more than three days in a year (giving a proportion of 0.01), then this is cause for concern. We will thus perform a one-tailed one-sample proportions test which tests whether the null hypothesis states that the number of exceedances of the threshold does not exceed 0.01, against the alternative hypothesis states that it does. We shall take a 0.05 level of significance. It is evident that Particulate Matter 2.5 (PM 2.5) and Nitrogen Dioxide (NO2) are of major concern given that the daily average is almost always above the WHO threshold limit. Indeed, a one-tailed one-sample proportions test rejected the null hypothesis in both cases - for PM2.5 ($Z = -58.59$, $p < 0.001$) and for NO2 ($Z = -67.48$, $p < 0.001$). Nitrogen Oxides (NOx) and PM10, on the other hand, had daily averages that were close to or similar to the WHO threshold limit. The test outcomes for PM10 and for NOx where ($Z = -34.88$, $p = 0.011$) and ($Z = -2.28$, $p < 0.001$) respectively. Moreover, Carbon Monoxide (CO), Ozone (O3) and Sulphur Dioxide (SO2) were well below the WHO threshold limit on all days of the study. Hence, it can be concluded that these pollutants were of no serious concern. The other pollutants, PM1 and Particle count, did not have a threshold limit. In conclusion, we deduce that PM2.5, NOx and NO2 are regularly or consistently above the WHO 99th percentile threshold, while PM10 exceeds the WHO 99th percentile threshold more than the recommended 3-4 days a year. On the other hand, the area does not appear to have a problem with high concentrations of CO, O3 and SO2.

5.2 UHI issues of the Gżira locality

Heat sensor data indicates that the Gżira locality has an elevated temperature level when compared to the surrounding areas. Lack of vegetation exacerbates this issue. Figures 3–5 shows intense solar energy radiation and the resulting excessive heat build-up within the Atmospheric Boundary Layer (ABL) of the locality. PH-1 conducted equivalent same-day tests in other localities that have implemented nature-based solutions (NBS), such as verged roads, as seen in Figures 6–8 to obtain a preliminary indication of whether NBS can counter the UHI effect in Gżira.

PESTLE Analysis	
Political	Economic
• Public spaces should remain public • Traffic management in the area • Quality of Life in the centre of the Government's political agenda	• Cars and restaurants are prioritised over residents • Overly privatised area • Stakeholder mapping to ensure inclusion
Socio-cultural	Technological
• Incomers to the area (expats & foreign workers, locals moving in) to be involved, as they may be social / linguistic barrier in communication • Possibly identify areas which can be pedestrianised, even if on a time based or for a limited number of days per week • Reuse existing spaces	• Open data portals • Use tools for citizen science to report biodiversity, environmental issues interactively • Data sharing which is important for evidence base
Legal	Environmental
• Lack of enforcement for infringements of building developers/air quality (apart from LESA) • Compliance with EU standards (air quality and noise thresholds)	• Pavements are horrible to walk on • Support local species • Large built areas in Malta reduce air exchange, and have heat an pollution pockets • Air quality targets • Improve ambient air in Gżira by improving air currents • Rue d'Argens is a heat trap. It would be great to look at it holistically to reduce fuel traffic and increase greenery. Plants and trees also absorb noise and vibrations (perceived noise)

Table 1: PESTLE Analysis results.

Another study by Mercieca (2021) using Sentinel-3 data from the EU's Copernicus Programme, identified a 2-3 degrees celsius temperature increase in the Sliema-Gżira-Msida urban area compared to other more rural areas in Malta. Both pilot studies identify a UHI problem in the Gżira area that requires NbS to mitigate (Sapundzhieva, Balzan et al., 2020). UHI has been linked to many health problems (Santamouris, 2014).

5.3 UHI issues of the Gżira locality

This section outlines the health conditions of Gżira residents. In 2020, the crude birth and death rates in Gżira were 8.6% and 7.9% (NSO, 2020). The below locality-specific statistics were obtained by Fabian Borg from the Directorate for Health Information and Research (DHIR) and the national hospitals information systems. It is estimated that the five major causes of death registered in the Gżira locality were: diseases in the circulatory system, neoplasm, diseases related to the respiratory system, dementia and diabetes. The percentage deaths caused by malignant neoplasm of the trachea, bronchus and lungs in Gżira were 8.5% as opposed to 5.3% for the rest of the Maltese islands. Furthermore, it was estimated that the incidence of cardiovascular diseases for Gżira in 2018 stood at 16.11 cases per 1000 inhabitants, and the incidence of respiratory diseases for Gżira in 2018 was estimated to be 11.91 cases per 1000 inhabitants. However, these were comparable to the rest of the Maltese islands. These statistics show that the health and mental well-being of residents in Gżira is different to the rest of the Maltese population. Other factors which have a significant impact on these health issues are demographic variables such as age, sex and ethnicity of residents, and their level of education, use of tobacco and alcohol, and status of employment, which play a significant role in determining the sources of these issues.

