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- 7. News and Views
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- 9. Errata

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- Brownsell, B. (2003). Assistive Technology and Telecare: Forging Solutions for Independent Living. Policy Press, Bristol.
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Editorial

Ecological, environmental and healthcare challenges

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Dear readers and authors of Xjenza Online, as Editor in Chief, I am pleased to announce the release of the first regular issue of the 12th volume of Xjenza Online. I also take this opportunity to welcome on board Dr Karl Pelka who has taken over the responsibilities as Copy Editor for the journal.

As always, I am excited to share with you the journal's latest free open access publications.

The issue opens with the manuscript by Grech et al. which aims is to delineate the current state of the art in non-contact red-green-blue (RGB) camera-based heart rate and rhythm monitoring in adult populations in the clinical setting while assessing the advantages and feasibility of the technology.

Next, Lynch at al. reports on conducting an online STEAM-themed treasure hunt event for 16-19-year-olds during the Covid-19 pandemic and assesses the impact of organising this event online on both the participants and organisers. Further suggestions for the improvement of the online intensive course and this event format are also discussed within the report.

Alexander and Attard's study presents then the current biological constraints and on-farm limitations affecting meat rabbit productivity in Malta through the means of questionnaires addressed to the various stakeholders and professionals working within the sector.

The following paper by Calleja et al. discusses the present situation in Gżira and describes the ways in which the Horizon 2020 project, VARCITIES, aims to co-create visionary solutions (VS) with the Gżira community and various stakeholders to address the ecological and environmental challenges faced by the town. The main challenges identified are linked to deprivation of green infrastructure, high levels of air and noise pollution, the Urban Heat Island effect and improper disposal of waste. The proposed VS included: the micro-greening of a bus stop area and pop-up activities in Rue d'Argens, air pollution

measurements conducted by residents and a green playscape outdoor of St. Clare Gżira Primary School.

Then, Henwood, Lanfranco and Merritt review the Vaucheria species list of the Maltese Islands based on existent literature and collected material.

Schembri et al. investigates next the effects of the topical use of Capsaicin cream in conjunction with physiotherapy for low back pain.

The issue closes with a study by Borg, Camilleri and Attard of the challenges and opportunities that are experienced by young farmers in Malta in order to understand their condition and discover strategies to help and promote new recruits into the business. According to statistical research performed on data collected from 202 respondents, there are significant correlations between factors like gender, age, working hours per week, primary sectors, European Union (EU) financing, and organizational membership and job status, or whether young farmers are registered on a full- or part-time basis, or are unregistered. Additional information exposes the educational and training background, trading customs, and other aspects of young farmers.

To conclude, as today's research is a global endeavour, so remains our commitment to serve the local professional scientific community. Grech, N. et al. (2024). Xjenza Online, 12(1):2-12.

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Research Article



Non-invasive Vital Signs Monitoring in the Adult Population in Clinical Settings — Current State of the Art and Beyond

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Abstract. The aim is to delineate the current state of the art in non-contact red-green-blue (RGB) camerabased heart rate and rhythm monitoring in adult populations in the clinical setting. In addition, the challenges that still exist for more widespread use of this technology are outlined, as well as potential ways to overcome them. A search using Boolean operators was carried out in PubMed, Google Scholar, IEEE Xplore, CINAHL and Cochrane databases using predefined inclusion and exclusion criteria. Studies within hospital settings that extract heart rate data from videos of adult patients were identified and their successes and limitations were analysed from a clinical perspective. Fifteen studies were identified that fit the inclusion criteria. Many of these studies took place in emergency department settings, with the postoperative care unit being another environment that was investigated. Although good correlation between gold standard measurements and camera-based values were obtained overall, there are still challenges related to patient movement, changes in illumination and standardisation of techniques. This may be the reason that the use of this technology is not yet commonplace. Although a lot of valuable work has been performed highlighting the advantages and feasibility of using camera-based photoplethysmography to extract heart rate data in clinical scenarios, challenges still need to be overcome before these systems can become more mainstream in clinical practise. Therefore more research needs to be conducted in the field of noninvasive vital signs monitoring in the clinical setting.

Keywords: Non–Contact Vital Signs Monitoring, Camera–Based Photoplethysmography, Contactless Heart Rate Monitoring, RGB-based monitoring

1 Introduction

Non-contact vital sign monitoring (NCVSM) is a relatively new scientific methodology in which health-related parameters are extracted from patients in a non-contact manner without the use of any leads or wires. Most commonly, this is done by means of cameras, namely red-green-blue (RGB) or thermal imaging cameras, or more sophisticated equipment such as various types of radar (Hall et al., 2017; Jiang et al., 2020; Kumar et al., 2015). The most commonly extracted vital signs include heart rate and rhythm, respiratory rate, oxygen saturation and, less commonly, blood pressure (Pham et al., 2022; Tamura, 2019; Zhao et al., 2016). These are parameters that are part of many early warning scores and are crucial in helping healthcare workers determine patient stability and prioritise care (Patel et al., 2015). This review will focus on the extraction of heart rate and rhythm data in real-world scenarios using videos taken by RGB cameras. This is because RGB cameras are very easy to acquire, they are not particularly large or bulky, and good quality videos can be obtained with minimal expense and personnel training. Therefore, such vital sign extraction should be easily reproducible by research teams around the globe.

NCVSM has gained increasing interest in the clinical setting in recent years due to its advantages to patients and healthcare workers in different clinical settings. NCVSM systems offer increased comfort to patients who can be monitored without wires constantly attached to them, enabling more freedom of movement and less discomfort. In theory, it can also allow monitoring during periods of time like interventions or physiotherapy, when traditional monitoring is impractical (Malasinghe et al., 2019).

In the case of patients with vulnerable skin such as burns

patients or the very elderly and frail, this can translate to actual medical benefits in terms of reduced irritation, skin damage and pain. Transmission of infectious organisms, which are often resistant to multiple drugs and pose a great problem in healthcare systems at present, is also reduced between patients. This is because the risk of leads and wires being inadequately disinfected between subsequent patient uses is eliminated (Boric–Lubecke et al., 2015; WHO., 2009).

For healthcare workers, using NCVSM means that there is a reduced need to be constantly checking that leads and wires are appropriately attached, disconnecting and reconnecting them every time that patients need to move from their bed or every time these leads get inadvertently dislodged. This saves time in already busy clinical scenarios. The advent of the COVID–19 pandemic has highlighted this even more, since healthcare workers need to fully don and doff every time that they need to enter the patient's area of a COVID positive individual. Apart from this being very time consuming, it also leads to wastage of personal protective equipment, which is expensive, detrimental to the environment and is often in short supply (Bella et al., 2021; Phua et al., 2020; Tsai et al., 2020).

NCVSM also allows patients to be monitored in remote locations such as their homes or quarantine facilities. This is another need that has come to the forefront during the pandemic. With overwhelming numbers of patients becoming infected with a disease about which little was initially known, many needed close monitoring since, although their health situation might be stable at the time of presentation to medical services, it could quickly and unpredictably deteriorate especially in patients with underlying comorbidities. The possibility of close monitoring while the patient remains at home is very useful in this scenario since it allows hospital beds to be reserved for patients who need active medical intervention. However it is obviously impractical for patients to be wearing leads at all times, and help may not always be available to troubleshoot leads that have come off or become tangled or displaced (Rohmetra et al., 2023; Watson et al., 2020).

The principle by which heart rate and rhythm data is extracted from videos taken using RGB cameras is termed photoplethysmography (PPG). Haemoglobin present in the blood vessels located underneath the surface of the skin will absorb wavelengths of visible light within the green spectrum, reflecting those in the red spectrum. These absorption peaks correspond to the fresh influx of oxygenated blood from the heart that happens with each beat, and may be enhanced and extracted by the application of various filters and algorithms (Antink et al., 2019; A. J., 2007).

Videos taken using RGB cameras usually include areas

of the skin from where PPG signals may be extracted, most commonly the face or a part of it, and sometimes limbs and neck regions. The selected area for signal extraction is termed the region of interest (ROI), and was traditionally manually selected by the data analyst from video segments or images to yield the best results. Newer algorithms are able to select the best ROI automatically and track it throughout the video sequence, using methods such as, for example, the Kanade–Lucas–Tomasi algorithm commonly referred to as KLT (Chen et al., 2019; W. et al., 2018).

Green filters applied to the images in a video frame can help enhance the signal and multiple algorithms are used to recognise the pulsatile waveform associated with heart rate activity (Tamura et al., 2014). Some examples include: the Fast Fourier transform (FFT), which can break down the noisy PPG signal into its component parts and extract the parts of interest in terms of heart rate (C., 2022); Eulerian Video Magnification (EVM), which decomposes the sequences in videos and magnifies the parts of interest to the operator; and Principal and Independent Component Analysis (PCA and ICA respectively), which seek to extract individual components and differentiate them from other signals which are considered unnecessary noise (Jaadi, 2022; Lauridsen et al., 2019; Talebi, 2022).

The most recent algorithms are based on a machine learning paradigm, termed convolutional neural networks (CNN). These are machine learning algorithms that may be trained to recognise particular components from videos and images, in this case the PPG signal, using training data where the ground truth corresponding values are also provided. Once trained, CNNs are able to extract the signals they have been trained to recognise, from new video clips presented to them. These networks have great potential in the field of NCVSM and they are becoming increasingly complex (Albawi et al., 2017; Saha, 2022; Zhan et al., 2020).

This clinical review aims to describe studies published within the last decade that deal with RGB video camera use in extracting heart rate and rhythm data in real world clinical and hospital scenarios, while delineating some of the more significant limitations which prevent their widespread use at present and possible directions for improvement.

2 Methods

A systematic search was carried out on academic search engines including PubMed, Google Scholar, IEEEXplore, CINAHL and Cochrane. In the case of Google Scholar, the first 200 results returned were analysed. The search term used was "(hospital OR patient) AND (RGB) AND (vital signs OR heart)". The following inclusion and exclusion criteria were predetermined for the articles encountered during the search.

Inclusion criteria included studies with patients above 18 years of age, that took place within hospital or clinical settings, recruited patients with documented pathology or symptoms of pathology, include the use of RGB cameras, measured heart rate or rhythm as vital signs and have been published in peer–reviewed journals in the English language since 2012.

Exclusion criteria were the following: studies including only participants below eighteen years of age or who were healthy without symptoms or documented pathology outside clinical or hospital environments; if the focus is on screening for diseases in general; if the studies did not make use of RGB cameras, did not include extraction of heart rate or rhythm data.

3 Results

The PRISMA diagram depicts the results of the search criteria (figure 1). Fifteen papers met all inclusion criteria and were included into the final analysis of data for this review.

The most common clinical areas where NCVSM was implemented include the emergency department and the post-operative care unit, however other interesting settings such as general medical wards and haemodialysis units are also represented (Huang et al., 2022; Malmberg et al., 2022; Rasche et al., 2016; Tarassenko et al., 2014; Wedekind et al., 2017). The studies included in this review were divided according to the environment in which they were undertaken in order to enable analysis of the limitations encountered in each setting.

One of the identified papers for inclusion in this review is a systematic review itself, and will be described separately since it does not fit into any specific category (Antink et al., 2019). It focused on NCVSM between the years 2016 and 2018. It included 116 studies, however only 16 of these included patients with actual medical conditions, and most of these studies recruited small groups of participants of 20 persons or less. These are small sample sizes, however over the years it is noted that study cohorts have increased in size as well as in the variety of diseases and environments studied. Most camera-based studies included in that systematic review used more sophisticated cameras as opposed to consumer grade equipment, thereby potentially increasing complexity and hiking costs. Although results obtained in terms of accuracy were acceptable, Antink et al. (2019) noted the lack of standardisation available for determining what is in fact an acceptable level of accuracy for NCVSM monitoring in the clinical setting. Another issue is the lack

of data and algorithm sharing between different teams, which would enable one team to build further on what another has achieved. Issues that prevent this include the often-sensitive nature of videos that show vulnerable patients and institutional data access regulations.

NCVSM in the Triage of Infective Patients

The COVID-19 pandemic has brought with it surges of patients presenting to the Emergency Department with suspected symptoms, not all of whom required immediate medical care, or indeed any medical care at all. Triage of patients according to the severity of their medical conditions will allow prioritisation of care, however it is often time consuming and requires a lot of resources which may be in short supply in a time of crisis. The idea of triaging of patients who present with symptoms of potentially contagious viral illness, however, precedes the COVID–19 pandemic, with influenza being the typical yearly culprit that makes these services necessary (F.T.Z. et al., 2021; Wang et al., 2020).

Three teams of researchers applied camera-based PPG to infectious disease screening, including patients with documented pathology or symptoms thereof, in the study cohort (Huang et al., 2022; Malmberg et al., 2022; Negishi et al., 2020). Negishi et al. (2020) included fortyone subjects, among whom were 22 patients with seasonal influenza, focusing on screening them for elevated temperatures but adding in respiratory rate and heart rate to increase the sensitivity of detection. This is because elevated temperature can easily be masked by simple antipyretic medication, which is one of its main criticisms as a screening test for contagious illness. Increased heart rate and respiratory rates, which are also common markers of viral illness, are much more difficult to hide. Tapered window and signal reconstruction were used to reduce the effect of background noise, with MUSIC algorithm used to extract heart rate values, obtained a root mean square error (RMSE) value of 5.93 beats per minute (bpm) (Negishi et al., 2020).

Huang et al. (2022) as well as Malmberg et al. (2022) focused on patients presenting with COVID symptoms to emergency settings. In the case of (Huang et al., 2022) an RGB camera was incorporated into a robotic device named Dr Spot, which was able to navigate rough terrain to cross over to a tent where potentially contagious patients were being triaged. Healthcare workers were able to operate Dr Spot remotely, reducing potential exposure and wastage of personal protective clothing. The forehead and cropped parts of the face were used as the ROI since they yielded the most accurate results, providing a mean absolute error (MAE) of 7.5 bpm. POS algorithm was used enabling the distinction between the pulsatile



Figure 1: PRISMA diagram, detailing included and excluded papers and the reasons for their exclusion from data analysis.

PPG signal and surrounding noise sources. The system was successfully used for triage being able to read heart rates of between 50 and 160 bpm (Huang et al., 2022).

Malmberg et al. (2022) similarly extracted heart rate data from a cohort of suspected COVID-19 patients, with the study sample comprising 214 individuals, mostly female and of Caucasian skin tone. Videos of the patients' faces were obtained under ambient lighting as well as under red lighting using an LED and using near-infrared detection. An unspecified AI algorithm was used to extract PPG signals and comparison with ground truth data obtained a MAE of 1.4bpm, making this method the most accurate of the identified studies in this section (Malmberg et al., 2022).

NCVSM in the Operative and Post-Operative Setting

The post-operative care unit is an ideal setting for the study of NCVSM, since the lack of leads and wires will enhance patient comfort. The relatively high patient turnover also means that inadequate disinfection of leads and wires will result in infection of several individuals.

Trumpp et al. (2018) were the only team identified for this review who tackled the issue of NCVSM in the operating theatre. This environment is ideal for the study of such new technologies because patients are immobile and most sources of noise such as ambient illumination are controlled. Access to an adequate ROI, however, may be problematic in cases where surgical drapes cover most of the patient's face and neck, highlighting the need to explore further ROIs. Trumpp et al. (2018) successfully extracted heart rate data from 41 intra-operative patients using RGB and near infrared cameras for 95% of the time that videos were taken, using Bayesian classifiers to segment and track the relevant ROIs over subsequent video frames. Application of a green filter enhanced the signal although constant ambient illumination over the ROI was still required for successful results. Ten second delays were experienced in obtaining PPG values, which may be significant in the case of unstable patients and complex surgeries. The quality of signal obtained reflects on the adequacy of microvascular perfusion and therefore could potentially be used to provide information to anaesthetists to titrate vasoactive infusions (Trumpp et al., 2018).

The effects of several vasoactive agents in the postop cardiac care unit were also investigated in a separate study (Trumpp et al., 2017). PPG signals were obtained from patients who were on different infusions to maintain blood pressure and their effects on pulse pressure signals were obtained. Not surprisingly, the effect on PPG was related to the vasoactive effects of the drug, with patients on glyceryl trinitrate (GTN) with higher haemoglobin levels showing better PPG extraction due to increased dermal microvascular perfusion. Noradrenaline proved to have the opposite effect due to its vasoconstrictive effects (Trumpp et al., 2017).

Post-op cardiac surgical patients were also monitored for extraction of PPG signals in two separate studies (Rasche et al., 2016; Wedekind et al., 2017). Between both studies, 88 patients were included, the majority of who were still intubated and mechanically ventilated. Several algorithms were used to extract PPG data from videos which were mostly around 30 minutes long with manually selected ROIs to optimise the obtained signal. Blind source separation (BSS) was used to distinguish the heart rate signals from other sources of background noise as well as PCA and ICA. A mean absolute error (MAE) of 5bpm was obtained for 83% of videos, however, changes in illumination, patient motion and hypotension negatively impacted results (Rasche et al., 2016; Wedekind et al., 2017).

NCVSM in the general medical ward

General medical wards are adequate environments for testing NCVSM technologies since patients admitted there often present with multiple complaints and underlying comorbidities, are often mobile and able to consent to participation and the environment is relatively uncontrolled. This allows for proper real–world testing of various conditions.

Several teams of researchers focused on different general ward settings in extracting heart rate data from RGB videos of patients. Ge Xu et al. recruited 38 patients with an average age of 40 years who had been suffering from diabetes and ischaemic heart disease for a period of three to five years (Xu et al., 2022). PPG signals proved harder to obtain from patients who had less well controlled disease, most likely due to the sclerotic effects that these conditions have on dermal microvasculature. Chrominance (CHROM) was used for denoising of the signal and bandpass filtering allowed selection of the frequencies of interest (Xu et al., 2022). Patients in atrial fibrillation, defined as an irregularly irregular heart rhythm, proved harder to extract PPG signals from. Similar issues were observed by Couderc et al. (2015) who recruited 11 patients with known atrial fibrillation presenting for elective cardioversion. Ventricular ectopic beats were missed on PPG signals when compared to ground truth ECG data, however, with a 20% error rate for the overall heart rate, the team postulated that this technique was feasible for monitoring of atrial fibrillation and identification of patients at risk of adverse sequelae such as cerebrovascular accidents (Couderc et al., 2015).

The accuracy of consumer grade mobile applications

that use non-contact PPG to estimate the user's heart rate was investigated (Coppetti et al., 2017). A total of 108 patients were recruited to trial these applications (namely "What's My Heart Rate?" and "Cardioversion") from a chest pain unit, obtaining respective correlation coefficients of 0.62 and 0.60 with pulse oximetry and gold standard ECG, respectively. These values were even lower when variation in illumination was observed or when tachycardia was present, and highlight the need for further standardisation and upgrades in relation to accuracy prior to these methods being made use of for medical purposes (Coppetti et al., 2017).

Elderly patients had multiple comorbidities including diabetes mellitus, hypertension and atrial fibrillation. In one particular study, the KLT algorithm was used for ROI tracking during periods of time when patients were moving (Yu et al., 2020). Recordings were obtained just before and after physiotherapy sessions, obtaining a root mean square error (RMSE) of 3bpm. However, monitoring during the actual physiotherapy session was not performed. Near infrared cameras were also used in this study and were considered to be good options for the geriatric populations since they do not require additional light sources for proper functioning, especially in dim light conditions and darkness. Adding a light source could worsen delirium in at–risk populations since their circadian rhythm could be interrupted (Yu et al., 2020).