Full details of the pilot characterisation of Gżira for VARCITIES can be found on this link: https://bit.ly/GziraCharacterisation

5.4 Results of PESTLE and SWOT Analyses

The results of the PESTLE analysis are summarized in Table 1 and the results of the SWOT analysis are displayed in Table 2.

6 Discussion, Outcomes & Conclusion

In view of the responses received in the first co-creation workshop and other research carried out as part of the pilot characterisation exercise, the persistent and prevalent problems in Gżira are the following; limited green and social spaces, narrow and dirty pavements, poor air and noise quality, excessive traffic, the urban heat island effect, and

Results of SWOT analysis		
Strengths affecting the planned Visionary Solution		
Please describe the endogenous factors that can favour the pursuit of VS objectives. *Outputs of the co-creation workshops		
VS1	**VS2**	**VS3**
• Assess the impact of the intervention on the wellbeing of those who live/work there • Propose road infrastructure measures that can lead to the use of sustainable modes of transport	• Establish exciting platforms to engage citizens and for continuity after the project • Possibly engage Local Council / NGOs, so people who cannot provide online / app-based feedback can still contribute and be engaged	• Participatory approaches and high level of community engagement are crucial
Weaknesses factors affecting the planned Visionary Solution		
Please describe the endogenous factors that can hinder or delay the VS implementation process. *Outputs of the co-creation workshops		
VS1	**VS2**	**VS3**
• Lot of traffic and small pedestrian space so hard to implement greenery • Diminish car parking spaces, create events to close the streets • Passage-ways, seating, pavements, etc. (which may be necessary) are all take up space, and could minimise the actual greening effect	No relevant factors identified	• Concerns about the accessibility and visibility of the space to the public, i.e. it could be perceived as a space which falls part of school property
Opportunities affecting the planned Visionary Solution		
Please describe the endogenous factors that can positively affect the VS implementation. *Outputs of the co-creation workshops		
VS1	**VS2**	**VS3**
• Study how planting could work effectively for reduction of noise pollution • Document the intervention in an audio-visual way since it will likely inspire others • At a research level, include biodiversity indicators to monitor project performance	• Citizens want to have access to the data collected by sensors about noise, air pollution and wind flow • In some cities people use a telegram or messenger bot to get updates about air quality in their neighbourhood (to raise awareness)	• Ensuring that the public is involved and aware of this opportunity to turn the space into a spot for cultural events, workshops, and leisure activities
Threats affecting the planned Visionary Solution		
Please describe the endogenous factors that can negatively affect the VS implementation. *Outputs of the co-creation workshops		
VS1	**VS2**	**VS3**
• About air quality and pollution levels, make point not to relocate the traffic pollution to other streets (possible pollution shifting) • Take into account a study on slow streets done by the Local council in general, pay attention not to create a good situation here and ruin it somewhere else	No relevant factors identified	No relevant factors identified

Table 2: SWOT Analysis results.

a lack of shading for people commuting on foot or by bus. These factors match the literature consulted (example European Environment Agency, 2008; WHO, 2016), and are all problems linked to urbanisation, which causes a number of health issues to the people experiencing these environments. Multiple themes were identified based on this data and were integrated into the VSs, which include; creating synergies between private and public stakeholders to support urban regeneration and the well-being of citizens, re-appropriating existing public spaces and unused buildings as social spaces to improve interaction and cultural integration, promote accessibility to green urban spaces for people in the area, ensure digital participation and data collection that is meaningful to citizens, mitigate air pollution to incentivise use of alternative modes of transport and embellish the streetscape in Rue d'Argens through added green infrastructure. The expected outcomes from the VS implementation in the Gżira pilot site are that

1. VS one may improve mobility by means of increasing shading surface area to protect bus stop users from the elements The intention is to incentivise the use of public transport and create temporary social spaces through benches integrated with the tree planters. The pop-up events then focus on raising awareness about the lack of green public spaces for social interaction.
2. VS two aims to raise awareness and educate the public about existing air pollutants through citizen science initiatives with local residents.
3. VS three focuses on the co-creation of a mixed-use playscape through participatory methods involving the school community - which may also become partly accessible to the public. It will provide students with an outdoor green space for learning by means of hand-on and engaging activities.

Among the concerns of stakeholders expressed during the PESTLE Analysis (see political factors) is that "public spaces should remain public", due to the dominance of the private sector in the area, as another stakeholder expressed. As stated in the results section, green infrastructure is very limited in Gżira and most of these areas are located within private spaces — meaning that the general public cannot access and enjoy spending their time in these spaces. Privatisation and overdevelopment in Gżira could pose more health risks to the users of space — some potential spaces could be proposed as sites which can accommodate green infrastructure at a later stage. There are several open urban spaces which could be developed into green infrastructure to support the local microclimate, biodiversity and community. In this respect, and also based on literature reviewed in relation to the UHI effect (European Commission, 2015; Vandecasteele et al., 2019), a large surface area where NBS can be implemented is needed to mitigate the adverse effects of the UHI and rising temperatures in general. Any outcomes from the micro-greening of Rue D'Argens can be used to ascertain potential benefits of additional NBS in the area. Unfortunately, the narrow road and lack of pavement space available in the Street provides limited opportunities for further implementation of NBS unless more substantial infrastructural changes are made with governmental support.