Sun et al. included a cohort of 11 subjects in a rehabilitation hospital obtaining PPG data via a robotic device termed Vital SCOPE that also included respiratory rate and temperature (Sun et al., 2018). Interestingly, the ROI chosen for this study was an area close to the carotid artery in the neck. Pearson correlation coefficient values of 0.91 were obtained when compared with ECG data (Sun et al., 2018).

Another study focused on a group of 46 patients receiving haemodialysis, also with no restrictions to patient movement or ongoing procedures (Tarassenko et al., 2014). In this case, autoregressive modelling and pole cancellation was used to extract PPG signals obtaining MAE of 3bpm in segments where patients were still. However, motion and ambient illumination changes negatively impacted the results (Tarassenko et al., 2014).

One small but interesting study was performed by Lin et al. (2019), who studied extraction of PPG signals in a series of three patients undergoing radiotherapy for uveal melanoma. Part of their thermoplastic mask was removed to uncover the cheek to be used as an ROI. Eye movement was also allowed to be monitored by this technique that used a camera and a dedicated LED light source above the patient. Manual ROI selection was performed and the KLT algorithm was used to track the ROI over time, although movement during a radiotherapy session needs to be minimal to allow targeted treatment and prevent collateral damage to nearby structures. MATLAB software based on FFT was then used to extract the final PPG signal. With this technique, MAE of 2.37bpm was obtained with the ground truth data being obtained from pulse oximetry. This is indeed a very accurate value (Lin et al., 2019).

Table 1 summarises the salient points of the studies included in this review. The studies are arranged in chronological order and details pertaining to the environment they were conducted in, the included study cohort and the best results obtained are provided.

care unit; PACU = Post-anaesthesia care unit; MAE = Mean Absolute Error; GTN = Glyceryl Trinitrate; PCA = Principal Component Analysis; ICA = Independent Component Analysis; RMSE = Root Mean Square Error.

4 Discussion

The use of NCVSM is advantageous to patients and healthcare workers alike, due to its ability to increase patient comfort and reduce risk of transmission of multidrug resistant organisms between patients (Malasinghe et al., 2019; WHO., 2009). In a time of crisis such as the ongoing COVID pandemic, when healthcare resources are overwhelmed, the ability to monitor patients remotely and identify those patients who require actual admission and those others who can be treated at home, will enable better allocation of resources. NCVSM also allows for reduced direct contact between healthcare workers and potentially infective patients, as demonstrated by several studies that devised robotic equipment capable of obtaining vital signs from patients while healthcare workers control it from a safe distance (Lin et al., 2019; Malmberg et al., 2022). This is beneficial both in reducing the risk of contagion of healthcare workers and the use of personal protective equipment which healthcare workers must don every time they approach infected patients, including the replacement of displaced monitoring leads. Such protective clothing is expensive, detrimental to the environment and is also often scarce (Bella et al., 2021; Phua et al., 2020).

As evidenced by the studies included in this review, camera-based PPG monitoring of cardiovascular parameters is capable of being performed to adequate standards in many different real world clinical scenarios. In some cases variations from ground truth data considered as the current gold standard was of less than 2bpm (Malmberg et al., 2022). However, these excellent results only apply to situations where the videos are obtained under idealised conditions with constant illumination, patients who are not moving, and ROIs which are fully visible. Delays in obtaining values still exist, and this can be an issue in critical scenarios when patient deterioration occurs within a matter of seconds (Trumpp et al., 2018). Once conditions start to become less than ideal, which is the usual situation in the real world, the accuracy of results starts to deteriorate. This highlights a need for further advancements in the algorithms (Tarassenko et al., 2014) such as to address these sources of error and unsatisfactory performance.

Many of these systems also require to be physically close to patients in order to be able to extract PPG data from videos. In one study, the robotic device was placed specifically two metres away from patients. While this is often not an issue, in cases where there is clinical equipment surrounding the patient's bed, it may be a problem to find adequate space for the monitoring equipment too (Huang et al., 2022). Overhead setups may overcome this problem especially when the patient is confined to a bed, but will incur costs of the infrastructural changes necessary to enable the attachment of cameras. When the patient is not in bed, such as during mobilisation to the armchair, the issue of the face (which is the most commonly used ROI) not being visible will come into play, highlighting the need for more ROIs to be available for data extraction.

There is also a notable lack of standardisation of techniques and sharing of datasets which would allow teams to build on each other's work, thereby accelerating improvements (Antink et al., 2019). This is understandable since videos of patients taken with RGB cameras are considered sensitive data and patients featured in them are easily identifiable. Therefore sharing of data needs to be governed by strict laws such as the General Data Protection Act in Europe and corresponding legislation in other geographical parts of the world (Mondschein & Monda, 2019). However, new frameworks could be set up that would allow such data sharing to take place between accredited institutions with patients' consent.

Over the years, the number of studies that consider real world clinical scenarios have increased in number as well as in the size of the recruited cohorts. This is beneficial since the sample of pathologies that patients present with and their underlying comorbidities are being increasingly represented, with common conditions such as diabetes, ischaemic heart disease and atrial fibrillation being increasingly included (Xu et al., 2022). The irregularity of microvasculature caused by these diseases has been noted to cause issues in obtaining accurate PPG signals, and this begs the question of what will be the effects of further comorbidities such as skin conditions and other diseases on PPG signals (Climie et al., 2019).

Although this review deals specifically with patients in hospital settings, interesting applications for NCVSM exist also for long term remote monitoring at home, for patients with chronic disease or the elderly who live alone in the community (Liu et al., 2019; Londei et al., 2009; Nasution & Emmanuel, 2007). This could provide peace of mind to many patients who would feel reassured that healthcare workers are monitoring them and will be able to help them should they become unable to call for help themselves. It would also allay the burden of outpatient work which often involves simply following up otherwise stable patients. Obviously, issues of privacy and transmission of sensitive data would need to be tackled. Such technologies are already being trialled in some instances, such as for the detection of falls in the community (Boric-Lubecke et al., 2014; B. J., 2021; Liu et al., 2019; Londei et al., 2009).

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5 Conclusion

In this review, there is an outline of the current state of the art in camera–based PPG for heart rate and rhythm monitoring in real world clinical scenarios. Although many significant advances have been made in the past several years, obtaining reasonably good results in idealised video segments, there is still more to be done in terms of accuracy in non-ideal conditions and in pathological cases before these technologies can be rolled out for widespread use in clinical practise.

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7 Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

8 Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection, analysis and write-up of the first draft were performed by N.G. All authors read and reviewed all the previous versions of the manuscript and approved the final manuscript.

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Research Article



Conducting an online STEAM-themed treasure hunt event during the COVID-19 pandemic

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Abstract. The in-person Malta-based STEAM Summer School intensive science communication course was transformed into the STEAM Digital School due to COVID-19 pandemic restrictions. Still retaining real world features, the course managed to incorporate individuals from three different continents to learn and work together simultaneously. Upon completion of the course, the students organised an online event during worldwide stay-at-home restrictions to stimulate excitement among youth about scientific topics; in this case, communication within nature. The organisers developed an online treasure hunt for teenagers, a novel format for online learning. The game involved solving puzzles with a science theme through an online platform. Through this medium, the participants were exposed to scientific ideas such as quantum waves, and how a microwave works, in order to increase their possible interest in the area. The organisers aimed to encourage the participants to develop an interest in science and research within society, against the backdrop of the COVID-19 pandemic. The event was evaluated to assess the impact on the participants and organisers, and the results indicated the event was generally enjoyed by the participants, though some puzzle difficulties were perhaps too high for those in the targeted age bracket of 16 -19-year-olds. Further suggestions for the improvement of the online intensive course and this event format are discussed within the report. We found the event format to be an overall success, with all participants indicating an increased interest in science as a result.

Keywords: Online event; treasure hunt; STEM communication; Covid-19 impact; youth event; STEAM

1 Introduction

1.1 An innovative science communication course goes online

STEAM (science, technology, engineering, arts, and mathematics) Summer School was originally created in 2016 as a 10-day intensive face-to-face science communication course that brought together the resources of science communication academics and practitioners led by Dr Edward Duca from the University of Malta. The collaborators included Rhine-Waal University, Science View, University of Edinburgh, Haaga-Helia University and European Union of Science Journalists' Associations. Their approach was to cover diverse science communication and arts-related topics, focused on providing participants with the opportunity to engage public audiences during the course with science through artistic approaches that ranged from stand-up comedy to theatre.

The course was run as an experimental model supported by ERASMUS+ funding of the European Union. The funding allowed partners to test and evaluate variants of the course in Germany (2016), Greece (2017) and Malta (2018) to determine the courses' content, approach, pedagogic model, and financial sustainability. In 2019 the course was successfully turned into a social enterprise.

The school now takes a student-centred learning ap-

proach, entirely focused on project-based learning with theoretical content shifted to a flipped classroom approach (Roche et al., 2021). Due to the COVID-19 pandemic the school was adapted to go purely online and renamed STEAM Digital School. Amanda Mathieson (BiOrbic, University College Dublin, Ireland) led the development of a multimedia online course that acts as a stand-alone science communication course and as a preparatory course undertaken by all intensive course participants. This online course covers science communication theory, presentation and writing skills, traditional and social media, branding and marketing, and event management and evaluation. The STEAM Digital School course was run over 5 days (18-22 January 2021) on Zoom, Slack and Google Drive, using online collaborative tools such as Mural. Over the 5 days, the course covered every part needed to develop an effective online science communication event using a STEAM approach. As a rough outline, the interactive workshops covered the many reasons to communicate science; these were then used to help the students develop their event's aims, followed by a target audience profile, then developing a tailored event for that audience with the appropriate branding and communications strategy. The participants of the STEAM Digital School also worked on their improv and theatrical performance skills, an evaluation plan, and started working on the chosen event's content. In the evening, online social events helped the participants socialise with the aim of more effective collaboration, and to expose them to innovative online science communication formats such as a STEM (Science, Technology, Engineering, Mathematics) Escape Room (Mathieson & Duca, 2021).

This preparation was then collated in the form of an outreach event which was scheduled to take place two weeks after the completion of the course, for all participants to gain experience in event creation and outreach. The students of the STEAM Digital School developed the event called "Swipe Right for Science Treasure Hunt" targeting 16 - 19-year-olds as a means to increase interest in STEM subjects during the COVID-19 pandemic. It was hypothesised that because of stay-at-home regulations in place in many countries, it was reasonable to believe that more students would be interested in joining such an online event from their homes. In addition, the students might also have an increased interest in the sciences in general due to the biological nature of the COVID-19 virus. The STEAM digital school students organised every part of the event themselves from the performances and the evaluation to the development of the puzzles based around science facts; specifically on the topic of communication within nature. This paper details the planning process, key learning points and insights of organising an

online engagement event during the COVID-19 pandemic that we hope other science communication practitioners and educators will learn from when planning future online training courses and events.

1.2 Literature Review

Online learning has evolved dramatically from simple text and images on webpages, to innovative interactive games and more sociable webinars and lectures. The internet has been used across various educational institutes in the delivery of learning activities. Learning through online teaching offers benefits our ancestors would never have fathomed; free online courses help bridge the gap of social inequality access to third level education, enables flexible learning for those who perform day jobs or have dependents, and of course enables learning while still engaging in social distancing and stay-at-home policies during the COVID-19 pandemic (ION Professional eLearning Programs, 2022). Even prior to COVID-19, online learning has been utilised as an accessible method of education where students feel comfortable interacting and to increase social inclusion (Cobb, 2009; Notley, 2009). At university level, studies have shown that student engagement and interactivity were similar in both online and inperson learning (Coiado et al., 2020), or actually increased in online learning (Caton et al., 2021). It has also been identified as a preferred learning approach for millennials and working adults due to its flexibility and convenience (Amemado, 2020).

Nevertheless, online learning comes with challenges especially regarding access and inclusivity, which have been amplified during the course of the COVID-19 pandemic. These challenges include the technological, social, and psychological sphere (Ferri et al., 2020). Families from disadvantaged socioeconomic groups struggled with online learning mainly for the lack of resources, including appropriate physical space to carry out the learning, reliable internet connection, insufficient number of devices, and lack of support from parents who often do no have the necessary digital skills to help their children (Outhwaite, 2020). In addition, the persistent lack of in-person social interactions with the teachers and with other classmates, as well as physical and mental fatigue due to increased screen time, showed negative consequences on the mental wellbeing of the students as well as on the effectiveness of learning (Syahputri et al., 2020). Nonetheless, few other options were available during the pandemic.

Effects of online education in secondary schools can vary depending on the type of subject they are enrolled in (Zhang et al., 2021). With the COVID-19 pandemic, online learning became commonplace rather than an exception in the delivery of learning. Schools shifted from face-to-face classes to synchronous and asynchronous classes, with over 1.6 billion children affected by school closures across the globe having to resort to alternate learning methods (UNESCO, 2020). This shift added to the challenge of making learning not only accessible but also of high quality and satisfaction (Amemado, 2020).

The decision of the organisers to target a younger age group with the online treasure hunt event stemmed from the aim of increasing interest in STEM subjects in the younger generation, particularly with science featuring so heavily in the news during the pandemic. Encouraging youth towards STEM (Science, Technology, Engineering, Mathematics) should start early as interest may wane with age (Talisayon et al., 2006; Wright, 2014). Science communication in a fun interactive format such as through theatre and art has previously been shown to be achievable through after-school science programs, interventions in pedagogical delivery of science and teaching science using a multicultural approach (Jones & Stapleton, 2017). Therefore, the event was developed as an online Treasure Hunt designed with the intention of including acting pieces of a humorous storyline to aid in maintaining interest and to introduce a "hook" or reason for completing the hunt as well as real time puzzles with a competitive element to increase the interactivity of the game.

Even prior to COVID-19, interactive learning had been shown to increase younger people's interest in STEM (Asheim & Parrilli, 2011; Rieber, 1996; Sirakaya & Alsancak Sirakaya, 2020). Goldee Jamwal of Utah State University evaluated the impact of using interactive learning modules against traditional methods of teaching in Logan High School in 2012 (Jamwal, 2012). The study asserted that improving the manner of teaching inside classrooms will increase student uptake for computer science careers. This goal of interactive learning was the basis of both the STEAM Digital School in science communication and also the event planned by the school's participants. To evaluate the effectiveness of more interactive learning modules, Jamwal used a series of surveys handed out to the students and in-class observations. The author's research demonstrated that more than half of the students participating preferred interactive learning and working in small groups, over more traditional learning methods. Similarly, the event reported here used evaluation methods of voluntary surveys to investigate the impact of the treasure hunt on the participants.

It is with these reasons in mind that this digital course and subsequent online event were planned using a STEAM approach: using the arts as a means of communication to a specific audience. Arts such as theatre are capable of incorporating informal learning methods very effectively (Kassing, 2007; Tomljenovic, 2015). Therefore, by utilising the arts as a communication method to design an online STEM themed event, it is possible to convey complex scientific ideas to non-scientific audiences such as teenagers. In the online Treasure Hunt developed science activities were embedded in a storytelling format, in which the organisers performed in first person as characters of the story. The next section describes in detail the development of the online Treasure Hunt format, from conceptualisation to the storytelling, logistic, content creation and finally the event hosting.

2 Methodology: The Online Treasure Hunt Format

The STEAM event was planned to take place in February 2021, in the middle of the COVID-19 Pandemic. In most countries, this meant citizens were cautioned against leaving their homes except for limited exercise within a couple of kilometres of their homes, and school and work activities shifted online. The virtual setting was thus the preferred option for running a STEAM event. The event was planned to target 16 - 19-year-olds with the aim to increase interest in STEM subjects during the COVID-19 pandemic. A virtual treasure hunt seemed the perfect balance between the event objectives (increase 16 - 19-year-olds' interest in STEM) and the logistic challenges of producing the final event (organisers working remotely from different locations around the world).

The treasure hunt format was conceived to allow participants to be the protagonists of the experience; they were at the centre of the action, interacting not only with the story but also with one another. The organisers elected to use the interactivity of Zoom platform as a tool to provide an active learning experience for all for the following reasons: it is free for participants to join an event on any main electronic device (mobile, tablet, computer); the targeted audience of teenagers has a high chance to be familiar with the platform already, since Zoom has been a popular platform chosen for online learning during the pandemic, with over 90,000 schools across 20 countries using Zoom during the first lockdown in March 2020 (Yuan et al., 2020). Zoom also supports flexible features such as break out rooms, texting boxes, sharing presentation mode, and a live annotation on screen mode that can be exploited for dynamic engagement online. It was decided to utilise the breakout room function to separate participants into teams and to introduce a competitive element to the game. Eventbrite was chosen as the means of registering participants and used to securely share the Zoom link needed for participants to join the event.

The event organisation team was split into different groups and each group was responsible for the production of one of following areas of the treasure hunt: story creation and script writing, content creation for the event, event communication and advertising, evaluation creation and execution. In the following paragraphs, we report how the work was organised and describe each part of the event.

2.1 Logistics of event creation

Much of the work to create an online treasure hunt would mainly involve autonomous tasks such as content creation, while certain group tasks could also be completed within smaller groups on Zoom to record the acting performances and design the script. Zoom was identified as a suitable platform for video meets, Google Drive was utilised for file sharing as everyone could have equal access to all necessary files. Slack was selected as a suitable messaging platform, due to its ease of access and some people's previous familiarity with the app. Doodle was used to set up polls to determine times of Zoom meetings, as all organisers were spread across different time zones.

2.2 Story and Script Writing

The treasure hunt event took place on Zoom as a live activity themed around superheroes and communication. During the idea generation stage of story development, the main ideas were decided as follows: the protagonists should be teenagers to increase relatability to the targeted audience of teenagers; humour should be a factor as it is proven to be attention-grabbing and entertaining (Dormann & Biddle, 2006); social media should play a part as this is one of the main methods of communication engaged in by teenagers (Villanti et al., 2017); a moral to the story should also be included, such as good social media practices or internet usage.

Combining these factors, the organisers came up with a story for the treasure hunt: the protagonists would be three teenagers with superpowers that had lost their powers through an online scam operated by a villain on social media platforms. The villain had encrypted the superpowers, so the audience needed to solve science puzzles to decode them. The scientific theme overarching the puzzles was chosen to be 'Communication in Nature with overall aim was to encourage interest in STEM subjects. The 60-minute time frame of the event was decided with the belief that the audience may begin to lose interest after this time point. The organisers of the treasure hunt game decided to incorporate theatre as an aspect of the event for entertainment and to provide a "story hook" to motivate participants to complete the game.

Once the story was decided upon, script development was then undertaken, taking into account principles of story-telling covered during the STEAM school: a hero, an obstacle, an objective, a journey to overcome



Figure 1: Example of a puzzle set from the event, created using Canva.

obstacles, and a satisfying resolution (Champagnat et al., 2010; Deniston-Trochta, 2003).

2.3 Content Creation

The short video performances for the story were recorded by using pre-existing software within Zoom. The feature of virtual backgrounds was used to give the villain a dark lair as a film set, while the speaker-view function within Zoom enabled the current speaking part to be put up front in the video recording. The full recording was then saved to the cloud and edited for better transitions and for sound effects by one of the performers with previous video editing experience. The Zoom format enabled the performance recording to seem more realistic, with each character in their own setting, interconnected in the plot by either a phone call or from a television screen, highlighting the topic of communication. These videos were then edited for effects and accessibility, with subtitles added to all speaking parts for accessibility.

For the creation of the puzzles, the organisers also carried out a brainstorming session using the scientific theme of the treasure hunt (communication in nature, specifically in terms of waves) to define different puzzle topics. The topics of each puzzle were decided as follows: x-rays, microwaves, the visible light spectrum, infrared, soundwaves, quantum waves, seismic waves, and genetics. The puzzle types were decided by what formats would carry effectively over an online format, including crosswords, hidden objects, morse code, pictograph math puzzles, and cryptography. For each puzzle solved, a brief scientific fact around the puzzle theme was provided, which was termed a "curiosity". Puzzles and curiosities were then standardised in a coherent visual theme using Canva in a slide format, which correlated to the overall treasure hunt theme. Figure 1 gives an example of a puzzle card used: the clue (left), the power unlocked (middle) and the scientific curiosity about the puzzle theme (right). The visual theme was decided upon by the marketing team, and was kept as a recurring visual theme throughout the



Figure 2: Poster for social media advertising.

event content.

2.4 Marketing

The marketing team created themed visuals which would link into the plot and created the event on the EventBrite platform. Figure 2 shows a banner for the event created to be shared on social media. This banner incorporated a superhero mask with some sound wave visuals and a treasure map to represent the various components of the event.

The title of the event was also decided upon: "Swipe Right for Science". This title was arrived at during the marketing team's creative brainstorming session where they discussed the target market's interests and the story arc. As the social media platform Tinder features within the story, "Swipe Right" was decided upon. This refers to a feature of Tinder whereby you decide to "like" a person's profile by swiping right on your mobile screen, hence the title of the event. The treasure hunt was then advertised on different social media platforms including Facebook, Instagram and Twitter one week before the event. These advertising platforms were chosen based on the event's target market of teenagers being hyper-represented on social media in general (Mas-Tur et al., 2016; Villanti et al., 2017).

2.5 Evaluation

Evaluation was performed to measure the effectiveness of the event and whether its objectives were met. The evaluation team for this event prepared three levels of evaluation: a questionnaire to be filled out after the beta-test with a limited number of test subjects, a questionnaire after the event itself sent to participants over a web-link, and an organiser-specific evaluation which took place after the event was competed and involved an informal discussion with recorded feedback points.

Before the event took place, a beta test was completed with five voluntary teenagers. Feedback from the beta test helped to improve the event before the final running in the following ways: the difficulty of some puzzles was reduced, the number of puzzles presented was shortened due to time limitations, and the running format was adjusted within the breakout rooms. From this beta-test, it was decided that the best way for engaging the participant in the puzzle solving was by remote screen sharing, using the annotation feature from the Zoom platform to allow the participants to interact with the puzzle simultaneously. A session leader guided each breakout room and the participants in that breakout room through the story and the puzzle solving, and a technical assistant was responsible for sharing the screen with the puzzles as well as for all the other technical needs for the session. This enabled the host of the individual breakout rooms to have the answers to the puzzles on screen themselves, in order to provide hints if the team was struggling with the puzzle.

2.6 The Online Treasure Hunt Event during 'Stay-at-Home' 2021

The event was hosted online in early February 2021, when many countries around the world were in a second 'Stayat-Home' mandate (Mathieu et al., 2020). The day before the event, 16 people signed up over EventBrite. The live event had 9 people participate through Zoom. The event ran smoothly and within the time limit, bolstered by the feedback received from the beta test and a final rehearsal the same day of the event for the organisers to practice screen-sharing and other technical features. The evaluation team also prepared a Google form to be given to participants at the end of the event. Five participants responded to the form, the results of which are discussed in the Results and Discussion section. One more meeting was held the day after the event, for the organisers to formulate their thoughts and feedback for their own evaluations which were then recorded and will be reported similarly in the next section.

The actual event started on a Saturday, with the MC (master of ceremonies) welcoming everyone to the event. One technical assistant in the main room shared their screen with the first performance video to introduce the story's hook to the audience. After watching the video, all participants were split into groups in breakout rooms, with a host and technical assistant in each one. The MC remained in the main room and sent messages to each breakout room to generate a competitive atmosphere with messages like "Group 3 is on the second puzzle already!". Progress was reported to the MC through Slack, which was operated by each team's host in the background as they solved the puzzles.

3 Results and Discussion

The STEAM Digital School was held on 18th – 22nd January 2021 and the Swipe Right for Science Treasure Hunt was held at 12 noon GMT on Saturday, 6th February 2021 as a free virtual event on Zoom. A synthesis of results is presented below, along with the outcome of the event participants' and organisers' evaluations.

3.1 Event Participants

There were 9 participants in attendance at the main event, from a total registration of 16 participants on EventBrite. After welcoming participants in the main room, the main host introduced the treasure hunt and played the intro video introducing the plot hook: aiding our protagonists in retrieving their lost superpowers. Afterwards, the participants were randomly sent into two groups. Two team members were assigned to each group; one served as the host of the group while the other was responsible for technical assistance. Of the nine participants, five filled in the voluntary feedback form; the main results of which are reported below:

3.1.1 Survey results and participant feedback

The gender ratio of respondents was 80% male and 20% female, while the participant ratio was 90% male and 10% female. The nationalities of the responders were British, Egyptian and Maltese. One respondent was from the targeted age group of (16-19), while the other respondents were of older age groups (Fig 3). 80% of the respondents were from third-level education, with 20% from second level. 60% percent of the participants heard about the event through Facebook, 20% from the STEAM Digital School website, and 20% from word of mouth. Every respondent indicated they found the event entertaining, with some finding puzzles mid-level (5/10) in difficulty (40%) and others (60%) finding them slightly more difficult (7/10). Every respondent rated the event 8 out of 10 or over, in terms of quality. All indicated they felt more inspired by science after the event and would recommend the event to friends.

As seen in figure 3, team 1 found the puzzles more challenging and took a longer time to complete the game (using the full 50 mins assigned as opposed to team 2, who finished ten minutes early). This may have been due to the lower age distribution of team 1. One participant from team 2 reported they would have preferred some additional puzzles to complete since they finished early: "Perhaps a few extra puzzles, they were fun but we completed them all well ahead of time". Additional puzzles, which would require some twists to the storyline could have helped overcome this issue, though our intended target audience was of the 16 - 19-year-old group and





Figure 3: Participant distribution from survey responses. Five out of nine participants responded to the survey, two from team 1 and three from team 2. Panel A represents the age distribution, while panel B was a rating of how difficult participants found the puzzles, with 10 being most challenging and 1 being easy..

they might have found the hunt more difficult if we did so. Therefore, we conclude that some optional additional puzzles may be a benefit in future events..

3.1.2 Accessibility

One participant was a special needs teenager, who struggled to interact at times with the group. They were non-verbal and could not write, therefore only communicated with gestures which were difficult to make out while sharing screen through zoom. Some consideration in this aspect could have been planned, such as having the puzzles on a smaller screen to show the participant's video more clearly.

3.1.3 Storyline

One participant remarked: "More videos showing the progression of the story - what happened to the people who lost their superpowers!". Further videos or additional graphics could have been shown between solving each puzzle to highlight participants' progression.

3.1.4 Puzzle Types

Some comments were also made about the content of the puzzles, such as "Memory recall puzzles are not very fun". This may not be a universal experience however, and a variety of different puzzle types are likely best utilised to ensure something will appeal to everyone in the game. Different genres of puzzles may be adopted for particular events either, where the puzzle type is known prior to commencing the game and perhaps ensuring a higher level of affinity with the intended audience. Further testing and evaluation would be needed to determine the content types that appeal to the widest target audience.

3.2 Event Organisers

The blended formats used within the course (presentations, improv role plays, live collaborative activities, etc.) gave a holistic experience that facilitated the practice of workshop sessions. Student feedback on the school itself was collected prior to the beginning of the course, and again upon completion of the course. The main points are reported as follows:

3.2.1 Organising a virtual online event vs. in-person event

Due to COVID-19 regulations, even the organising of this event had to be carried out through online meetings, which were interspersed with each organiser's usual workloads. After the five-day long course, two weeks were scheduled for individual and collaborative work towards the Treasure Hunt. Many participants of the school found it difficult to devote more time away from work or study, and to spend even longer times online in front of screens. Often this would take place at inconvenient hours in the day due to many organisers in different time zones. Considering the time investment required for preparation of the event, student team members generally agreed that the course could have been extended by two workdays. These days would have been devoted to finalising most event paraphernalia such as advert design, script writing, video recording, and development of the evaluation tools that were used during the Treasure Hunt. Completing tasks that required collaborative, large hands-on engagement could have been concluded before parting ways, leaving those tasks which were more autonomously dependent to be completed after this.

A noted benefit however from an online based organisation was that team members did not have the large cost associated with travelling to a predetermined destination and could do so from the comfort of their own homes. The organisers agreed that if most organisation activities had been concluded before the end of the workshop sessions with two extra days of active preparation, the whole experience of preparing an online event virtually could have been even less stressful than doing so inperson. The online event had the potential of attracting more participants, particularly if more time had been devoted to marketing the event after the course.

3.2.2 Communication

Most student team members hoped to be available for meetings and collaboration towards the Treasure Hunt during the intervening two weeks. However, not all could attend such meetings or contribute actively to executing event plans and communicating with these participants through online means proved difficult. Individuals within these teams were forced to take on larger workloads than originally expected as a result, and some took the lead in coordinating their respective team members towards presenting the necessary deliverables on schedule. The student feedback indicated that creating contingency plans for unavailability of team members could have made the plans move on more smoothly. An apt contingency plan could have been having some people work in more than one team. If the event organising took place inperson, this issue would not have arisen due to everyone being reachable at the same location in the school. Although overall communication was made much easier by the large variety of online platforms which were in frequent usage during the COVID-19 pandemic: for example Slack, WhatsApp, Google Docs, and Zoom.

3.2.3 Event Rehearsal

The Treasure Hunt was rehearsed by the organisers a day before the event. Due to time constraints, each team member was not able to completely test their assigned roles. This led to some technical difficulties on the day of the event, though these were fixed within short time frames. Having a full run through of the event would have aided in preparing substitutes to cover for others in case there was need. It would also have helped organisers to familiarise themselves with their assigned roles.

3.2.4 Target Audience

The treasure hunt targeted teenagers between the ages of 16-19 years old. This target audience was published in the fliers and the adverts. However, of the nine participants we had only seven were teenagers while others were older. Also, some organisers who had not seen the puzzles yet also joined in as participants, helping the other participants feel at ease with turning on their own videos and participating more vocally. The content and flow of the hunt was shown to be equally interesting for teenagers and for older participants based on these participants' feedback. The target market may have been narrowed too much by announcing that the hunt was primarily for teenagers. This factor may have limited participation. Specifying teens in the adverts excluded the possibility of families or adults without children joining in, when they may have enjoyed the event. Since the content of the event was relevant to wider demographics of participants, the decision to participate could have been left to the discretion of the prospective participant. Also, in a situation where participants have no prior interaction with one another, it is recommended that some sort of ice-breaker activity should be incorporated early into their separation into breakout rooms. This will facilitate collaboration, which will aid their progress through the treasure hunt and inspire an engaging environment from the beginning.

3.2.5 Technical Issues

Some participants (six teenagers sharing three devices) had technical difficulty joining the Treasure Hunt. Internet connection at their locations was bad almost throughout the event. Puzzles, clues, scientific curiosities, fun facts, and other items to be shared on-screen with participants at future events should be designed with mobile users in mind. They should be adapted to small screens, and participants should be able to easily annotate on them. This is especially important since as of January 2021, 59% of internet users access the internet from mobile devices: 55.68% on mobile phones and 2.87% on tablets (Stat-Counter GlobalStats, 2021).

While organisers agreed that Zoom was an innovative and user-friendly platform for use in an online event, there could have been technical backups such as live streaming on Facebook or YouTube, both of which require less bandwidth than a live event on Zoom. Live streaming on these platforms can also allow real time engagement. The links for accessing and downloading event resources should be shared on Zoom and on these platforms so that participants can download and enlarge them to suit their preferences. With these, individual participants could have been able to actively contribute to the event live, irrespective of the platform through which they joined. In addition, videos of the event flow could have been accessible to all afterwards. Notwithstanding, proper consideration should be taken for regulatory obligations such as those required under the General Data Protection Regulations (GDPR) and the Data Protection Act (DPA).

3.2.6 Videos

The intro and outro videos worked well with subtitles. It was agreed that including videos that showed the recovery and use of the different superpowers could have been a great way to keep participants' interest in the story, inbetween the puzzles. It could have been more engaging if the story was not completely linear. We could have had videos that depicted other possibilities, for example, in a situation where a superpower was not successfully recovered or when the villain set out to use one of them because it was not recovered early. The short time span between the workshop and the event was the main limiting factor for video production, but with a longer time frame, this addition could have increased the quality of the event.

3.3 Conclusion

The purpose of events such as this is to engage with the audiences on topics within STEM in a fun and casual way. While the "Swipe Right for Science" Online Treasure Hunt was a small event, it serves as an example of what can be achieved through creative online learning approaches

such as those employed by the STEAM Digital School. In pre-existing literature, there is no mention of an online STEM treasure hunt event in this format being completed before, as treasure hunts are traditionally seen as active, in-person events which may be difficult to move onto an online platform. Online events have some flaws, for example since signing up is free, as a result many people who sign up will not necessarily show up at the event itself. Even so, the benefits tend to out-weigh the disadvantages; the format of online events is accessible to people across the globe and can be made to be as user-friendly as possible with a wide range of software now available. COVID-19 pandemic restrictions have led to a revolution in how online learning is achieved; this generation is now the most tech savvy and internet proficient as a direct result of the struggle of pandemic living. COVID-19 regulations may have made online event planning an annoying necessity, but without these the online treasure hunt may have never been investigated as a medium for scientific communication. We conclude that fun, STEAM-themed online events like treasure hunts are both achievable and rewarding for organisers and participants.

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Research Article



Biological constraints and on-farm limitations affecting meat rabbit productivity in Malta

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Abstract. Literature on the production characteristics and constraints of intensive commercial rabbit meat production in Malta is scarce. This paper presents the current situation of the sector as it emerged through questionnaires addressed to the various stakeholders and professionals working within the sector. Agriculture holdings in Malta are limited in size, thereby restricting farm design, which very often requires improvised adjustments and compromises based on the available footprint. Furthermore, Malta's geographical position is a consistent constraint whenever imports are required; hence, all manufacturing and production industries, rabbit production included, have a significant disadvantage over their European counterparts as there are added expenses associated with transport costs. Other constraints are that the sector is not organised to harmonise production. Furthermore, producers are in need to upgrade their skill sets with regards to the basic principles of husbandry and stockmanship.

Keywords: Malta, Meat rabbit, On-farm limitations, Biological constraints

1 Introduction

Rabbit production in Malta has always been an ongoing activity throughout the years, so much so that the role of rabbit meat in Maltese culture and gastronomy is well documented (Buttigieg & Cassar, 2020; Cassar, 1994, 2016). De Battista (1985) documents the gradual evolution of the rabbit meat sector in Malta. He claimed that the general scenario in post-war Malta was of rabbits kept on the floor in farmyards together with other livestock to produce a poor-quality carcass and at times being infected with coccidiosis as was evident from spots on the liver. The sector gradually evolved through the importation of foreign genetics, the availability of balanced feeds, improvements in housing and the continuous dissemination of knowledge and information through the Rabbit Breeders Association (De Battista, 1985).

Rabbit meat consumption has a strong historical culinary tradition in Malta. It is well entrenched into Maltese cuisine, culture, and traditions, so much so, that the Maltese national dish is cooked rabbit known as 'Stuffat tal Fenek' (Cassar, 1994, 2016; De Battista, 1985). A recent report by the Directorate-General (DG) for Health and Food Safety of 2017 estimates that the average per capita rabbit meat consumption is more than 3 kg, which is significantly higher than in any other European country. This rate of consumption translates to the production of market rabbits (1.5kg dressed carcass) from 20,000 does; hence a significant sector. Rabbits are very delicate and sensitive animals, having a complex biology in terms of their nutritional physiology and requirements, health and susceptibility to disease, reproductive capabilities, and their response to environmental conditions and stressors. Yet, despite Malta's long association with rabbit meat consumption, it appears that there is a lacuna in information regarding the constraints and challenges faced by this sector. However, a potential reservoir of accumulated knowledge and experiences is undoubtedly present among the various professionals and stakeholders involved in the local rabbit industry. Hence, this study aims to retrieve this information from the professionals and stakeholders using questionnaires to take stock of the current state of affairs with regards to the biological and on-farm constraints affecting the Maltese commercial rabbit meat sector, and in so doing present a baseline reference on which further research is based.

[†] These authors contributed equally to this work.

Туре	Criteria	Number of people selected for interviews
Rabbit producers	Farms registered with VRD as having more than 50 breeding does	11
Feed mills	Local manufacturers and distributers of rabbit feed	4
Importers of feed and equipment	Importers of ready formulated rabbit feed and equipment	3
Veterinarians	Veterinarians known to be involved in the management of rabbit farms	14
Pharmacists	Pharmacists specialising in pharmaceutical products used in the livestock sector	8
Breed stock supplier	Supplier of imported breeding stock	1

Table 1: Selection of participants.

2 Methodology

A qualitative research approach through the use of questionnaires was identified as the most suitable for this study since the data collected would reflect the personal perspectives and experiences of the selected participants.

Questionnaire The questionnaires were developed and designed following a review of similar studies found in the scientific literature. Four questionnaires were devised, three intended for professionals, addressed aspects of nutrition and feeding, rabbit health, farm biosecurity, and availability of genetics and a fourth was targeted at rabbit producers.

Criteria for selection of participants A background search to identify suitable professionals and stakeholders was conducted based on the criteria displayed in Table 1. A number of individuals who satisfied the criteria of having significant exposure to the sector were chosen, as presented in the following table.

Conduction of the survey The rabbit producers were interviewed in person. However, in the case of professionals, questionnaires were sent by email and followed up by a telephone call to encourage their participation. This study commenced on the 10th of December 2022 and was concluded by the 20th of February 2023.

Data analysis Results were analysed and interpreted using the Microsoft Excel Database.

3 Results

The response rate of the survey Registered an encouragingly high response and participation rate: rabbit producers 82%, feed mills 75%, importers of feed and equipment 67%, veterinarians 50%, pharmacists, 63% and the sole breeding stock supplier.

Producers' knowledge and access to extension services Feed suppliers offer their clients feeding advice usually based on the formulations that they represent. Results indicate that producers seek advice from veterinary pharmacists, other producers, online information, and the local rabbit breeder associations, but rarely from veterinarians. None of the producers referred to having any on-farm animal welfare issues, however, results indicate that few are aware of the basics of animal welfare principles.