Interestingly, access to green open spaces is associated with improvements in people's health and wellbeing through reduced mental distress, anxiety and depression (Barton & Rogerson, 2017), increased physical activity (ibid.), improved air quality and reduced exposure to noise while decreasing prevalence to allergies and asthma (WHO, 2016). The need for increased greenery in the target area was highlighted in the PESTLE analysis and data collected from the pop-up park activities. While the relationship between trees, air flow and pollution is a rather intricate one, positive effects of urban greening seem to outweigh negative ones. As mentioned by stakeholders during the workshop, trees provide shading and cooling to pedestrians, which is especially beneficial during the summer period due to higher temperatures. Among the responses, stakeholders also expressed those trees attract more biodiversity into our urban environments. One of the inputs in the environmental section of the PESTLE analysis mentions that built up areas in Malta, such as places like Gżira, impede air exchange and create heat pockets in streets. Proper management of local urban areas is required to enhance streetscapes and liveability of residents in the area and users of space in general. The implementation should be guided by scientific research and community inclusion as advised by authors cited in the literature review (European Commission, 2015; Vandecasteele et al., 2019). A context-specific and strategic approach based on the co-evaluation of health and wellbeing parameters with stakeholders is necessary when implementing green infrastructure and NBS to maximise the outcomes of the investment. Access to green social spaces and proper maintenance of the streets can instil a sense of belonging within the communities in urban spaces to prevent social alienation, individualisation and exclusion, while promoting inclusive urban environments.

In an attempt to mitigate air pollution, VS2 aims to publicise research gathered by the core team and the immediate community through various channels to reach citizens with diverse backgrounds. These citizen science mechanisms are being implemented in this research pro-

ject to evaluate whether access to knowledge and digital tools to share environmental data in creative ways can yield better results in terms of health and wellbeing to support the micro-greening in the area. From feedback collected during the workshop and the literature consulted, the impact is not expected to be highly significant in terms of reduction of airborne emissions and noise pollution. Given the budget limitations of the project and the scarce opportunities for high volumes of greening in the area, the NBS to be implemented will be assessed to identify improvements in the micro-climate, quality of life and environment in the context of the local challenges, which could eventually lead to replication in Gżira, neighbouring localities or others with similar context to Gżira.

The pertinent health risks brought by inhalable PM10 and PM2.5 particles on a short- and long-term basis are associated with increased morbidity and mortality rates relating to cardiovascular and respiratory disease, including asthma and lung cancer. It is stated that "All-cause daily mortality is estimated to increase by 0.2 - 0.6% per 10 μ g/m^3 of PM10. Long-term exposure to PM2.5 is associated with an increase in the long-term risk of cardiopulmonary mortality by 6–13% per 10 μ g/m^3 of PM2.5" (WHO, 2013). Various case studies in Japan, England, Spain and Canada show the evidence of people with access to green spaces, or those who live in urban green spaces, stating that such factors contribute to people's longevity (WHO, 2016). Other sources show that trees could entrap pollutants and hinder dispersion if proper tree management is not carried out in relation to airflow (Jin et al., 2014). Other health issues may arise from NOx, particularly NO2 which are typically associated with cardiovascular and respiratory mortality (Meng et al., 2021), being similar symptoms of other aforementioned pollutants. Traffic and combustion engines are once again the main sources of these risks and experts propose strict restrictions related to NO2 to prevent such health complications (ibid.). The air quality preliminary results have been included in the Appendix below. For the research to have a more conclusive data set on which to base the analyses, a larger sample is required. Additional sensors will be installed to measure and assess the impact on a larger geographical and temporal scale.