Farm layout and production unit design Agriculture holdings in Malta are limited in size, thereby restricting farm design, which very often requires improvised adjustments and compromises based on the available footprint. All farms have comfortable and direct access through paved roads, and also connections with the municipal water and electrical supply networks. All units implement a closed-cycle production system, keeping the breeding stock and growing/finishing rabbits on the same premises and often in the same barn. The barns are constructed with locally available building materials and roofed over with concrete. In some instances, claims were made that the roofs were insulated to mitigate against the strong summer solar radiation. The widths and lengths

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Ingredient	Alfalfa	Grass meal	Maize	Wheat bran	Wheat pollards	Wheat middlings	Triticale	Barley	Barley distillers dried grains	Barley straw	Sunflower meal	Sunflower	Sunflower hulls	Dehulled soybean meal	Soybean meal	Soya	Soy hulls	Soy lecithin	Peas	Carob pulp	Carob seed husk	Carob seed meal	Grape pips extracted	Rapeseed	Sugar beet pulp	Molasses	Calcium carbonate	Sodium chloride	Sodium bicarbonate	Monodicalcium phosphate	Dicalcium phosphate	Calcium phosphate
Local 1	x			x	х			x				x			x	x			x					x		x	x					
Local 2	x			x				×								×											х					
Local 3	x			x				×			х									Х					×	x	х	х		х		
Import 1	x					x	Х	×		×	х	x		x									Х		×	x	х	Х			х	
Import 2	x			x				×					x							Х					×	x	х	х	х		х	
Import 3	X	х		x																	х	х				x	x					

Table 2: Ingredients used in different brands of breeding doe feeds.

of the barns are not standardised and reflect the limitations present site. All of the barns have doorways for access to the inside and high-level windows to let in light. None are naturally ventilated. Another aspect that reflects space limitation is the lack of an on-site workshop and office space or feed silos, while the presence of a quarantine/isolation holding facility is only available in a limited number of farms. Since no silos are present on any of the farms, they all purchase commercially-available balanced feeds in 25 kg bags. Manure and litter are regularly removed from the inside the barns and kept in a purposely built manure clamp according to the Maltese Code of Good Agricultural Practice (COGAP).

All the health specialists interviewed commented on the proximity of some farms creating clusters of livestock farms, which pose biosecurity threats. However, producers do not share the same concerns. The health professionals confirmed that producers underestimate the importance of on-farm biosecurity measures so much so that most producers confirmed the implementation of just a pest control programme, while completely ignoring even the most rudimentary ones, such as having disinfectant pits at each entry point to the farm. Other basic measures such as the presence and use of footbaths, the practice of showering of personnel before contact with the rabbits, and the use of clothing exclusively worn on-farm are not practised. Only 44% of the farms have toilet facilities on-farm, and in some cases also showers; while 22% use the toilet and shower facilities located in their nearby home. The larger commercial farms follow a supervised animal health control programme that includes vaccination programmes and records on the use of pharmacological products on-farm, whilst the smaller farms have an unsupervised home-developed programme.

Most producers claimed that their barns are adequately equipped with devices for the monitoring and control of the internal environment of the barn, including temperature, humidity, ventilation, and lighting programs. The types of cages found on the farms were procured from European manufacturers that specialise in rabbit equipment, with the most common design being either a flat deck, a two-tiered Californian-style design, or a combination of both. The type of cage system chosen is often determined by the production space available, as well as the production goals. All models are equipped with automated water supplies; however, feeding is mostly done manually.

Feed availability and quality All grains used by the local feed mills are imported, thereby the cost of locally manufactured feed is highly vulnerable to market fluctuations at the international level. The main imported ingredients include alfalfa, wheat bran, sunflower, pollard, barley, soya, other vegetable fibres, vegetable oil, vitamins, and minerals, with Europe and Ukraine being the main suppliers of raw materials. The local feed mills claim to match their formulation with the recommended French and Italian standards. Only one feed mill has a qualified in-house animal nutritionist capable of developing least-cost feed formulations and addressing producers' concerns. The other feed mills rely on the technical support from their pre-mix suppliers and on the cooperation with various veterinarians acting on behalf of the producers. All rabbit feeds on the market are in compliance

Ingredient	Alfalfa	Grass meal	Maize	Wheat bran	Wheat pollards	Wheat middlings	Triticale	Barley	Barley distillers dried grains	Barley straw	Sunflower meal	Sunflower	Sunflower hulls	Dehulled soybean meal	Soybean meal	Soya	Soy hulls	Soy lecithin	Peas	Carob pulp	Carob seed husk	Carob seed meal	Grape pips extracted	Rapeseed	Sugar beet pulp	Molasses	Calcium carbonate	Sodium chloride	Sodium bicarbonate	Monodicalcium phosphate	Dicalcium phosphate	Calcium phosphate
Local 1	x			x	х			×				x			x				x					×		x	х					
Import 1	x		x			х		×	x	x	х	x		x				×					х		x		х	х				
Import 2	x			x				×					x							Х					x	x	х	х	х			
Import 3	x	×		×							x										х	х				x	x					

Table 3: Ingredients used in different brands of weaning rabbit feeds.

with the feed safety requirements as per Regulation of the European Commission (EC) No 178/2002. From an analytical point of view, all feeds (both locally manufactured or imported) trace back to the fact that their formulations were developed by expert nutritionists on an in-house basis, or provided by the pre-mix suppliers. At the time of the survey, the various types of locally manufactured feed formulations as well as imported ones on the local market are presented in Tables 2 to 9. Imported feeds are not procured in bulk, but rather arrive in pre-packed 25 kg bags, originating from ISO-certified feed mills in Italy and Spain. Results indicate that the local market is well supplied with properly formulated rabbit feed available. However, a point of contention exists among producers, whereby a perception exists that feed is lacking in terms of protein and fibre content, and should be improved.

Although none of the feed importers have qualified inhouse personnel to provide professional advice on feeding, they nonetheless rely on the professional expertise available that is offered by their suppliers at the local level. The advice given by the importers to producers is to adopt a feeding regime during the weaning phase that provides a diet rich in fibre and low in protein, or a medicated feed that is gradually replaced by a grower/finisher feed at the latest three weeks before dispatching to market. The local feed mills recommend that newly weaned rabbits are started on adequate amounts of weaner feed that is gradually replaced by the grower-finisher feed and the amounts increased slowly until the daily feed consumption per rabbit reaches 120 grams. Most feed suppliers agreed that producers are using different types of feed according to its recommendations; however, this aspect mainly depends on the size of the farm; with small units generally tending to feed all the rabbits one type of formulation,

while the larger ones are more inclined to adopt the practice of feeding the different animal classes according to their nutritional requirements and hence use multiple feed formulations.

Feeding strategies Most producers purchase feed from one supplier, while a few prefer to use feeds from different suppliers. The feeding strategies are not homogenous across the farms. Six producers use three different feed formulations to meet the requirements of the breeding doe, weaner and grower/finisher rabbits. The rest all implement a unique feeding programme. One uses four types of feed to meet the requirements of the doe, weaner, grower and finisher rabbit. Another uses two types of feed: one for the does and another feed used from weaning up to market. The last farm uses only one type of feed to cover all the life stages present on the farm. Only one producer referred to the feeding of the buck, and in this case, grower/finisher feed is being used. Several producers claim that the does are provided with loose hay to augment fibre consumption and to provide additional bedding during nest building. Medicated feed is used by the majority of producers during the weaning stage and results indicate that at times the recommended withdrawal period of medicated feed is not always respected.

Rabbit health The majority of producers claimed sufficient veterinary coverage, however, the other three stated that the advice received from the health professionals may at times lack consistency. On the other hand, the general consensus amongst professionals providing health-related services to commercial rabbitries felt that the sector is not adequately covered from the veterinary perspective.

The survey revealed that the local market is adequately supplied with the necessary vaccines and medications to

Ingredient	Alfalfa	Grass meal	Maize	Wheat bran	Wheat pollards	Wheat middlings	Triticale	Barley	Barley distillers dried grains	Barley straw	Sunflower meal	Sunflower	Sunflower hulls	Dehulled soybean meal	Soybean meal	Soya	Soy hulls	Soy lecithin	Peas	Carob pulp	Carob seed husk	Carob seed meal	Grape pips extracted	Rapeseed	Sugar beet pulp	Molasses	Calcium carbonate	Sodium chloride	Sodium bicarbonate	Monodicalcium phosphate	Dicalcium phosphate	Calcium phosphate
Local 1	х			x	х			x			1	x			х													1				x
Local 2	х			x				×								х											х					
Local 3	х			x				×			х									х					×	x	х	х			x	
Import 1	х		x			×		×		x	х												Х		×	x	x	х				
Import 2	х	х		x																	х	x				x	х					
Import 3	х			x				x					x							Х					x	×	X	х	х			

Table 4: Ingredients used in different brands of grower/finisher rabbit feeds.

satisfy the requirements of the sector. Table 10 presents a list of available pharmacological products registered for use on rabbits at the time of the survey. All producers agreed on the accessibility of pharmacological products whenever required. However, although the required pharmacological products are available, the survey has indicated that there is a lack of locally available diagnostic services to facilitate the identification of the agent responsible for a particular morbidity.

An overview of the most common on-farm diseases identified by the various interviewees is listed in Table 11.

Reproduction efficiency All producers observed that conception rates are generally better during the November to April window (when ambient temperatures are cool) when compared to the rate of successful copulations during the May to October period (when ambient temperatures fluctuate between warm and hot). Hence, producers contend that the main constraint related to rabbit fertility is the effect of seasonality.

Production genetics There are no specialised registered rabbitries that supply hybrid breeding stock to commercial rabbit meat producers. At the time of this survey, only one local agent was involved in the importation of genetic stock from the renowned French company HYLA which has a proven track record of reliable supply of good quality genetic lines having superior maternal and paternal genetic merit.

On the other hand, the producers claimed that the breeding stock is procured either through importations from France and Italy, or by sourcing in-house through an on-farm selection taking into consideration size, pro-

claim that the main rabbit hybrid lines found on farms are HYLA and Martini, while others use pure breeds of California and Cheeker giants for the paternal line and pure breeds of New Zealand White for the dam line. One producer claims to have an on-farm selection pro-

duction performance and meat production. The producers

gramme using stock from various sources (HYLA, Martini and Grimaud Frères) imported over the last 30 years to develop a rabbit type with better conformation and a higher capacity to adapt to local conditions. However, there are no qualified livestock geneticists on the farm to direct, develop and implement this genetic selection programme.

4 Discussion

Malta's isolation from mainland Europe Malta's small agricultural area within the semi-arid climatic conditions cannot produce the grains and roughage required to sustain the local livestock sector, hence, livestock feeding is heavily dependent on the importation of cereals and roughage together with vitamin/mineral pre-mix. However, the fact that Malta is geographically separated from mainland Europe crates two constraint aspects: 1) the sector is highly vulnerable to market fluctuations abroad and 2) the logistics of continuous reliable supply. As a rule of thumb, feed costs cover around 75% of production costs; however, in Malta's case, importation has additional expenses. Similarly, the procurement of equipment, including cages with the associated paraphernalia, to the procurement of new stock for improved genetics are also burdened with additional costs. This creates a significant disadvantage when compared to the European counterparts, and in order to offset these extra costs and remain

Ingredient	Alfalfa	Grass meal	Maize	Wheat bran	Wheat pollards	Wheat middlings	Triticale	Barley	Barley distillers dried grains	Barley straw	Sunflower meal	Sunflower	Sunflower hulls	Dehulled soybean meal	Soybean meal	Soya	Soy hulls	Soy lecithin	Peas	Carob pulp	Carob seed husk	Carob seed meal	Grape pips extracted	Rapeseed	Sugar beet pulp	Molasses	Calcium carbonate	Sodium chloride	Sodium bicarbonate	Monodicalcium phosphate	Dicalcium phosphate	Calcium phosphate
Local 4	x		x		х			x				x			x		x								x		x	х				
Local 1	x			X	х			x				x																				x
Import 1	x		x			x		x			х			x									x		×		x	х				
Import 2	×			×				×					×	x						Х					×	×	×	х				

Table 5: Ingredients used in different brands of complete rabbit feeds.

competitive, the local sector has to strive for excellence with regards to production efficiency.

Stakeholder knowledge and advisory services Through this study, it emerged that there is a siqnificant lack of knowledge amongst the majority of stakeholders who are active within the Maltese commercial rabbit sector. The majority of producers came across as having weak technical knowledge; indeed, they implement antiquated management practices based on amateurish hands-on experience rather than practices backed by scientific principles. This situation is very different from what De Battista (1985) reported; in that the majority of rabbit producers at the time were aware of the basic principles of rabbit husbandry and stockmanship due to the dissemination efforts of the Rabbit Breeders Association to educate their members.

Producers' perceptions on how to increase on-farm animal welfare were limited to aspects of controlled temperature and humidity within the production barn, having larger cages, allowing for longer intervals between mating, and any other actions which in their opinion reduce stress on rabbits. However, what has emerged from this study is the fact that a third of the producers lack sufficient knowledge pertaining to on-farm animal welfare. These producers are not aware of the five freedoms of animal welfare (basic animal welfare principles) and therefore, they may be unable to identify poor animal welfare conditions onfarm or such problems may be identified when it is too late. The lack of knowledge on this subject may be linked to the questionable absence of animal welfare issues reported on their farms, especially considering their lack of knowledge of basic animal welfare freedoms. The fact that a significant number claimed not to be aware of basic animal welfare principles can only mean that they are not well-read even in the most basic aspects of management, and operate within a bubble, oblivious of current developments in the sector.

Results also indicated that a full array of rabbit feed formulations, whether imported or manufactured locally, are available on the market to meet the recommended nutritional requirements of the full cycle of rabbit production. However, producers implement feeding programmes that they perceive to be adequate, ignoring recommendations from professionals advising the use of specific feed at different parts of the production cycle. Indeed, medicated feed intended for weaners is at times fed throughout the growing/finishing stages, and the withdrawal periods of medicated feeds are not respected. On the other hand, some feed suppliers act on a purely commission basis, meaning that they are middlemen between overseas feed manufacturers and the local rabbit producer. Hence, their sole interest is the selling of feed without being knowledgeable on aspects of rabbit nutrition, thereby being incapable of recommending the use of the various formulations that they supply. The same applies to local feed mills that manufacture rabbit feed on formulations supplied by the suppliers of the pre-mixes being used without actually having an in-house animal nutritionist.

In the absence of a local structured advisory service offering advice and recommendations on livestock production management practices, rabbit producers seek advice from veterinary health professionals, word of mouth, online information, and fancy rabbit breeder associations. Nonetheless, the ultimate understanding of the acquired advice and recommendations pivots on the depth of understanding by the actual producer. A case in point is a recent episode where a lower VHD vaccination dose was being administered by the producers with the repercussion
Brand	Directions for use	Price	Crude protein	Crude fibre	Crude oils & fats	Crude ash	Calcium	Sodium	Phosphorous	Coccidiostats & Histomonostats
Local 1	Complete feed, can be	€9.75	16.8%	15.5%	5.0%	7%	1.0%		0.57%	1mg/kg
	also used for breeding									
	does with kits									
Local 1	Breeding does and lac-	€10.85	17.5%	14.4%	6.0%	7.2%	1.0%		0.6%	1mg/kg
	tating breeding does									
Local 2	Last period of gestation	€10.50	14.3%	11.5%	3.79%					
	and during lactation									
Local 3	Breeding does and	€10.00	16.5%	16.8%	2.8%	8.5%	14 g/kg	1.5 g/kg	6.0 g/kg	66mg/kg
	pregnant does									
Import 1	Breeding does	€10.80	16.92%	15.44%	3.96%	7.26%	1.09%	0.2%	0.71%	66mg/kg
Import 2	Breeding rabbits	€10.40	18.0%	15.0%	4.5%	9%	1.10%	0.20%	0.70%	66mg/kg
Import 3	Breeding rabbits	€10.35	14.5%	15.0%	3.3%	6.5%	1.01%	0.08%	0.63%	1mg/kg

Table 6: Analytical analysis of breeding doe feeds.

that these farms suffered significant losses.

Climatic constraints The climate of the Maltese Islands can be described as being a typically Mediterranean one, characterised by mild, wet winters and hot, dry summers. Nonetheless, the archipelago receives a significant amount of sunshine all year round (mean 8.3 hours of bright sunshine per day), peaking in solar radiation in summer registering almost 8 kWh/m²/day, while dropping in winter to a minimum of 2.5 kWh/m²/day (Schembri, 1997). On encountering a surface, the radiation may be reflected, transmitted or absorbed. If absorbed, the surface will heat up and act as a heat collector. Within this context, the roofs and walls of buildings that directly receive this solar radiation act as an absorbent material that collects and accumulates heat energy, which is later released into the inside of the production barns. The insulation of farm buildings is critical to maintain internal temperature controls. In fact, McNitt et al. (2013) recommend that both the walls and ceilings of an environmentally controlled building should be insulated. An insulated building is necessary to complement the action of cooling systems and to minimise radiation of heat from the roof into the rabbitry.

Producers have indicated that they are experiencing lower production performances during the summer months. The seasonality in performance is linked to the variations in the internal ambient barn temperature. Hence, despite some producers claiming that their barns are insulated, in reality, they all face problems related to heat stress. This situation leads one to assume that neither producers nor their consulting building engineers have adequate knowledge on the construction of suitable livestock housing, much less the technology required to maintain the internal barn temperatures within the species-specific thermoneutral zone, also known as the comfort zone. Hence, none of the barns on the farms included in this survey can be considered as being adequately insulated or equipped with cooling systems.

The ideal environment in a rabbit housing unit is about 15°C to 20°C with around 50% relative humidity (McNitt et al., 2013). Marai and Rashwan (2004) reported that when ambient temperatures surpass the 30°C mark, in an attempt to reduce environmental heat load, rabbits adapt specific behaviour strategies associated with efforts to dissipate body heat. These behaviours include: increasing respiration rates, stretching to expose a higher body surface area to increase heat loss by radiation and convection, and the orientation of the ears away from the body. Heat stress is also associated with a reduction in feed intake and overall farm productivity

The reproduction efficiency of the doe decreases when the internal barn temperature falls outside the 15°C to 20°C window (Liang et al., 2022). When this ambient temperature is exceeded, does are prone to experience heat stress, which will consequently have a negative effect on their reproductive performance (Marco-Jiménez et al., 2017). In particular, heat stress impacts conception rates, embryonic development, litter size, milk production (Hen & Wang, 2004), and litter weights (Marai et al., 2002). Reduced oestrogen secretion resulting in irregular oestrus, and complications in egg cell fertilisation were reported by Garcia and Argente (2017). During episodes of heat stress, larger quantities of blood are diverted to the extremities in an attempt to lose heat. In the case of pregnant does this redirection reduces the volume of blood nourishing the uterus and umbilical cord, causing insufficient supply to the developing embryos (Marco-Jiménez et al., 2017); thus, embryo survival is jeopardised and may lead to a high in-uterine mortality and abortions (Song et al., 2006). The results obtained by the various studies consulted above are in agreement with a local study con-

Brand	Directions for use	Price	Crude	Crude	Crude oils	Crude	Calcium	Sodium	Phosphorous	Coccidiostats &
			protein	fibre	& fats	ash				Histomonostats
Local 1	Weaning stage	€10.00	16.5%	17.0%	5.5%	6.9%	0.8%		0.6%	
Import 1	Weaning stage	€11.00	14.44%	19.37%	3.61%	7.41%	1.81%	0.2%	9.45%	66mg/kg
Import 2	Weaning stage	€10.20	16.5%	17.5%	3.2%	8.5%	1.2%	0.20%	0.60%	66mg/kg
Import 3	Weaning stage	€10.45	14.0%	14.2%	3.6%	5.5%	0.62%	0.06%	0.61%	1mg/kg

Table 7: Analytical analysis of weaning rabbit feeds.

ducted by Sammut (2008). The latter study found that the breeding stock kept in housing equipped with cooling systems performed better than others kept in barns not equipped without such facilities

Notably, rabbit bucks kept under heat stress conditions exhibit suppression of testosterone secretion, libido, and spermatogenesis. Liang et al. (2022) reported that bucks are more sensitive to high temperatures when compared to does. The synthesis and secretion of hypothalamic gonadotropin-releasing hormone (GnRH) are reduced under high temperatures, which significantly affects the function of the testis and decreases semen quality (viability), thus affecting bucks' reproductive performance (Daader et al., 2016).