The comments from stakeholders reaffirm that air pollution is a persistent problem in Gżira, but also state other benefits of trees, such as their cooling effect and flood reduction. Citizens have expressed their desire to have more green infrastructure in the locality in the preliminary pop-up engagement activities. The data collected from passers-by comprised 66 responses when asked about their relationship with the environment in the locality providing the following percentages; 56.1% being residents, 31.8% local business employees and 25.8% commuters. Some respondents selected multiple responses due to different categories which are relevant to their situation, and therefore fall into more than one category. The age group majority was that of 56.3% aged between 27–40 years old, followed by 14.1% of participants aged between 41–60, 12.7% were between 61–80 years old, 9.9% were young adults of 18–26 years of age while the rest chose not to disclose such information. In terms of gender, the research team engaged 57.7% males, 42.3% females and none from other genders. The nationality of 52.2% of these respondents is Maltese, while the rest are expats from various continents. When respondents were asked about what kind of greenery they think would be most suitable for Gżira, the majority said they found all types of greenery to be appealing, most of them expressed the need for more greenery and to decrease pollution in any form (air, noise and inadequate disposal of garbage). When asked to provide suggestions for improvements in the area, some commented that they "want to see greener [areas], more trees, anything that is green and no noise and pollution", "all the types of greenery in the area, less cars and less trash", or "reduce traffic, plant more trees, lower the buildings, diminish CO2 emissions." Most of the other responses recommend similar improvements, however a few of them also expressed concern to provide more parking spaces due to the high number of cars and activity in the area. From the feedback collected, it seems that most respondents (experts, local residents and expats) agree on the need to improve the environmental conditions of the area and traffic management and believe that greenery and NBS play a role in shaping healthier and inclusive urban spaces. However, additional data is required to understand their impact and why there is still a severe lack of local green infrastructure in general. This issue might be that people need to be consulted more often, and perhaps also engaged in greening projects to foster a culture of co-creation. It is significantly important to engage local community members with diverse social backgrounds so that public spaces can be designed more inclusively by integrating all the feedback that might be offered by people of different cultures, ages, expertise and health problems.

A few respondents stated that there is "too much noise" in the area or that a "calmer street" is needed, as well as others also suggesting a shift in the road infrastructure to have more pedestrianised spaces and a change in the traffic flow in Rue d'Argens, in Gżira. In the neighbouring locality of Sliema, similar issues were raised by residents in a study conducted by Calleja, K. (2018), who mentions that the main source of urban noise was that produced by intense traffic and multiple construction projects oc-

curring simultaneously. That study noted that constant urban changes and a road infrastructure which prioritises car users seem to be causes of social alienation, individualisation, and exclusion for people with restricted mobility as well as a lack of sense of belonging among some residents. Malta suffers from high traffic intensity and congestion levels, with approximately 18,000 vehicles per km^2 of road (NSO, 2022) and around 13,700 total passenger cars per km^2 of roads. This may partly be due to its high population density. Rapid urban development has also resulted in a high number of residential projects. These factors can contribute to both the air and noise pollution reported in our results. Parking related issues flagged in the results suggest that the road infrastructure presents challenges in accommodating the number of cars. Proper enforcement in construction-related activity and traffic management are required in order to manage the detrimental psychological effects brought about by noise pollution.

The pilot characterisation data shows that Gżira has high air pollution levels, high UHI effect, and a lack of green infrastructure as well as health and wellbeing issues—further research is needed to determine whether these factors are correlated. The air pollution, health stats, and UHI preliminary indications all identify that Gżira is a locality where NBS has the potential to improve the health and wellbeing of citizens. The challenges listed are often associated with increased urbanisation , lack of investment in and attention to greenery, and deficient long-term measures to improve liveability. Failure to address such concerns can negatively impact the quality of life of residents (WHO, 2016). To evaluate the impact of the VARCITIES' VSs, post-implementation health and wellbeing data will be collected to allow comparison with pre-intervention measures and. facilitate development of a replication toolkit. The VARCITIES project aims to improve the health and wellbeing of citizens in Gżira by bringing three VSs to increase vegetation in the Gżira locality, raise awareness and mitigate air and noise pollution, improve walkability, boost civic participation, community ties, social responsibility, and environmental awareness. Furthermore, the project seeks to replicate these VSs in localities facing similar challenges. This study foregrounds preliminary social and environmental results for the locality, and also includes additional data received by stakeholders in the development of the VSs. Baseline data will be made publicly available once the implementation of VSs is carried out.

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Appendix

Air pollution Data

Figure 1: Daily averages, Upper bounds, Lower bounds and WHO target concentration for Particle count, PM1, PM2.5, and PM10.

Figure 2: Daily averages, Upper bounds, Lower bounds and WHO target concentration for CO, NOx, NO2, O3 and SO2.

UHI figures

Figure 3: UHI amplified Solar Heat Energy Radiation taken in Triq D'Argens, Gżira on the 4th July 2019.

Figure 4: UHI heat entrapment throughout night, despite passing vehicles air drag that is presumed to cool the surfaces to ambient temperature. Taken in Triq D'Argens, Gżira on the 8th July 2019 21:00 hours.