The fact that all producers commented on experiencing a decrease in reproductive performance indicates that most likely, the production barns are not adequately insulated and thus, the extreme outside temperatures are causing heat stress on the animals. Although the general situation is that the breeding stock and progeny are kept in the same barn, surprisingly none of the producers commented on the effect of heat stress on the growth parameters of the growing/finishing market rabbits. The literature review retrieved a previous study published in a peerreviewed journal that was conducted locally on the effect of heat stress on growing/finishing rabbits Marongiu et al. (2006) investigated the effects of high ambient temperatures in terms of water-to-feed ratio and daily weight gain in two groups of growing/finishing rabbits from the ages of 6 to 12 weeks. One group was kept outside under a canopy with ambient temperatures during the test period varying from 35-46°C, while the other group was kept indoors in an environment-controlled barn with a constant temperature of 20°C. The results indicated that the rabbits kept within the comfort zone had higher FCR and higher average daily weight gains.

Rabbitry design and adherence with the Maltese Code of **Good Agricultural Practice** Barn facilities found on farms are not homogenous and vary from purposely built facilities to the modification of older structures that were previously used for other livestock, such as swine or poultry. Due to space limitations, farm designs tend to maximise the usability of available areas, often resulting in cramped conditions. Consequently, most farms have only one production barn and no feed silos are present.

Although some of the producers declared the presence of a quarantine/isolation area, in reality, this facility may be a room located within the main production barn. The fact that the quarantine/isolation space is within the same barn as the production stock supports the previous reference to the producers' lack of knowledge on rabbit production and in this case, also with regard to biosecurity aspects and rabbit health. Quarantine procedures usually include a designated area to receive procured replacement stock or to act as a sick bay for rabbits that need individual attention. Ideally, this quarantine facility should be located away from the barn housing the main stock with a separate entrance to comply with the European Animal Health Law Regulation (EU) 2016/429.

Since no on-farm feed silos are present, producers have no choice but to procure feed in 25kg bags at a higher cost per ton (McNitt et al., 2013) On-farm silos would not only allow for lower feed costs but would also store feed in a more manageable manner and enhances biosecurity measures with regards to contamination from pests and rodents.

Only one farm claimed to have an automated feeding system installed, whilst the rest resort to manual feeding incurring higher labour costs. Although it is more work intensive, by default, manual feeding obliges the producers to inspect every cage as they move down the alley.

Locally manufactured rabbit cages are mostly aimed to meet the demands of very small-scale backyard producers. Commercial farms usually opt for purchasing imported cages from renowned companies that specialise in rabbit cages sourced from European companies that manufacture cages according to European standards. All cages are equipped with all the necessary compartments for feeding, drinking, and nesting, and are constructed out of wire mesh and supported on stainless-steel stands. This type of cage material facilitates the cleaning and disinfection of cages during the cleaning process. Although the same manufacturing companies provide automated feeders to complement their cages, only one has opted for them. On the other hand, all farms have automated drinking

Brand	Directions for use	Price	Crude protein	Crude fibre	Crude oils & fats	Crude ash	Calcium	Sodium	Phosphorous	Coccidiostats & Histomonostats
Local 1	Market rabbits	€9.80	16.0%	17.8%	5.0%	6.5%	1.0%		0.4%	
	> 7 weeks of age									
Local 2	Growing rabbits	€9.80	13.8%	16.8%	3.05%					
Local 3	Growing rabbits	€9.75	16.5%	15.3%	2.5%	8.1%	10.0 g/kg	1.5 g/kg	6.0 g/kg	60mg/kg
Import 1	Fattening rabbits	€10.20	14.11%	18.01%	2.71%	7.83%	1.13%	0.2%	0.55%	
Import 2	Fattening rabbits	€10.00	13.4%	14.10%	3.3%	5.6%	0.65%	0.06%	0.60%	1mg/kg
Import 3	Fattening rabbits	€11.20	16.5%	16.0%	3.5%	8%	1.10%	0.20%	0.60%	

Table 8: Analytical analysis of grower/finisher rabbit feeds.

water systems: water is delivered through a nipple system where water flows through gravity from overhead tanks. The majority of farms are equipped with different cage sizes and designs to meet the requirements of various life stages (from kindling to market rabbits) as well as to accommodate the projected rabbit population inventory.

The most frequent cage designs found on-farm are flat deck, a two-tiered Californian style, and a combination of both. In this regard, one needs to refer to the latest European Food Safety Authority (EFSA) published opinion on the health and welfare of farmed rabbits in 2020. This opinion states that from an animal welfare perspective, the commercial conventional wire cages ranked last when compared to other rearing designs. As a follow-up to this, the European Commission is putting forward a legislative proposal to ban all cages for a number of farmed animals, including rabbits. If approved, this legislation will most likely experience resistance from the local producers. All the interviewed producers expressed their resentment towards this proposal and are of the opinion that loose farming would not be economically feasible on a commercial scale level. They anticipate that loose housing systems will give rise to aggressive behaviour due to territorial instincts and to secure access to feed. They also voiced their concern about the increased predisposition to disease and the challenging conditions of maintaining adequate hygiene and health controls. Furthermore, the demand for a larger area per animal in a reality where space is scarce makes this proposal redundant. On the same line of thought, organic rabbit production in Malta is a non-starter.

All livestock operations have to comply with the relevant measures stipulated in the Maltese Code of Good Agricultural Practice. The measures that relate to rabbitries were identified and each of the measures is discussed in light of the results from the survey.

(A) Have careful preparation, storage and transport of feed:

All farms abide by this measure, however, the absence of feed bins due to lack of space does not allow for

the purchase of feed in bulk.

(B) Ventilation should always secure good indoor air quality for animal health and welfare without creating environmental hazards:

The majority affirmed that the farms are adequately equipped with ventilation systems, and thus are in compliance with this measure. However, upon further inquiry, producers do not have a good grasp of the scientific principles behind ventilation. In their view, ventilation encompasses the installation of extractor fans only without taking into account the rate of air exchanges in the barn.

(C) Good artificial lighting should be secured in production areas:

Artificial lighting is to be provided if natural lighting is not sufficient. All of the interviewed producers indicated that their production barns have high-level windows to let in natural daylight. In addition, some of the producers claim to have in place a lighting programme to deliver a 16-hour light followed by a dark period of 8 hours.

(D) Manure to be stored outside in proper storage facilities:

The results indicate that mechanical manure handling systems are present on larger farms, while the smaller ones rely on the manual removal of manure. In all cases, a purposely built manure clamp is present on-farm. These practices and structures dedicated to the safe storage of manure are compliant with all the measures recommended in this respect by COGAP.

(E) Solid and liquid manure has to be stored in covered clamps from the 15th of October to the 15th of March:

Manure is kept on-farm during this timeframe due to the rainy season and to prevent excessive nutrient runoff and leaching. The producers participating in this study adhere to this measure. In accordance with another measure, manure is spread on land between the 16th of March to the 14th of October.

(F) The producer and/or contractor has to keep records

Brand	Directions for use	Price	Crude protein	Crude fibre	Crude oils & fats	Crude ash	Calcium	Sodium	Phosphorous	Coccidiostats & Histomonostats
Local 4	Complete feed. Feed to breeding and fattening	€9.85	16.5%	17.5%	2.5%	7.5%	1.0%		0.5%	
Local 1	Complete feed for all stages of productions	€9.00	16.0%	15.9%	2.0%	6.7%	1.0%		0.6%	
Import 1	Complete feed for all stages of productions	€10.50	17.02%	15.91 %	3.0%	8.38%	1.44 %	0.2 %	0.65 %	0.02mg/kg
Import 2	Complete feed for all stages of productions	€10.00	16.5%	16.5%	2.8%	8%	1.2 %	0.1 %	0.60 %	66mg/kg

Table 9: Analytical analysis of complete rabbit feeds.

of manure transports:

Producers are obliged by the Nitrates Directive Act to keep a record of when and how much manure is removed and where it is being spread.

Biosecurity In the European Animal Health Law Regulation of the European Union (EU) 2016/429, biosecurity is defined as: 'the sum of management and physical measures designed to reduce the risk of the introduction, development, and spread of diseases to, from and within: (a) an animal population, or (b) an establishment, zone, compartment, means of transport or any other facilities, premises or location'.

Results indicated that biosecurity measures on local rabbit farms are of poor standard since the majority of producers just implement a basic pest control programme. Producers lack sufficient training and knowledge on the subject, and they underestimate the importance of implementing on-farm biosecurity measures. In some cases, the most basic biosecurity measures are lacking, such as facilities for personal hygiene such as an anteroom, toilets, and showers, and the lack of a rabbit quarantine/isolation area. It is of utmost importance that all farm personnel's visits to the rabbit farm should begin in an anteroom, where visitors and staff can put on farm-specific clothing and footwear and wash their hands appropriately (Neumann & Hall, 2019). This further decreases the possibility of pathogen transmission. The presence of a quarantine/isolation holding facility is mandatory as per European Animal Health Law Regulation (EU) 2016/429. Sick rabbits that have been potentially exposed to an infectious or contagious disease should be isolated from the stock present on the farm. Purchased new stock should also be kept separate from the rest of the stock present on the farm for at least two weeks. The mentioned precaution may prevent the spread of diseases on rabbit farms in case such diseases are at an incubation stage at the time of purchase (McNitt et al., 2013).

Furthermore, risks from pathogens being carried over by

wind from neighbouring farms are also of concern. This is of particular interest to Malta since only 8% of the days are considered to be calm. The predominant wind is the North-western, which on average blows on 19% of windy days (Schembri, 1997). The other winds are all nearly equally represented. Given that Malta is a relatively small island, disease transmission between one farm and another can in theory be a threat, as highlighted by health professionals. Indeed, Ellwanger and Chies's (2018) study revealed that wind must also be considered a crucial factor in the transmission of various diseases since it can modulate the dynamics of different vectors and pathogens. The Maltese Code of Good Agricultural Practice also includes biosecurity measures that have to be adhered to. The measures that relate to rabbitries were identified and each of the measures is discussed in light of the results from the survey.

- (A) A vehicle disinfection pit is recommended to be present at the entrance of the farm: Results indicated that the majority of producers do not have a disinfectant pit and hence are not compliant with this measure.
- (B) Good animal welfare and health conditions ensure good animal performance:

The fact that all the producers observe a decrease in performance during the summer months can only imply that the animals are under a constant state of heat stress during this period. Furthermore, as already commented previously, locating a quarantine/isolation facility within the same production barn defeats its purpose. This further confirms the producers' lack of understanding of basic concepts related to animal welfare and animal health, irrespective of them claiming otherwise

Rabbit health The survey revealed that the local market is well stocked with pharmaceutical products to address all of the ailments faced by the commercial rabbit

VET number	Name of veterinary medicinal product	Dosage form	Active ingredients
Vaccines			
VET 467	Toxipra plus	Vaccine	Costridium toxoids
VET 56	Cunivax Mixoma	Vaccine	and anaculture Live-attenuated Borghi strain
VET 117	Cunivax P.B.	Vaccine	of rabbit Myxomatosis virus Pasteurella multocida 15 bn, Bordotella bronchosoptica 15 bn
VET 142	Cunipravac -RHD	Vaccine	Virus RHD strain 3116-AP
VET 145	Mixohipra-H	Vaccine	Live attenuated Sanarelli
VET 282	Castorex	Vaccine	RHD RHDV PHB 98 - min. 1PD 90
VET 451	Castomix	Vaccine	Attenuated Myxomatosis virus . MAV;
VMA 86	Castorex Neo	Vaccine	Inactivated Rabbit Haemorrhage
			Disease Virus type 2, Strain
CA 71	Nobivac Myxo-RHD PLUS Iyo-	Vaccine	Live myxoma vectored RHD virus
	philisate and solvent for suspen-		strain 009, Live myxoma vectored
	Sion for injection for raddits		RHD VIrus strain MK1899
VEI 416	l rimetoprim-Sulfadimetossina	Oral solution	Irimethoprim 40mg/g; Sulfadimethoxine 200mg/g
VET 829	Trisulmix liquide	Oral solution	Sulphadimethoxine sodium 186.7mg/ml; Trimethoprim 40.0mg/ml
VET 346	Ganadexil Enrofloxacino	Oral solution for use	Enrofloxacin 100mg/ml
VET 370	Bacipremix	Medicated feed premix	Bacitracin 0.05g/g
VET 415	Ossitetraciclina 20%	Powder for oral solution	Oxytetracycline 200mg/g
VMA 81	Apravet 552 IU/mg	Powder for use in	Apramycin (as Apramycin
VFT 703	Paromomicina	drinking water/milk Medicated premix	sultate) 552 IU Paromomycin 200g/kg
	huvepharma 200g/kg		
VET 700	Bacivet S 4200 IU/g	Powder for use in drinking water	Bacitracin zinc 4200 IU/g
VET 882	lsathal 10mg/g eye drops sus-	Eye drops	Fusidic acid 10mg
	suspension for dogs,	suspension	
VET 31	Fatroximin spray	Spray	Rifaximin 0.5g /142g
Anti-parasites			
VET 308	Aca Cerulen R 300ml	Ear spray	Chlorocresol 1.2g/100ml,
			Pyrethrum 1.2g/100ml, Piperonyl butoxide 3g/100ml
Hormones			
VET 694	Receptal	Solution for injection	Buserelin acetate 0.004mg/ml
VET 976	Gabbrostim, 2 mg/ml injectable solution for cattle, pigs, horses and rabbits	Solution for injection	Alfaprostol 2mg/ml

 Table 10: List of available pharmacological products grouped according to type.

Viral Diseases	Bacterial Diseases	Fungal Diseases	Parasitic Diseases
VHD	Enterotoxaemia	Dermatophytosis	Sarcoptic mange
Myxomatosis	Pasteurellosis		
	Mastitis		

 Table 11: The most commonly/prevalent diseases occurring on commercial farms.

sector in Malta, as presented in Table 10. These products are readily available from various veterinary pharmacies, while some pet shops provide over-the-counter products. A common comment expressed by all health professionals is the lack of specialised veterinarians in rabbit health and the lack of diagnostic laboratory facilities. On the other hand, the producers believe there are sufficient veterinarians to service the sector. This may indicate that the few veterinarians who work within the sector provide constant services to the producers' satisfaction.

The most commonly occurring diseases on commercial rabbit farms in Malta as reported by the health professionals and the producers are presented in Table 11.

Despite the substantial advancements made in the fields of genetics, feed, and management, the higher productivity, the high selection of breeds, and their crosses made the presence of disease on-farm still inevitable (Espinosa et al., 2020). Animal diseases have an important effect on animal productivity and welfare (Grace et al., 2015). Numerous studies have been carried out, analysing the monetary costs of diseases including the outcome of mortality losses, reduced productivity and control expenses (Grace et al., 2015). Solans et al. (2019) reported that in many EU countries, enteric problems are considered to be the main cause of monetary losses on meat rabbit farms.

Subsidiary Legislation 437.47 of the Maltese Law obliges all livestock producers to have an animal health control programme in place and implemented under the responsibility of a professional registered with the Veterinary Surgeons Council. The first lesson taught in animal health management is that prevention is better than cure; however, the results of this survey indicated that irrespective of the requirements of the legislation, the prevention aspect, usually implemented through the application of a proper on farm biosecurity programme is lacking. This calls for urgent action to be taken by the competent bodies to offer training and instruction to producers in order to improve their awareness of the importance of implementing a proper biosecurity programme to cover the whole farm. Morbidity has a huge financial implication since animals' compromise production while they continue to consume feed.

As described in the section of biosecurity, farms have

Farm	Conception	Kindling	Weaning	Efficiency
A	70 %	85 %	90 %	53.6 %
В	75 %	95 %	95 %	67.7 %
C	50 %	50 %	50 %	12.5 %
D	90 %	95 %	90 %	77 %
E	90 %	95 %	90 %	77 %
F	80 %	80 %	85 %	54.4 %
G	85 %	80 %	85 %	57.8 %
H	70 %	70 %	70 %	34.3 %
	95 %	95 %	95 %	85.7 %

Table 12: Conception, kindling, weaning rates and conceptionto weaning cycle efficiency ranked according to farm size. Efficiency Formula = $100 \times (Conception \% / 100) \times (Kindling \% / 100) \times (Weaning \% / 100)$

severe limitations due to space and have to make do with what is available and maximise its use. Thus, the most common production system is what is known as a continuous cycle within the same barn, as opposed to the recommendations to practise the all-in/all-out principle. Thus, cleaning and disinfection protocols between different production cycles cannot be carried out (Huneau-Salaün et al., 2015). In this scenario, the on-farm biosecurity measures that need to be implemented have to be even more robust and complemented with a purposely designed animal health control programme that would include preventive measures such as vaccination programmes and sanitisation measures.

Feeds and feeding strategies As already alluded to previously, the supply of rabbit feed is susceptible to the volatility of international markets. The results indicated that the local market is well supplied with a variety of feed brands, each having a number of different feed formulations. The brands can be classified into two groups: one that encompasses locally manufactured feed, while the other includes suppliers that import balanced feed from abroad. Within these various entities involved in the supply of rabbit feed, only one has an in-house nutritionist. Hence, the majority of entities supplying rabbit feed lack the basic knowledge on rabbit nutrition and thus are not in a position to provide proper advice to their clients. Thus, although the market is flooded with a variety of differently formulated rabbit feed, producers do not necessarily implement a feeding programme that would maximise feed efficiency.

Producers commented on the fact that since feed needs to be imported, there may be instances when availability is inconsistent, and the abrupt switching to other brands or types is claimed to result in metabolic problems leading to

Category	Quantity	Diet				
Young Does						
Early mating 15-16 weeks	Ad libitum	Fatteners				
Late mating 17-20 weeks	Restricted	Fatteners or specific rearing diets				
	Does					
Late gestation Lactation	Ad libitum Ad libitum Kits < 3 weeks	Lactation Lactation Lactation Weaning				
In pre-gestation cages	Restricted	Fatteners				
	Males					
Young until 18 weeks	Ad libitum	Fatteners				
Adult	Restricted	Fatteners				
Weaned rabbits						
4-9 weeks 8-11 weeks	Restricted Ad libitum	Fatteners Fatteners / Finishing				

 Table 13: Feeding strategies for commercial rabbit meat production.

diarrhoea. In addition, they also commented that in their opinion, the quality of the feed found on the local market should be improved, especially in terms of protein and fibre content. Upon comparing the analytical analysis of the feeds found on the local market (Tables 6 and 8) with the recommendations of de Blas and Mateos (2020), it is evident that this claim is unfounded; however, it reinforces the fact that producers lack basic knowledge of feed and rabbit nutrition.