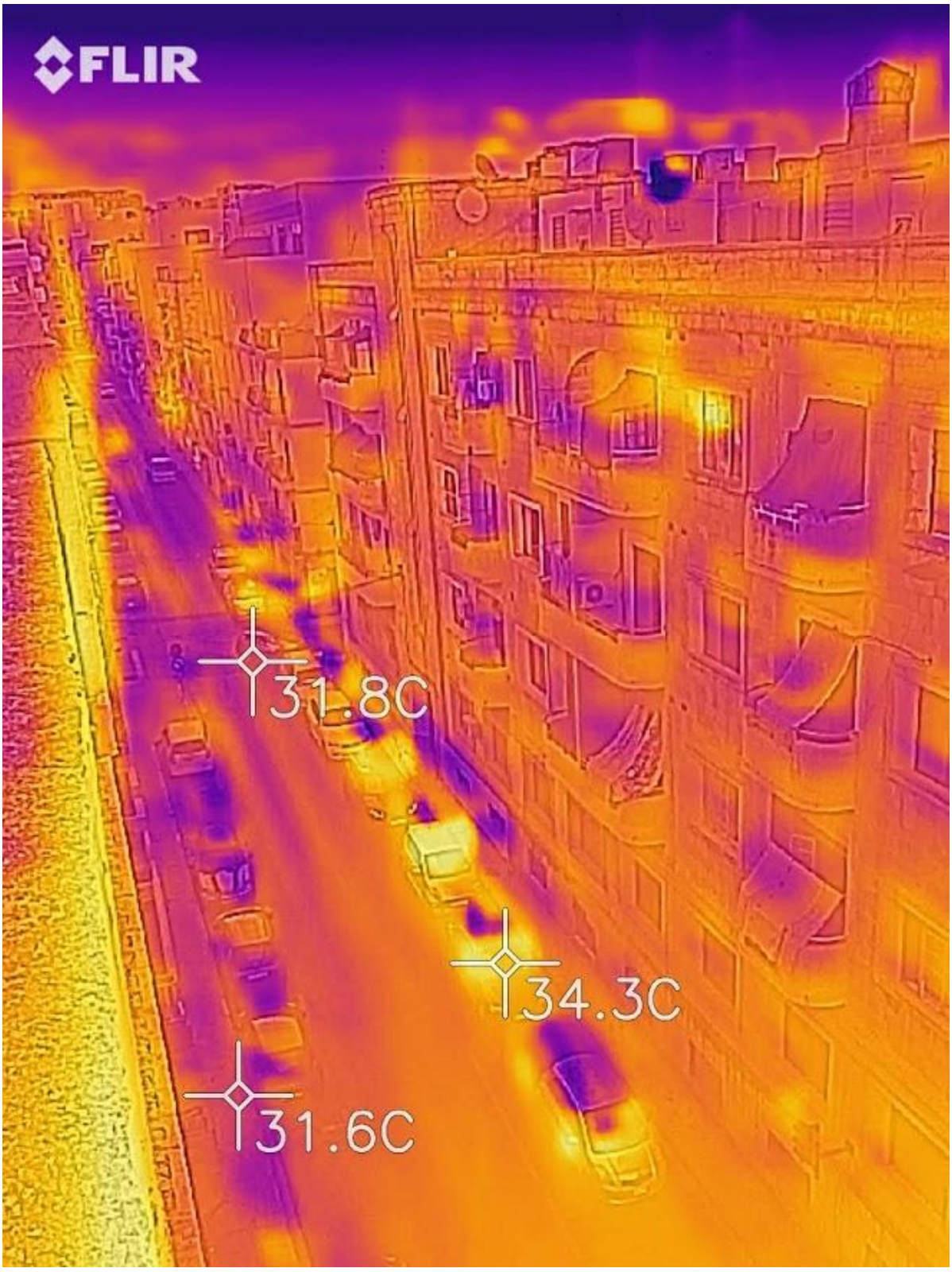

Figure 5: Triq D'Argens, Gżira (shaded from the sun) remaining warmer than the nighttime ambient temperatures despite passing vehicles air drag that is presumed to cool the surfaces to ambient temperature. Taken in Triq D'Argens, Gżira on the 9th July 2019 07:00 hours.