The survey has indicated that the weaning stage is a very delicate phase that needs particular attention. Newly weaned rabbits are highly susceptible to morbidity and mortality; hence, it is a crucial stage that reflects strongly on the overall profitability of the farm. Weaning is a very delicate stage regardless of whether the kits are physically removed from the doe or if the doe is removed since in both cases, the newly weaned rabbits have to endure the stress of transitioning from a liquid feed to a solid diet. Feed suppliers recommend to producers that in order to maximise growth efficiency, rabbits need to be given the appropriate feed at the right age, offered ad libitum with a constant supply of good quality water and follow good biosecurity practices. These recommendations are in line with the feeding strategies suggested by Maertens (2020), which are presented in Table 13.

With the gradual shift by the producers from a generic diet fed across the stock inventory to a feeding strategy that involves a number of specifically formulated diets, the feed suppliers commented that over the last 30 years, they have experienced a higher request for larger quantities and better-formulated rabbit feed to meet the producers' demand. The results suggested that the feeding strategies differ across farms and vary from the better ones employing precision feeding by using 4 types of formulations, to other farms that give just one type of feed across the board. This obviously will result in different production results across the farms. Rabbits at various stages throughout their life cycle have different nutritional requirements; hence, the use of unified will create instances where the feed oversupplies the required nutrients and other instances where the feed does not meet the nutritional requirements. Therefore, the feeding of a single formulation throughout the farm could potentially lead to consequences in aspects of growth, productivity, digestive functions, and ultimately the overall profitability of the farm.

The effects of heat stress on rabbit physiology have already been discussed in the previous section. Rabbits exposed to temperatures higher than their comfort zone require specialised diet formulations taking into account this environmental stressor. Such formulations are not currently available on the local market.

Of particular interest is the fact that in some cases, the text on the labelling of the imported feed is in a foreign language. Apart from not being in line with Article 14 point 1 of Regulation (EC) 767/2009, this would only lead to confusion among the producers. The directions for use as printed on the labels are often too small to comprehend or misinterpreted and hence applied incorrectly.

Although a wide spectrum of feed formulations is present on the local market, this study has identified the existence of several challenges related to feed handling and feeding. These include: the storing of feed in bags in environments that are hot and humid, which may lead to the rapid deterioration in feed quality; the inconsistency of feed supply from suppliers; and inappropriate feeding strategies (including overfeeding), which may lead to episodes of diarrhoea.

Reproduction efficiency The reproductive efficiencies of the interviewed farms are indicated in Table 12, which presents the results according to farm size. Based on the declarations made by the producers, conception and kindling fall within the 70% to 95% success rate; however, one farm reported significantly lower conception and kindling rates. The discrepancy in these success rates can be due to a variety of reasons. Issues related to heat stress and the practice of improper feeding strategies have already

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been discussed. Other issues identified in this study that may contribute towards reducing the fertility rate will be discussed hereunder.

In a number of farms involved in this study, the stud bucks are housed in the same barn together with the breeding does and their progeny. This means that the bucks are subjected to the same light programs as the does, usually consisting of 16 hours of light and 8 hours of dark. Boiti et al. (2005) claimed that bucks exposed to a constant lighting stimulus under a programme of 16 hours of light affects the hypothalamus-pituitary axis which releases hormones, thus increasing spermatozoa production. In the case where bucks are not housed within the main production barn, they are usually exposed to natural day length. As reported by Theau-Clément et al. (1990), Mirabito et al. (1994), and Gerencsér et al. (2008) the conception rate of does exposed to 16 hours of light 8 days before insemination increases by 10%.

The length of breeding cycles, also known as the period between two successive copulations, is an important parameter to take into consideration. Most of the producers reported that the most common re-mating strategy follows a 51-day cycle. According to Mayer (2022), if the inter-litter time is too long, the does start accumulating fat and reducing fertility. However, if it is too short, they may become underweight and have a reduced receptivity to the buck and fertility. Azard (2006) reported that the 42-day breeding cycle is the most common cycle used in Europe. Furthermore, Gerencser et al. (2011) compared the 42 and 56-day breeding cycles and noticed that the amount of kits/doe/year of the 42-day breeding cycle was higher by 19% to 23% when compared to the 56-day breeding cycle.

Similarly, to the case discussed above regarding the availability of various pharmaceutical products to prevent and cure ailments, producers have easy access to pharmaceutical preparations and associate paraphernalia to synchronise the oestrus of does and to administer AI. Most of the interviewed producers practise AI using semen from stud bucks present on farm while the others prefer to use natural mating using the on-farm bucks. Another option is to procure semen from a local source specialising in the supply of fresh semen from imported high genetic merit bucks. This supplier indicated the largest demand for fresh semen is from the backyard industry. The larger commercial farms prefer to purchase genetically superior bucks from abroad and practise on-farm AI. Shuji (2009) reported that AI is a more suitable mating practice for small and large commercial farms than natural copulation. Performance on farms using AI benefits in productivity parameters and access to superior genetics (Nassif & El-Sabrout, 2020). However, the AI procedure requires a high level of technical competence under aseptic conditions to ensure appropriate sanitisation to safeguard the health and well-being of the doe. Generally speaking, the procedure involves that a number of does are synchronised so as to be receptive for insemination on a particular day, thereby also serving as a means to pre-program kindling dates to fall with normal work days when operators are available to inspect the does.

Supplies to carry out AI and synchronisation procedures are very accessible and have a reasonable cost. The indicative prices for the purchasing of AI equipment and supplies for synchronisation are the following: single disposable pipettes cost $\in 0.50$ each; diluent including receptacle is $\in 50$ for 500 does; $\in 35$ for hormones per 100 does; and artificial vagina for $\in 50$. If semen is also purchased, this costs $\in 0.50$ for each insemination. Although one can easily access all the necessary apparatus to conduct AI, the fact remains that there is no training programme specialising in rabbit AI available.

Production genetics As alluded in the results, currently there are no local entities dedicated to the supply of genetically improved rabbits through a franchised agreement with internationally renowned breeding companies nor from entities dedicated to the local development of hybrid rabbits. One of the most important aspects of rabbit breeding is the selection of an ideal breed for meat production. De Battista (1985) reported that the Flemish Giant was the most popular breed in Malta during that time due to its genetic makeup, however, the importation of foreign genetics took the place of this breed by introducing the New Zealand white and the Californian that ranged as the most popular breeds in Malta. Recently, Busuttil (2005) reported that a Maltese rabbit breeder, the late Mr Joe Gauci Maistre, had claimed to have developed on his farm a hybrid line of white rabbits with brown eyes having superior meat production traits. This hybrid line is locally known as the Maltese Silver.

Today, breeding stock is imported, usually from Southern European countries (historically from Italy, France or Spain) where companies specialising in the selection and genetic improvement of rabbits exist. Producers identified 4 types of imported rabbits: the importation of F1 female day-old kits; the importation of juvenile grandparent stock on the dam line as well as for the paternal line; the importation of juvenile dam and sire F1 parent stock; and the importation of genetically superior bucks to supply semen for AI. The challenges faced when importing rabbits include remarkably high transportation costs, transport stress on the animals, and potential delayed delivery. Delays in consignments because of the suspension of shipping services between Sicily and Malta due to weather conditions cause disastrous effects on the stock since prolonged transit time in cargo conditions results in increased stress on the juvenile rabbits, which could also lead to higher-than-normal mortality rates.

Assuming that the issue of ferry suspension is only a rare occurrence, the Maltese producers are at par with their European counterparts with regard to access to high genetic merit rabbits. In fact, over the last 30 years, the commercial hybrids - HYLA, Martini and Grimaud Frères - have all been represented on local rabbit farms in varying amounts. Producers are also aware of the occurrence of hybrid vigour when crossbreeding two pure breeds. The results indicated that some producers utilise the California and Cheeker giant breeds as sires due to their carcass characteristics, while the New Zealand White females are used as does due to their excellent maternal characteristics. This cross-breeding scheme is in agreement with Szendro et al. (2012), who recommend the use of New Zealand White, California, and other medium-sized breeds as the best choice to improve reproductive or productive performance.

Genetics is a strong tool that can have a significant contribution towards overall farm efficiency. The use of hybrids and crossbreeding to capitalise on the vigour so as to produce robust parent stock has already been mentioned. Another aspect of genetics that none of the interviewed stakeholders made reference to is that carcass characteristics are highly heritable, and hence can easily be transmitted from parent to progeny. For example, the use of specialised bucks to produce offspring with heavier and meatier thighs to meet consumer demands was only mentioned by one producer.

The indicative prices for locally produced and imported F1 parent stock are the following: imported does of 10 weeks cost \in 35- \in 40 while bucks of 14 weeks cost \in 120- \in 140, and locally produced does/bucks at 5 weeks are sold for \in 12, with an increment of \in 1 per week.

5 Conclusion

It is evident that the rabbit meat sector is in urgent need to become organised within an administrative structure. Such a structure would represent the larger commercial farms as well as the small backyard operations that currently are considered ghost operations and are not captured in any official statistics or any official register held by competent authorities. When rabbit meat producers, irrespective of size, are given the opportunity to come together under an umbrella structure that will act on their behalf in negotiations with national competent authorities as well as to disseminate information to their members, the members would represent the majority of rabbit holdings and thus a quasi-accurate estimation of the size of the industry can be forecasted.

National statistics are at a loss in sizing this sector since according to Legal Notice 165 of 2011, operations with less than 50 does are exempt from the obligation to be registered with the competent authorities. Although backyard rabbit production is not captured in the national statistics, one could safely assume that this segment includes small rabbit units comprised of up to 10 does kept for home consumption (Attard et al., 2023). Hence, anyone who is keeping rabbits that falls within this category and is not a registered farmer escapes the system. This thriving backyard sector contributes significantly towards the total amount of locally produced rabbit meat. The report by DG for Health and Food Safety estimates that out of the 550,000 rabbits slaughtered in Malta in 2016, 90% or rather 500,000 were sourced from backyard farms, direct and local sales. This clearly indicates that the bulk of rabbit meat originates from these small holdings that while being invisible due to the lack of registration they potentially have a significant hidden contribution towards the national efforts to increase food security and minimise food waste. While these operations do not necessarily operate on a truly commercial basis, they embrace circularity. These rabbits are usually fed small amounts of pelleted feed supplemented with all the edible scrapes that the owner's kitchen can generate.

Other constraints that emerged in this study are the following:

- (A) The fact that Malta is detached from mainland Europe renders the islands dependent on other countries for the procurement of feed-grade grain, feed supplements, cages and equipment, pharmaceutical products, and breeding stock. This dependency exposes the sector to the volatility of international markets, while connectivity to mainland Europe is weather-dependent.
- (B) As a general rule, although a course is offered by one of the higher educational institutions, producers have a lack of basic knowledge on rabbit husbandry and practice, and less than adequate stockmanship. There are no extension services in place on rabbit husbandry and stockmanship.
- (C) Climate, inadequate environmental control in barns, and the restricted farm footprint, leading to makedo and crammed farm designs come together and translate into a significant constraint both on day-today operations and also with regard to the potential further expansion of the activity.
- (D) The current state is that there is a limited amount of health professionals that tend to commercial rabbit farms, animal nutritionists, agriculture engineers capable of designing adequate production barns, and laboratory diagnostic facilities. Since these con-

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straints have an international as well as a local dimension, the recommendations for improvement of this sector can only address the ones that have a local context. The results indicate that the overriding constraints relate to the fact that the sector does not have an administrative structure, as well as the poor level of producer knowledge on aspects of husbandry and stockmanship. Thus, there is a desperate need to re-train and upgrade the educational level of the producers and organise the industry.

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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. Gzira is a small, highly densely populated town in the Maltese Islands measuring just 0.6 km² 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 Gzira 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 Gzira Local Council and University of Malta, with VSs being suggested involving microgreening 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 Gzira 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 Gzira 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

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 longterm 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 Gzira. 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 Gzira 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 VARCIT-IES 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 envisaged 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 cocreation process, which includes; a co-identification, codesign 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 Gzira

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 Gzira 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 Gzira Gardens in collaboration with the Gzira 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 Gzira 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 various 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 Gzira 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 Gzira 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

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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 preimplementation 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 Gzira Local Council. Since 2017, PH-1 has developed the following UHI framework to determine UHI and its contributors within the locality of Gzira (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 Gzira 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). Gzira 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 Gzira: 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 Gzira, 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 Gzira, 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, Gzira'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 Ghollieqa, 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 Gzira 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 Gzira and their connection to Wied Gholliega 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 Gzira can be listed as Council of Europe Garden (1), Wied Gholliega (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, healthrelated issues in Gzira 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 Gzira 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 \pm 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 Gzira 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	E 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 Gzira locality

This section outlines the health conditions of Gzira residents. In 2020, the crude birth and death rates in Gzira were 8.6% and 7.9% (NSO, 2020). The below localityspecific 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 Gzira 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 Gzira 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 Gzira in 2018 stood at 16.11 cases per 1000 inhabitants, and the incidence of respiratory diseases for Gzira 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 Gźira 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

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	Results of SWOT analysis								
Strengths affecting the planned Visi	onary Solution								
Please describe the endogenous factors t *Outputs of the co-creation workshops	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 pla	anned Visionary Solution	·							
Please describe the endogenous factors t *Outputs of the co-creation workshops	hat can hinder or delay the VS implement	tation process.							
VS1	VS2	VS3							
 Lot of traffic and small pedestrian space so hard to implement green- ery 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 minim- ise 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 t *Outputs of the co-creation workshops	that can positively affect the VS implement	ntation.							
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 neighbour- hood (to raise awareness) 	• Ensuring that the public is involved and aware of this opportunity to turn the space into a spot for cul- tural events, workshops, and leisure activities							
Threats affecting the planned Vision	ary Solution								
Please describe the endogenous factors t *Outputs of the co-creation workshops	that can negatively affect the VS impleme	ntation.							
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 cre- ate 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 Gzira 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 Gzira, 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 project 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 Gźira, neighbouring localities or others with similar context to Gźira.

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/m³ 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/m³ 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 Gzira, 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 occurring 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 km² of road (NSO, 2022) and around 13,700 total passenger cars per km² 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 Gzira 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 Gzira 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 Gzira by bringing three VSs to increase vegetation in the Gzira 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, Gzira on the 4th July 2019.

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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.

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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.

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Figure 9: displays a map of Gzira 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

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Research Article



Vaucheria (Heterokontophyta, Vaucheriaceae) from the Maltese Islands (Central Mediterranean)

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Abstract. The *Vaucheria* species list of the Maltese Islands is reviewed based on literature and collected material. Since many collections were sterile, culture was necessary for identification. Eleven species of *Vaucheria* have been found from saline and freshwater habitats, including several additions to previous lists, namely *Vaucheria cruciata, Vaucheria dillwynii, Vaucheria longicaulis, Vaucheria pseudogeminata* and *Vaucheria synandra*. In addition, *Vaucheria mulleola* was recorded again. Several other past records remain unidentified.

Keywords: Vaucheria, wetlands, algae.

1 Introduction

Vaucheria (Division Heterokontophyta, Class Tribophyceae) is a notable component of wetland flora frequently encountered in damp substrates in freshwater, marine, brackish water and terrestrial habitats (John et al., 2002). Rieth (1980) lists 32 species from Europe, many with world-wide distributions. It has been given widespread attention as in Cambro (1992), Calvo & Bárbara (2004), Christensen (1973, 1987), Entwisle (1988), Nemjová & Kaufnerová (2009), Schneider et al.(1993) and Woronin (1869).

There are very few in-depth published algological studies, such as (Henwood, 2004, 2006), in the Maltese Islands and therefore knowledge of Malta's non-marine algal flora is rather late in coming. The basic text outlining the Maltese species of algae is Sommier and Caruana Gatto, (1915) with subsequent records given by Lanfranco (1967), Lanfranco (1969) and Lanfranco (2002). Within these records, mention of *Vaucheria* is sparse, although it has been occasionally noted in saline wetlands, estuarine channels, coastal rockpools, valleys (both temporarily and permanently flooded) and cupular rockpools in karst habitats.

Traditional taxonomy of the genus *Vaucheria* is based on morphology of their reproductive structures. The difficulty in identifying *Vaucheria* populations to species level in nature is based on findings of sterile filaments. *Vaucheria* are composed of siphonous, multinucleate tubes filled with huge vacuoles and parietal, discshaped chloroplasts, usually without pyrenoid. Members of the genus propagates asexually by synzoospores, aplanospores and akinetes, whereas sexual reproduction takes place by oogamy with individual species being dioecious or monoecious and with the reproductive structures on the same short stalk (gametophore), or individually on the tube.

The aim of the present report is to compile a species list for *Vaucheria* in the Maltese Islands. This has been done through critical review of published records, namely (Lanfranco, 1967, 1969, 2002; Sommier & Caruana Gatto, 1915), and carrying out of field surveys between 2004 and 2022.

2 Materials and Methods

The Maltese Islands, located in the Central Mediterranean region, are characterised by numerous inland freshwater systems (such as ephemeral valley waters and cupular rockpools) and coastal habitats (such as lagoons, rockpools and estuaries). The semi-arid climate makes these systems predominantly temporary, though freshwater springs or sea water infiltration may prolong flooding to various degrees and vary their salinity. Only a small proportion of wetlands, both coastal and inland are therefore permanent.

Table 1 lists the areas where *Vaucheria* records have been noted in literature. It also notes the locations for



Figure 1: Location of sampling (not for interpretation).

collection of fresh material from substrata. The predominant habitat of each site is also noted in Table 1. Figure 1 depicts the general location of the sampling points.

Collected material was preserved in a moist state at 5-15°C for microscopical examination at x10- x400, in which case the field collections were examined for the presence of gametangia. Characteristic features were noted. Material without gametangia was cultured *in vitro* for a short period of time (Schneider et al., 1993) until fruiting was observed, thus enabling identification.

Voucher specimens have been deposited in the collections of JH (CJH), EL (CEL) and RM (CRM).

3 Results

Species list The following species were recorded from literature and field studies.

Order Vaucheriales

Family Vaucheriales

1. Vaucheria cruciata (Vaucher) de Candolle in Lamarck *et* de Candolle 1805 Fig. 2b

Local Record: None.

Material examined: Salina salt pans (10.12.2004, CJH) from damp substratum forming dense mats.

2. Vaucheria dichotoma (L.) Martius 1817 Fig. 2c

Local Record: Collected by Adrian Mallia (7.1992; CEL) from Qawra and from Kalanka t-Tawwalija by Sylvana Buttigieg (11.1992; CEL) from a depth of 5m.

Material examined: Dense mats were recorded at Salina estuary and the adjacent saltpans (06.03.2005; CJH). Also recorded at Ghadira (17.01.2005 CJH) and

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Ghadira ż-Żghira (04.02.2005; CJH) as dense floating masses. Dense mats were recorded from il-Ponta tar-Reqqa (22.02.2009; CJH) mixed with *V. synandra*.

3. Vaucheria dillwynii (Weber et Mohr) Agardh 1812 Fig. 2d

Local Record: None.

Material examined: Collected from Salina salt pans from damp soil (10.12.2004, CJH). Also recorded from damp soil at Maghluq ta' Marsaxlokk (02.12.2004; CJH), il-Qaliet pools (04.02.2005; CJH) and Ghadira (14.03.2005; CJH).

4. *Vaucheria geminata* (Vaucher) de Candolle in Lamarck *et* de Candolle Fig. 2e

Local Record: First recorded by Lanfranco (2002) from samples collected from Wied Guno (Gozo) in pool along the valley (07.12.1999; CEL). Material was also collected from damp soil in Buġibba on 17.01.2000 by Roy Merritt. **Material examined:** Material was collected from Maghluq ta' Marsaxlokk (02.12.04; CEL) on damp substratum and Ghadira (15.12.2004 CEL). The valley in the Qattara area yielded dense mats (21.03.2005; CEL) in a freshwater stream. Maghluq and Ghadira within the lagoon yielded aerial specimens (22.10.2022; CJH).

5. Vaucheria longicaulis Hoppaugh 1930 Fig. 2f

Local Record: None.

Material examined: Recorded in Maghluq area (23.10.2022; CJH) from damp soil.

6. Vaucheria mulleola Skuja 1964

Local Record: Material was collected from a pond at Buġibba by Roy Merritt (17.01.2000; CRM).

Material examined: Recorded in Salina salt pans (10.12.2004; CRM) from damp soil.

Distribution: This species was originally described from the Swedish Lapland (Skuja, 1964) and seems to have been successively recorded only in the Maltese Islands.

7. Vaucheria pseudogeminata Dangeard 1939 Fig. 2g

Local Record: None.

Material examined: Collected in Salina salt pans (10.12.2004; CRM) from damp soil mixed with other *Vaucheria* sp. Recorded at Mistra stream and Ta' Qali (10.12.2004; CRM). Fertile siphons were detected on damp substratum at il-Maghluq ta' Marsaxlokk (02.12.2004; CJH).

Fig. 1 ref.	Site Name	Habitat type	Coordinates	Sampled year,
		(salinity)	(when sampled)	source, record
1	Wied Ġuno/ Qattara ¹	freshwater course	36°3'3.71"N	2006,
		and pool	14°11'32.46"E	Lanfranco (2002)
2	Wied is-Seqer ¹	freshwater course	/	CEL
3	II-Ponta tar Reqqa	valley leading	36°4'53.14"N	2009
		to rocky coast	14°14'10.49"E	
4	Kemmuna ¹	rocky coast	/	CEL
5	Ta' Qassisu	saline pool (\sim 34) ²	35°58'53.31"N	2004-2005,
			14°19'46.06"E	2015
6	Daħlet ix-Xmajjar ¹	rocky coast	/	CEL
7	Għadira	saline lagoon	35°58'12.32''N	2004-2005
		(30-40) ²	14°20'53.25"E	
8	Ghadira ż-Żghira/	saline pool (\sim 30) ²	35°57'59.12''N	2004-2005
	il-Ħofra		14°21'6.82"E	
9	Mistra	freshwater course	35°57'27.58"N	2005
		meeting coast	14°23'21.95"E	
10	Rdum Irxawn ¹	rocky coast	/	CEL
11	Buġibba ¹	rocky coast	/	Lanfranco (2002)
		and rockpools		
12	Qawra ¹	rocky coast	/	CEL
		and rockpools		
13	Salina ¹	estuary (\sim 33) ²	35°56'39.73"N	2004
			14°25'14.71"E	
14	II-Qaliet pools	rocky coast	35°55'24.34"N	2006
		and rockpools	14°29'37.51"E	
15	Valletta ¹	terrestrial	/	CEL
16	Kalanka t-Tawwalija ¹	rocky coast	/	CEL
17	ll-Magħluq	saline lagoon $(\sim 32)^2$	35°50'20.63''N	2005, 2022
	ta' Marsaxlokk		14°32'55.79"E	
18	Għar Lapsi ¹	rocky coast	/	CEL
19	Attard ¹	freshwater pools	/	CEL
20	Ta' Qali ¹	freshwater pools	/	CEL
21	Wied il-Għasel	freshwater course	35°55'4.55''N	2010, 2016
			14°25'37.41"E	

 Table 1: Location name in map and habitat type. ¹Indicates old record at CEL- material deposited in collection of EL. ²Salinity is shown in Practical Salinity Units (PSU) as per Henwood (2006).


Figure 2: Plate showing specimens identified by corresponding author with scale bar of length 100µm: a. specimen as sterile siphonous filaments found within wrack, b. *Vaucheria cruciata*; c. *Vaucheria dichotoma*; d. *Vaucheria dillwynii*; e. *Vaucheria geminata*; f. *Vaucheria longicaulis*; g. *Vaucheria pseudogeminata*; h. *Vaucheria synandra*.

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8. **Vaucheria sessilis** (Vaucher) de Candolle in Lamarck *et* De Condolle 1805

Local Record: Recorded by Sommier & Caruana Gatto (1915), in freshwater (location not mentioned in record). **Material examined:** None.

9. Vaucheria synandra Woronin 1869 Fig. 2h

Local Record: None.

Material examined: Fruiting siphons were collected Ghadira reserve (03.2005; CEL). Dense fruiting mats were recorded from il-Ponta tar-Reqqa (22.02.2009; JH) mixed with *V. dichotoma*.

10. Vaucheria terrestris (Vaucher) De Candolle 1805

Local Record: Recorded by Sommier and Caruana Gatto (1915) from Valletta and Attard. **Material examined:** None.

11. Vaucheria verticillata Meneghini 1837

Local Record: None.

Material examined: Collected from a pond in Bugibba (17.01.2000; CRM).

Doubtful species

12. Vaucheria repens Hassall 1843

Local Record: Recorded by Sommier & Caruana Gatto (1915) in fresh and brackish water from Imtahleb.

Considered by many authors to be a form of *V. sessilis* named *V. sessilis* f. *repens* (Hassall) Hansdirg (see Venkataraman, 1961). Christensen (1987) places it as a synonym of *V. bursata*. This little-known species is therefore regarded as doubtful.

Material examined: None.

Other records Other records of unidentified *Vaucheria* species exist. A description of each record is given below.

- Ghar Lapsi: (09.1992; CEL)
- Kemmuna (southern coast: (10.1992; CEL))
- Dahlet ix-Xmajjar: Recorded with *Jania corniculata* and *Cystoseira* (11.1992; CEL)
- Wied is-Seqer (Gozo): (10.01.1993: CEL)
- Rdum Rxawn: Several species recorded (08.1993; CEL)
- Ta' Buleben (Qawra): *Vaucheria* spp. Mixed with microepiphytes, most notably *Lyngbya rivulariorum* (7.1992; CEL)
- Wied il-Ghasel: Material collected from freshwater was scanty and did not yield fruiting bodies (10.02.2005; CJH)
- Ta' Qassisu pool: Mixed with *Cladophora* sp. Material was abundant but did not yield fruiting bodies (28.02.2005; CJH)

4 Discussion and Conclusions

The checklist includes 12 species of which the following 5 are new records collected from field surveys: *V. cruciata, V. dillwynii, V. longicaulis, V. pseudogeminata* and *V. synandra* and other species are recorded in literature for the first time. One species is considered doubtful.

The collection sites covered the major coastal wetlands in the Maltese Islands. These were the only areas where dense turfs and mats of *Vaucheria* were noted. For example, notable turfs were examined at il-Ponta tar-Reqqa, a relatively isolated and undisturbed coastline which is flooded through surface runoff from the hinterland. Comparatively, inland areas such as temporary freshwater rockpools, though studied in detail (Henwood, 2004) did not yield any *Vaucheria* specimens. Similarly, few records of *Vaucheria* species in inland freshwater habitats occur.

When comparing the number of species with the sampling location, it is noted that the majority of species have been recorded from the largest coastal wetland in Malta- Salina and Ghadira (5 species each) and Maghluq (4 species). The prolonged flood period in these sites, with differing salinity recorded at Ghadira and Maghluq (Henwood, 2006) contributes to formation of dense mats of Vaucheria. Similarly in the salt pans at tar-Reqqa, influx of sea water and surface freshwater runoff allow prolonged flooding in a depression of circa 1 metre depth and the formation of dense mats of V. dichotoma and V. synandra, both marine species according to Guiry & Guiry (2022). The prolonged hydroperiod allows for formation of dense mats and co-occurrence with a dense population of Ruppia drepanensis Tineo ex Guss, a similar situation to Ghadira and Maghluq.

Of the species recorded, *V. dichotoma*, a predominantly marine species, is the most widespread in the local scenario. However, a most interesting record is that of *V. mulleola* at Salina by one of the authors, which confirmed a previous unpublished sighting by the same author. This species has only been previously recorded from the Swedish Lapland and Australia. The direct connection of these sites with Malta is doubtful although records of migratory birds between Malta and Sweden exist.

In general, although the data collected is on the increase, the catalogue of species is prone to enlargement. In particular, the freshwater *Vaucheria* species of the Maltese Islands needs further investigation and the zonation patterns of *Vaucheria* along estuarine regions should be studied. In particular, in view of the temporary nature of freshwater systems in the Maltese Islands, culturing through rehydrated samples such as in Dunphy et al. (2001) would aid in identifying any propagules and species present in substrate.

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Research Article



0.075% Capsaicin cream and wind-up in chronic lumbar radicular neuropathic pain - a phenotype-stratified, case series

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Abstract. Personalized treatment for low back pain disorders is a high research priority and stratified medicine using sensory profiling can potentially improve the outcomes. Wind-up, or temporal summation, is the progressive increase in action potential firing rate of spinal cord neurons to repetitive stimulation of C-fibre afferents at a constant intensity. Wind-up can occur in neuropathic pain, and it is augmented by the presence of central sensitization, which can lead to $A\delta$ -fiber-induced wind-up rather than solely being activated by C-fibre stimuli. Topical capsaicin activates the transient receptor vanilloid-1, which is expressed in C-fibres and some A δ -fibers of the peripheral nervous system, leading to a reduction in skin evoked pain. Despite the supporting evidence for the 8% capsaicin patch, there is evidence that specific patient subgroups treated with 0.04% capsaicin formulation obtained better analgesia compared to the higher dose. However, that research did not evaluate sensory profiles nor predictive biomarkers.

Due to the common neurophysiological pathways implicated in wind-up and capsaicin, our study posited that the adjunctive use of low-dose capsaicin cream (0.075%), coupled with physiotherapy, may offer analgesia in a subset of patients with chronic lumbar radicular neuropathic pain (n = 9, median pain duration of 5 years) who exhibit wind-up phenomena. The combination of topical capsaicin and physiotherapy yielded clinically significant analgesia (Hedges' g = 2.96). Therefore, we propose investigating through a randomised controlled trials the utility of a simple bedside test as a predictive marker for a favourable response to 0.075% capsaicin cream in individuals with chronic lumbar radiculopathies who exhibit wind-up.

Keywords: Radiculopathy; Sciatica; Neuralgia; Cap-

saicin; Phenotype; Precision Medicine; Low Back Pain; Chronic Pain; Case Reports.

1 Introduction

First-line oral pharmacological treatment for neuropathic pain (NP) is hindered by the relatively poor number needed to treat (NNT) (Finnerup et al., 2015), an adverse effect profile coupled with a failure rate of \geq 70% (Moore et al., 2013). Therefore, evidence-based oral pharmacological management of NP is probably not very effective (NICE, 2020). Besides, individualizing treatment for low back pain disorders has been identified as a high research priority by international expert panels (Vollert et al., 2017). The current treatment of NP, including radicular NP, is usually empirical, it is not guided by foreseen efficacy, but instead, it is based on tolerability and personal preference of the prescriber. Persons with NP exhibit different profiles in respect to their comorbidities, pain intensity, dysesthesias, and neurological changes. The sensory profile is the cluster of signs that a particular individual exhibits when undergoing sensory testing. In turn, this profile can be predictive of the outcome of certain treatments and hence can be exploited in stratified medicine by matching treatments to persons who have a higher likelihood of a

NRS — numerical pain rating scale

- PHN postherpetic neuralgia
- PDN painful diabetic neuropathy

NP — neuropathic pain

 $[\]mathsf{NNT}$ — number needed to treat

TRPV-1 — transient receptor potential vallinoid-1

TS — temporal summation

IASP — International Association for the Study of Pain

PGIC — patient global impression of change scale

better outcome (Themistocleous et al., 2018). Such examples include the efficacy of oxycodone being predicted by the magnitude of heat pain threshold (Eisenberg et al., 2010), and high temporal summation (TS), especially in

a pain-free control site, which predicted the immediate analgesic response to acupuncture in chronic pain patients (Baeumler et al., 2019). Due to the shared neurobiology underlying wind-up/TS (Woolf, 2011) and capsaicin (Basith et al., 2016), mediated by transient vanilloid receptor-1 (TRPV-1) within the peripheral nervous system (Kupers et al., 2011), we hypothesized that the application of a low dose capsaicin cream (0.075%), would provide analgesia in a phenotype-stratified cohort of patients, specifically exhibiting skin-evoked wind-up/TS and having a definite NP grade (Finnerup et al., 2016) due to chronic lumbar radicular pain. The null hypothesis was that the capsaicin would not provide an analgesic effect. To the authors' best knowledge, there are yet no reports evaluating the effect of 0.075% capsaicin cream in a phenotypestratified cohort of patients, specifically exhibiting windup.

2 Material and Methods

The participants were recruited from a larger study (Schembri et al., 2020) and were identified during their initial physiotherapy examination for chronic low back pain and lumbar-related leg pain within the Musculoskeletal Physiotherapy Outpatients Department (secondary level of care) at a local rehabilitation hospital in Malta, Europe, between March and November 2019. These patients were approached by an intermediary (doctor at the pain clinic), and written informed consent was obtained from all of them. A convenience sampling strategy was adopted. The sample size of the case series (n = 9) was determined by the number of patients with radicular pain and simultaneously exhibiting wind-up who attended the clinic during the eight-month data collection period, which culminated in the onset of the COVID-19 pandemic. Ethical approval for the study was obtained from the research committee at a local rehabilitation hospital in Malta, Europe (04/03/2019). Figure 1 provides a flow diagram of the participants in this study.

Participants from both sexes were included in this case series if they fulfilled all the following criteria: 1) over 18 years of age; 2) referred to the Musculoskeletal Physiotherapy Outpatient's facilities for chronic low back and/or lumbar-related leg pain; 3) with pain duration of \geq three months; 4) had a definite NP grade according to the International Association for the Study of Pain (IASP) grading system (Finnerup et al., 2016); 5) exhibited windup on bedside sensory examination, based on the protocol by Kupers, Lonsdalel, Aasvangl & Kehletl, (2011)



Figure 1: Flow diagram of the participants in the study. [†]Participants were identified from Schembri, Massalha, Spiteri, Camilleri & Lungaro-Mifsud, (2020).

and Scholz et al. (2009). The exclusion criteria were the presence of any implanted medical device specifically to treat NP, fibromyalgia, complex regional pain syndrome, severe musculoskeletal pain other than chronic low back pain and/or lumbar-related leg pain, significant medical and/or psychiatric comorbidity, cognitive impairment, or intellectual disability, ex-smokers, pregnant, known diabetic/metabolic/drug-induced neuropathy and known hypersensitivity to capsaicin.

2.1 Pain assessment

Demographic data on sex, age, and pain chronicity (years) were recorded. The primary outcome measure was pain intensity, which was assessed using three separate Numeric pain Rating Scales (NRS) for lowest, mean, and highest pain intensity. Each of the three individual NRS had the anchors "no pain" and "pain as bad as you can imagine (0-10)." The worst pain location was classified as either in the lower limb or in the low back. The most distal pain radiation was categorized into five sections: the low back, knee level, upper calf, lower calf and/or ankle and in the foot (Hasvik et al., 2018). The STarT Back (Hill et al., 2008) and the DN4 questionnaires (Bouhassira et al., 2005; Schembri et al., 2019) were also scored.

The procedure to grade the certainty of NP in the participants was adopted from Schembri, Massalha, Spiteri, Camilleri & Lungaro-Mifsud, (2020) and it is briefly reported hereunder. The bedside sensory examination was conducted by the primary author (ES) and it included the response to static pressure, dynamic light tactile touch (SENSELab[™] Brush-05, Somedic SenseLab AB, Sösdala, Sweden), pinprick (5.1g Semmes-Weinstein type monofilament, Baseline[®] Tactile Monofilaments[™], Fabrication Enterprises Inc, White Plains, NY, USA), vibration (Rydel-Syffer 128 Hz graduated [8/8 scale] tuning fork, Baseline[®] Rydel-Syffer, Fabrication Enterprises, White Plains, NY, USA), warm and cold (using two test tubes each one filled with water at 25°C or 40°C), and sensory threshold to punctate tactile stimulation (Semmes-Weinstein type monofilaments, 0.07g - 300.0g, Baseline[®] Tactile Monofilaments[™], Fabrication Enterprises, White Plains, NY, USA). Initially, a demonstration was performed on the patients' arm, followed by testing in the most painful lower quadrant area. The latter was compared to a homologous contralateral reference site. Two repetitions of each test procedure were done.

2.2 Testing for wind-up

The terms wind up or TS will be used interchangeably throughout this report. They refer to a neurophysiological process coined by Mendell and Wall (1965) describing the progressive increase in action potential firing rate of spinal cord neurons to repetitive stimulation (minimum stimulation of 0.3Hz; though more substantial effects occur at 1-2Hz) of C-fibre afferents at a constant intensity (Woolf, 2011).

Wind-up was assessed using a 5.1g Semmes-Weinstein type monofilament (Baseline[®] Tactile Monofilaments[™], Fabrication Enterprises, White Plains, NY, USA), and applied at 2Hz for 30 seconds (Kupers et al., 2011; Scholz et al., 2009). The stimuli were delivered by hand but taking great care to standardize the stimulus delivery mode aided with an Android mobile metronome (Pro Metronome, Soundcorset) to cue the frequency of the stimulation. Windup was tested via an A δ -fibre stimulating modality (using Monofilaments) rather than a C- fibre modality (via heat) for ease at bedside examination (Papagianni et al., 2018; Suzan et al., 2015) and since A δ - neurons exhibit wind-up specifically after peripheral nerve injury (Kupers et al., 2011) such in the case of lumbar radiculopathies. Two possibilities occurred in the presence of wind-up, depending on the severity of the pain elicited during the procedure. If the participant experienced intolerable pain during wind-up testing and asked to stop the test, the intensity and the time (\leq 30 seconds) for the onset of such pain intensity was recorded. In the case of tolerable pain, the NRS score (0-10) was recorded at the end of the 30 seconds.

2.3 Therapeutic intervention

The pain consultant at a local hospital prescribed the 0.075% capsaicin cream, which was bought and selfapplied by the patients four times daily for eight weeks, spread evenly over the painful area that exhibited windup. During this treatment period, the patients were advised not to change their chronic pain medications or use any other topical pain medication on the affected area, including different capsaicin formulations. However, in case of an initial burning sensation, the patients were instructed to pre-emptively use a topical local anaesthetic cream 10 minutes before applying the capsaicin cream until the patient got used to the initial burning sensation.