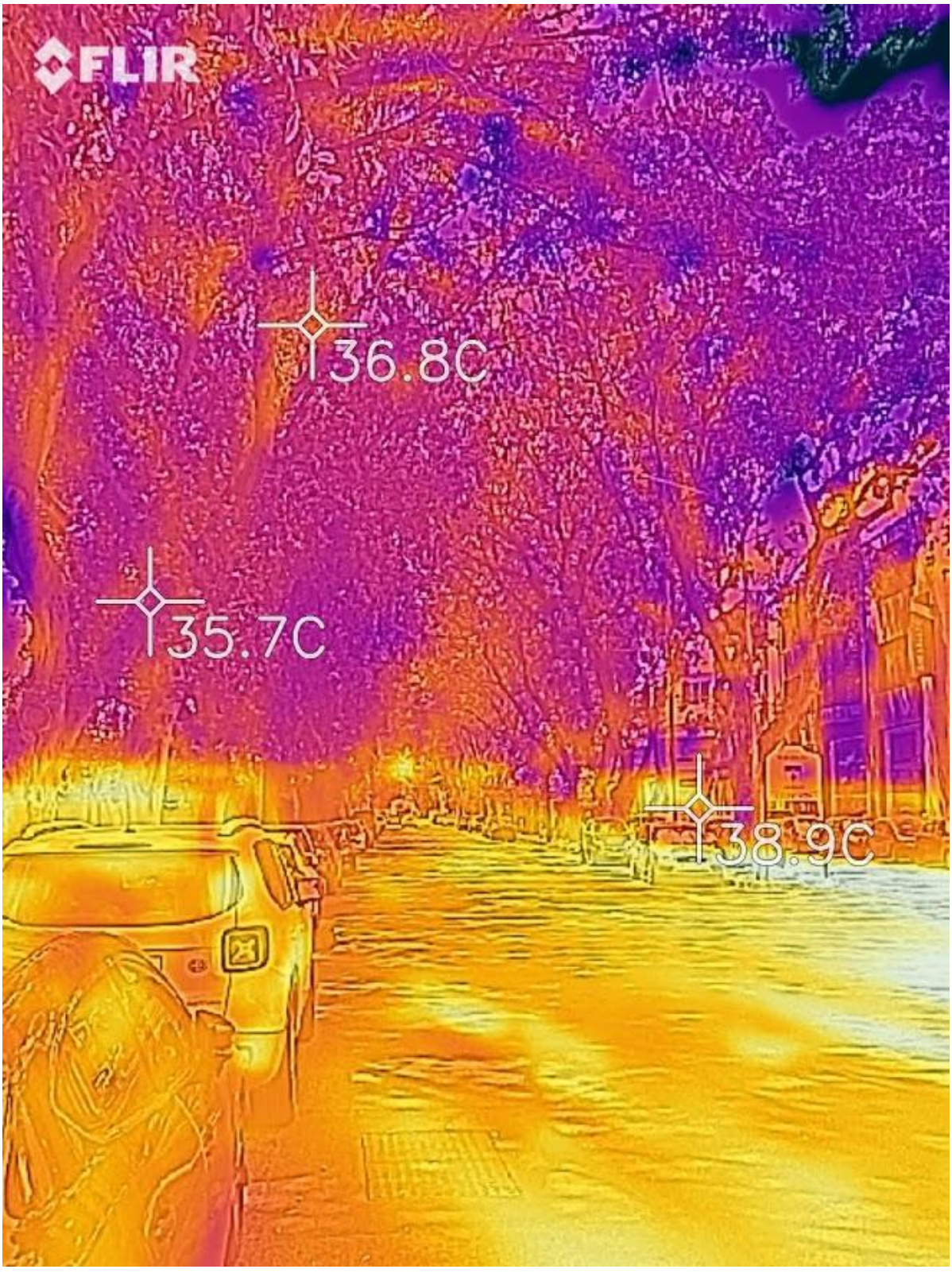

Figure 6: Temperature readings of the verged canopy in Valley Road, Birkirkara. Taken on the 9th July 2019 15:00 hours, during an intensive heatwave with a recorded temperature high of 39° Celsius. This visual analysis demonstrates the trees cooling effect through the process of transpiration that kept the tree cooler than the ambient temperature.

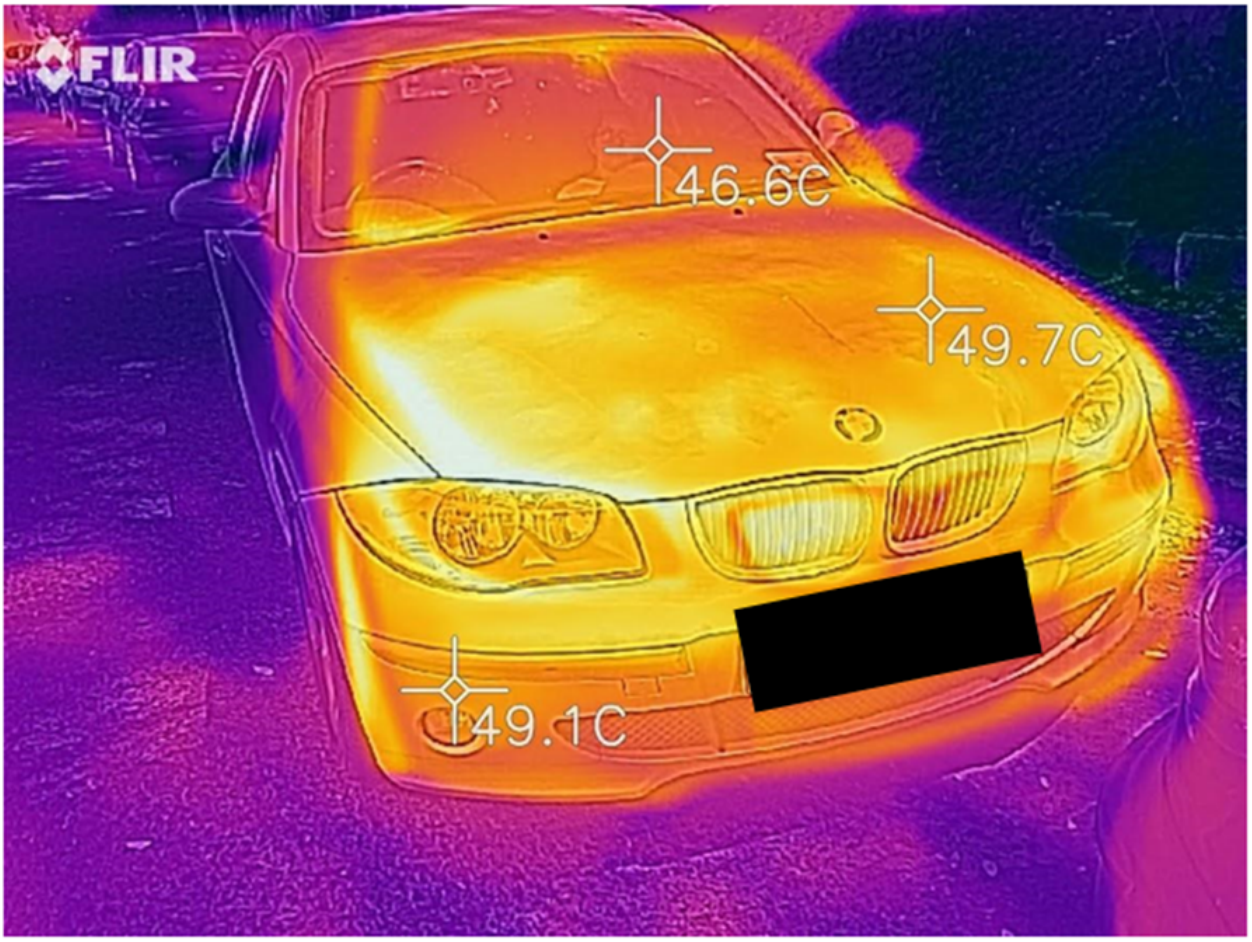

Figure 7: Temperature readings of the vehicle parked under partial verged canopy in Valley Road, Birkirkara. Taken on the 9th July 2019 15:00 hours, during an intensive heatwave with a recorded temperature high of 39° Celsius. This visual analysis demonstrates lesser solar energy radiation, despite the partial shading from the verge when compared to Thermal Image Analysis 1.

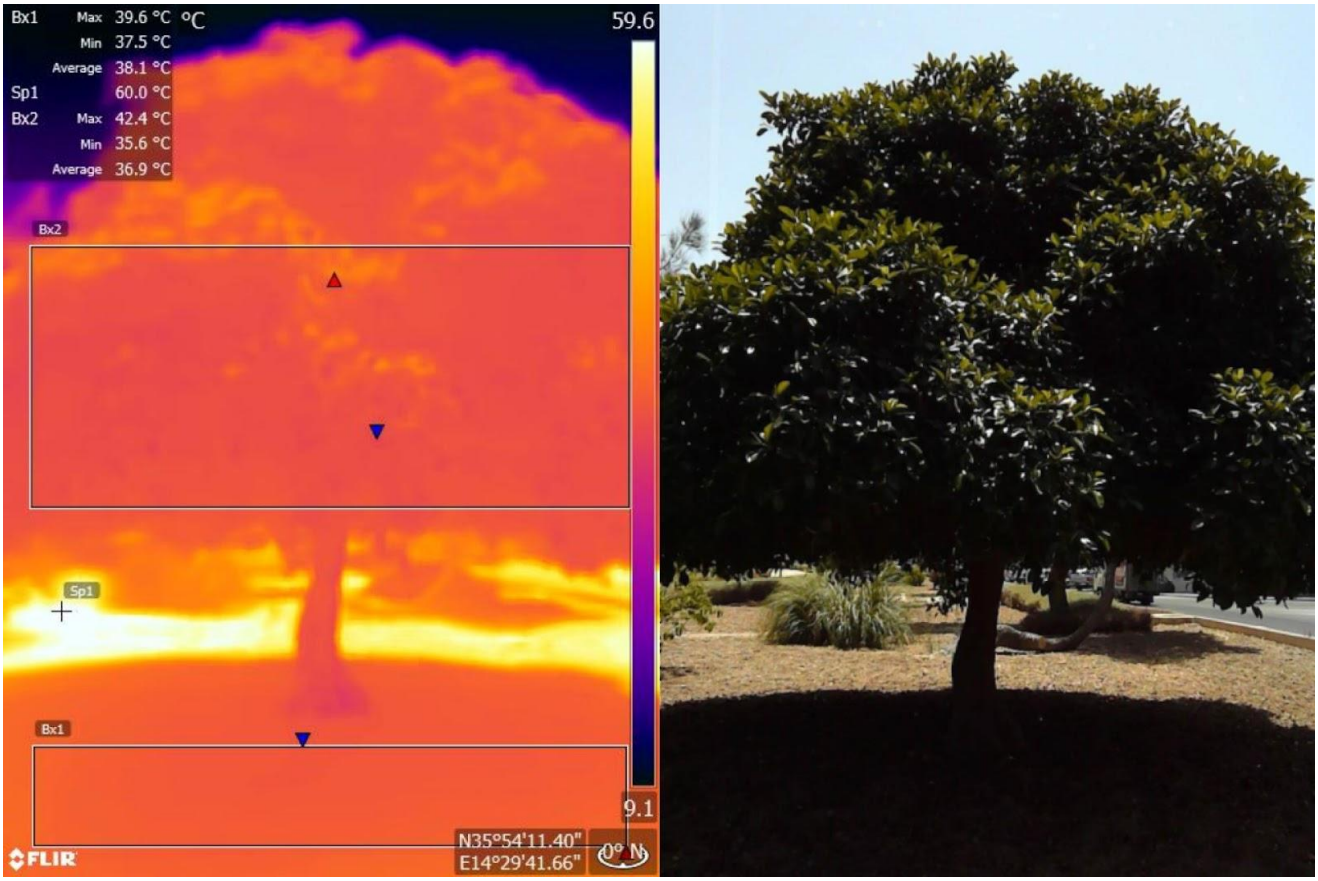

Figure 8: demonstrates a study of the transpiration and cooling attributes of trees taken on the 8 July 2019 at 1:30 p.m. being the sun's meridian during a heatwave with a recorded temperature high of 39 degrees Celsius. Notice the tree's average temperature was 36.9 degrees Celsius and its shade had an average of 38.1 degrees Celsius compared to the bare unshaded soil which had a reflective temperature of 60 degrees Celsius.

Map

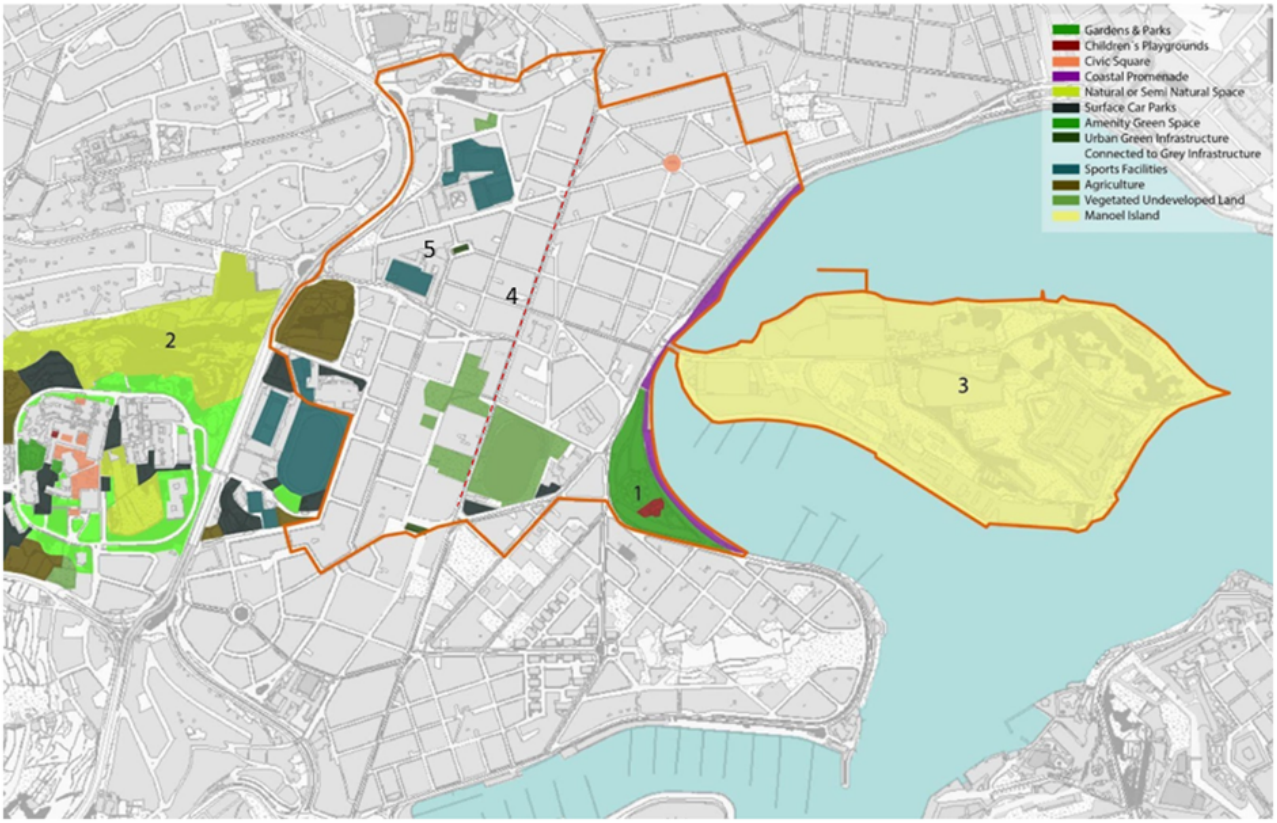

Figure 9: displays a map of Gżira showing the different types of areas in the locality, and the scarcity of greenery thereof. 1—Council of Europe Gardens; 2—University of Malta; 3—Manoel Island; 4—Rue d'Argens (dotted red line); 5—St. Clare Primary School