Apart from 0.075% capsaicin cream, all the patients underwent individualized physiotherapy as usually provided by the department, including pain neuroscience education, sleep hygiene, cognitive restructuring of counterproductive beliefs, pacing, lifestyle modifications, dealing with flare-ups, and an individualised graded exercise program, comprising stretching and strengthening exercises. Previously, most of the participants had received multiple treatments for their pain, including medications, spinal infiltrations and surgery. These treatments were provided at least four months before the participants' acceptance to engage with the current therapeutic regimen. Hence it did not affect the outcome of the current intervention. Due to the large recall bias from the patients, these treatments were not recorded.

2.4 Clinical outcome

Follow-up assessments were conducted at one month, two months, and six months post-treatment. Pain intensity was measured using the 0-10 NRS at each time point. Additionally, global improvement with treatment compared to baseline was assessed using the 7-point scale Patient Global Impression of Change (PGIC) scale. This scale ranges from 'very much improved' to 'very much worse', with 'no change' positioned at the midpoint (Perrot & Lantéri-Minet, 2019).

2.5 Statistical analysis

Two statistical tests were used to make inferences about the patient population using the data set drawn from this population. The Wilcoxon rank test compared the median scores between the median baseline NRS and the median NRS scores at one month, two months, and six months. The estimate of effect using Hedges' g statistic was calculated using the same time points. The same test was used to compare the PGIC score at one month and two months and then from 1 month to 6 months. A 0.05 level of significance was used for both tests, where P values less than this 0.05 criterion indicate a significant difference between the two median scores. Statistical analysis was done using Jamovi version 1.6.23.

3 Results

Table 1 demonstrates the baseline characteristics of the nine participants recruited for this phenotype-stratified case series. Of note there was a high percentage of current smokers (77.8%) and who previously underwent

Age (years) [†]	63 (50 to 68)
Gender (% female)	44.4%
Chronicity (years) [†]	5 (3 to 5)
Current smoker (% yes)	77.8%
Past lumbar surgery (% yes)	44.4%
Least NRS $(0-10)^{\dagger}$	5 (0 to 5)
Median NRS (0-10) [†]	8 (7 to 10)
Highest NRS (0-10) [†]	10 (9 to 10)
Analgesic drug classes consumed [†]	2 (0 to 2)
Worst pain location (% lower limb)	100%
Most distal radiation (% into the foot)	55.6%
STarT Back score (0-9) [†]	7 (5 to 8)
DN4 score $(0-10)^{\dagger}$	4 (3 to 5)
Hypoesthesia within a neuroan-	100%
atomically plausible distribution	
Myotomal weakness*	66.7%
Tendon reflex reduction or loss*	66.7%

Table 1: Baseline characteristics (n = 9).*At least having a deficit in one modality. [†]Median (interquartile range).

lumbar surgery (44.4%).

Compared to the baseline NRS, the intervention led to a statistically significant reduction in the median NRS already from the first month (P = 0.048, Hedges' g = 0.2533), however this became larger by the second month (P = 0.009, Hedges' g = 2.0186) and at the sixth month (P = 0.009, Hedges' g = 2.96) (Table 2). The patients started to show improvement in the PGIC values from the first month of follow-up. Yet, a significant change in the PGIC was experienced at the second month of follow-up (P = 0.01) compared to 1-month follow-up, which further improved at six months follow-up (P = 0.008), indicating that the intervention continues to exert its effect on the PGIC until at least six months in our cohort (Table 2).

At 2 months follow-up, 5 participants continued to experience wind-up in the previously tested skin area, but at 6 months follow-up only 2 participants continued to experience wind-up. However, the latter two participants reported at six months follow-up an improvement in the NRS. Four patients reported very mild, transient (maximum 1 hour) burning, itching sensation after applying the capsaicin cream, which either reduced or they got accustomed to it after the initial applications, and none of the participants required the pre-emptive use of a topical local anaesthetic cream. The other five patients did not report any adverse effects. None of the participants self-reported difficulties with adhering to the treatment regime, and none required the use of rescue medications to manage any adverse effects. Furthermore, all patients reported positively on the intervention, despite the commitment to the frequent application of the cream and the need to actively engage with the physiotherapy regimen.

4 Discussion

This phenotype-stratified case series provides seminal evidence for the predictive effect of wind-up in mediating the analgesic effect of 0.075% capsaicin cream applied four times daily for eight weeks, in combination with physiotherapy, to treat skin-evoked wind-up pain in subjects diagnosed with definite NP due to chronic lumbar radicular pain. The type, intensity and frequency of physiotherapy interventions were not controlled within this study to reflect real-life clinical practice. Already in the initial one-month follow-up, the reduction in NRS reached statistical significance (P = 0.048). However, at the second and sixth month follow-up, there was a more significant change in median NRS (g = 2.96, P = 0.009). Such results were mirrored in the PGIC scores too.

4.1 Temporal summation and capsaicin

Initially, TS was thought to reflect an alteration in neuronal excitation of the dorsal horn. However, this is also regulated by supraspinal mechanisms (Cheng et al., 2015) and it frequently occurs in healthy individuals (Wong et al., 2023), but the presence of central sensitization enhances this process, and it can predict pain outcomes (Arendt-Nielsen et al., 2010). TS is thought to arise mainly due to increased C-fiber induced second pain, which under normal conditions, can only be elicited by stimulation at C-fibre strength (Woolf, 2011). Yet, a peripheral nerve injury can lead to an $A\delta$ -fiber induced wind-up (Kupers et al., 2011).

The primary target of capsaicin is the TRPV-1 receptor, which is predominantly expressed in C-fibres and some A δ -fibers of the peripheral nervous system. Capsaicin application leads to an overstimulation of the cutaneous nociceptors and TRPV-1 channels, causing the defunctionalization of the terminal nociceptive nerve fibres, ultimately reducing spontaneous nerve activity, reducing skin-evoked nociception, in turn, leading to a reduction in peripheral NP since the area becomes "desensitized" (Baeumler et al., 2019). However, usually, the epidermis becomes re-innervated within six weeks after discontinuation of the 0.075% capsaicin cream (Nolano et al., 1999). Considering that both wind-up and capsaicin share underlying neurophysiological processes, primarily through activation of C-fibres and A δ -fibres, it was theoretically, expected to obtain positive results in a phenotypestratified group. The identification of the presence of wind-up as a possible biomarker facilitates the identifica-

Outcome measure	Baseline	1 month	2 months	6 months	P-value*	P-value [‡]
NRS Scale [†] (0 to 10)	8 (7 to 10)	8 (6 to 9)	3 (2 to 4)	2 (1 to 7)	0.008	0.008
PGIC Scale [†] (-3 to +3)	/	1 (0 to 1)	2 (1 to 2)	3 (2 to 3)	0.010	0.008

Table 2: Numeric pain Rating Scale (NRS) and the Patient Global Impression of Change (PGIC) scale at the follow-up points (n = 9). *Wilcoxon rank test, change from one month to two month follow-up. [‡]Wilcoxon rank test, change from one month to six month follow-up. / means that it could not be measured at baseline. [†]Median (interquartile range).

tion of responder subgroups.

4.2 Current indications for the low-dose capsaicin cream

In the UK, the 0.075% capsaicin cream is indicated for the treatment of postherpetic neuralgia (PHN) and painful diabetic neuropathy (PDN) in adults and the elderly, with a recommended daily application of 3-4 times for eight weeks (Teva UK Ltd., 2024). Furthermore, NICE, (2020) considers using the 0.075% capsaicin cream in non-specialist settings for patients with localized NP who cannot tolerate or wish to avoid oral pharmacological treatments.

4.3 Responder subgroups for the low dose capsaicin cream

Despite studies (Derry et al., 2017) showing the inferiority of the lower dose capsaicin formulation compared to the higher dose patch for peripheral NP, a previous Cochrane review (Derry et al., 2012) and a subsequent study (Martini et al., 2013), both concluded that the lower dose capsaicin formulations [0.075% (Derry et al., 2012), 0.04% (Martini et al., 2013)], may still provide some analgesia. The Cochrane review (Derry et al., 2012) included six double-blind RCTs comparing topical capsaicin cream (0.075%) (n = 198) to placebo (n = 191) for NP, with the cream being applied four times daily for 6, 8 or 12 weeks, depending on the individual study design, and it found that 41% of the subjects treated with the 0.075% capsaicin cream had a positive outcome compared to 26% who received a placebo. This review concluded that the 0.075% topical capsaicin cream had an NNT of 6.6 (4.1 to 17) over 6 to 8 weeks, which is comparable to the NNT of oral pregabalin (NNT = 7.7) (Finnerup et al., 2015), which is considered as first line of treatment for NP. However, an update of this Cochrane review (Derry et al., 2017) revealed that there was insufficient data to draw any conclusions about the efficacy of low-concentration capsaicin cream (< 1%) in the treatment of NP. Hence it concluded that its effect is comparable to placebo and that it is unlikely that low-concentration topical capsaicin has any meaningful use in clinical practice. However, both Cochrane reviews (Derry et al., 2012, 2017) did not evaluate specific responder subgroups. Furthermore, both reviews evaluated the effect of the low dose capsaicin in patients based on the aetiology of their NP condition rather than on particular patient characteristics and sensory profiles at baseline, which can provide a higher chance of identifying responder subgroups (Themistocleous et al., 2018).

Martini et al. (2013) pooled data from four doubleblind, randomized controlled trials (RCTs) comparing the efficacy of capsaicin 8% patch (n = 722) to an active control (0.04% capsaicin cream) (n = 526) in patients with PHN and highlights the importance of identifying patient responder subgroups. This study found that both formulations had similar response profiles, yet the proportional distribution of patients favoured the high-dose preparation. Nonetheless, the group randomized to 0.04% capsaicin patch obtained an overall 23.9% reduction in the NRS score. Martini et al. (2013) found that out of the available five patient subgroups, one of these subgroups (subgroup 5) experienced a 69.6% reduction in pain intensity score at 12 weeks with the low dose capsaicin, while an analogous subgroup using the high dose capsaicin experienced a decrease in pain scores by 67.4% at 12 weeks. The current case series results are reminiscent of subgroup five by Martini et al. (2013) since our phenotype-stratified group continued to experience a decline in mean NRS values with an increase in the follow-up period. However, our participants did not obtain the same level of analgesia (57% reduction in NRS).

However, there are considerable methodological differences between Martini et al. (2013) and the current report. First, the aetiology of the NP is different since Martini et al. (2013) evaluated subjects with PHN while the present study looked at NP originating from chronic lumbar radicular pain. Secondly, the studies evaluated by Martini et al. (2013) used a 0.04% capsaicin patch applied as a single dose for either 30 or 60 or 90 minutes by a clinician. In the current study, a 0.075% cream was used to deliver capsaicin, and it was applied four times daily for eight weeks by the patient him/herself. Thirdly, Martini et al. (2013) did not provide any information on the sensory profiles of the patients, not even at the level of responder subgroups. Most importantly, Martini et al.



Figure 2: The change in numeric pain rating scale (NRS) values (0-10) over the six months follow-up period.

(2013) obtained data from large RCTs, while we adopted an observational approach.

4.4 Strengths and limitations

In this case series, the application of capsaicin was through a self-applied cream, which avoided the need for further hospital visits, being highly practical since it was applied by the patients themselves in the comfort of their own homes. However, such a length of treatment (8 weeks) necessitated a substantial level of compliance and adherence from the patients, which cannot be ascertained. The fact that the patients within this report were compliant and motivated enough to comply/adhere to the whole length of the treatment could potentially be a source of bias.

Previous studies looked at the prognostic potential of quantitative sensory testing (QST) (Georgopoulos et al., 2019), but this is an expensive piece of equipment, the procedure is time-consuming and necessitates specific clinician training. However, the simple procedure adopted for testing for TS in this report could be completed in the clinic in less than 30 seconds, necessitating only everyday clinical equipment, which is relatively cheap, and no lengthy training is necessary for the clinician doing this testing procedure.

The methodology adopted, i.e., case series, poses severe limitations on the strength of the evidence of the current study. Furthermore, having a single clinician performing the assessment and treatment improves the standardization of the testing procedures but greatly increases the chance of introducing bias. Besides, the combination of capsaicin cream and physiotherapy precludes any conclusion on the isolated positive effect of either intervention in this population of chronic low back pain sufferers. Still, it can portray a synergistic effect targeting various modifiable aspects within the biopsychosocial model of pain.

5 Conclusions

Given the study participants, despite previous treatments, had pain chronicity of approximately five years, where spontaneous recovery (da C Menezes Costa et al., 2012) and regression to the mean are limited, the combination of physiotherapy and the 0.075% capsaicin cream provided analgesia in persons with previously refractory chronic lumbar radicular NP. Given such treatment effect (Hedges' g = 2.96 at six months follow-up), it is unlikely that this outcome is attributed solely to the placebo effect despite the biases imposed by the methodology of this case series. Hence, this treatment approach warrants further evaluation in a phenotype-stratified, placebo-controlled RCT.

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Conflict of Interest None declared.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional research committee and with the 1975 Helsinki declaration and its later amendments or comparable ethical standards.

Informed consent Written informed consent was obtained from all individual participants prior to enrolment in the study.

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Research Article



Challenges and opportunities of young farmers in Malta

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Abstract. Agriculture in Malta has seen substantial development over time and serves a number of functions. Malta has fewer young farmers and a smaller labor force than the rest of Europe. This study intends to analyse current trends and features of young farmers in Malta in order to understand their condition and discover strategies to help and promote new recruits into the business. The data came from 202 respondents who made up a representative sample. According to statistical research, there are significant correlations between factors like gender, age, working hours per week, primary sectors, European Union (EU) financing, and organisational membership and job status, or whether young farmers are registered on a full- or part-time basis, or are unregistered. Additional information exposes the educational and training background, trading customs, and other aspects of young farmers. This study provides information on the challenges and opportunities that are experienced by the young farmers, independent of the opinion and thoughts of the older generations.

Keywords: Agriculture; Agricultural entrepreneurship; Farm management; Rural development

1 Introduction

The multifunctional role of local agriculture has been given more importance over the years. Providing information about farmers is crucial not only because they are the workforce driving the sector, but they are also considered as environmental stewards and a source of wealth of information about food production, traditions, and culture (Atriga Consulting Services Ltd. [ACS], 2018). Agriculture in Malta is characterised predominantly by small-scale holdings. The majority of holdings (96.5%), occupy less than five hectares of land (European Commission [EC], 2020), with a total cultivating area of 10,731 hectares as at 2020 (National Statistics Office [NSO], 2023). Furthermore, the number of farms in Malta appears to be decreasing with only 7% of the total number of farms being managed by young farmers (EMCS Ltd, 2021).

The total number of registered persons actively engaged in agriculture amounted to 13,341 in 2020 (NSO, 2023). Young farmers form part of this workforce and are the farming generation of the future (CEJA, 2023). The retreat of the younger generation mentioned by Beeley (1960) is not a new phenomenon in Malta. Cirillo (1955) investigated the attitudes of farmers back in the fifties and stressed the crucial position of young farmers in agriculture in Malta. The aging farming population in Malta is considered to be a pressing issue by various local authorities (ACS, 2018). In 2016, 31.8% of farm holders were older than the age of 64. Only 3.8% of farm holders were under the age of 35 years (EC, 2021). This study primarily aims at investigating the trends and characteristics of young farmers in Malta. For this study, the definition of a young farmer is that of a person working in the industry and is of less than 40 years of age, as described in Regulation (EU) 1305/2013.

In 2020, there were 1239 farm managers who were 40 years old or younger, while in 2010, there were a total of 1260 farm managers who are 40 years old or younger. These figures are related to the number of persons that have registered agricultural land on the Land Parcel Identification System (LPIS) and/or livestock listed in the national veterinary register, as well as farmers who sold their produce at the Pitkali market in 2019. An email (Tanti, 2020) confirms that the various local registers available have been assimilated together to draw the list farmers utilised for the agricultural census conducted in 2020. In 2016, Malta marked a declining share of young farmers (3.8%) of total farm managers, when compared to the 5.1% average at EU level.

The information available at hand instigated the need

for a study that reveals the status of the local young farming community. Consequently, the main aim of this study was to obtain first-hand information from young farmers, whose situation was analysed in terms of challenges and opportunities.

2 Method

2.1 General Methodology

Deductive analysis is the foundation of the methodology, which examines a sizable sample of respondents. The participants in this study were chosen with the aim to provide information regarding the sort of operations, social life, and opinions of young farmers in Malta. The questionnaire is mostly used to obtain quantitative data. The data input phase converted every piece of acquired data into a digital format, so as to carry out comprehensive statistical analysis.

To achieve both breadth and depth of understanding as well as corroboration, R. B. Johnson et al. (2007) define mixed methods research as the type of research in which a researcher or team of researchers combines participant viewpoints, data collection, and analysis, and makes use of inference techniques.

Responses were acquired during the last stages of data collection using a questionnaire (Table 1) that contained both closed- and open-ended questions (Martin & Hanington, 2012). This was thought to be crucial for obtaining reliable and pertinent data. An extensive set of questions allowed for a thorough analysis of the subject, which would better characterise the particular circumstance of young farmers. Results were compiled and processed after both paper-based and electronically filled questionnaire modalities were made available.

All respondents were guaranteed complete knowledge and had freedom to express themselves because the questions were presented in English and/or Maltese. The primary way of gathering data was through informal oneon-one encounters. Such encounters allowed for unrestricted contact with the young responders while the questionnaire was being finished, as well as gaining insight into the current situation, even though they took more time.

Participants either completed the responses on their own or with the help of the researcher. At the conclusion of the data collecting session, the researcher who had been tasked with composing the responses verbally relayed these to the respondent for verification and validation. Every participant in this study gave their consent to participate. The consent form outlined the engagement of the participant and the conditions of the study. This served as a verbal and written explanation of the scope of this research. This form was then given out and signed by each respondent as confirmation that they had read and understood the terms. All individuals who agreed to complete the questionnaire had the option to stop participating in the study at any time without suffering any repercussions. Additionally, it was stated at the outset that if they were uncomfortable, they could choose not to respond to any of the questions. By using a questionnaire template without any personal information, privacy was protected. To enable responders' traceability, these were listed separately in a Personal Information Sheet.

According to Ary et al. (2006), sample is defined as "a portion of a population". In this study, a sample of young farmers was required to representatively investigate current trends and characteristics of this important segment within the local farming population. The following equation was used to determine the sample size (Mweshi & Sakyi, 2020)

Sample size
$$= \frac{\frac{z^2 \times p(1-p)}{e^2}}{1 + \left(\frac{z^2 \times p(1-p)}{e^2N}\right)}$$
(1)

where N denotes population size, e denotes the margin of error in percentage in decimal form and z denotes the z-score.

Information obtained from the National Statistics Office (Tanti, 2020) revealed that the population size of young farmers having a managerial role who were 40 years old or younger stood at 1239 at the time of research. Considering a margin of error of 6% and a confidence level of 95%, a sample size of 200 young farmers was therefore required. The criteria making young farmers eligible to participate in this study are discussed in the section below.

To select participants a set of criteria was drawn. This provided a greater definition of who might be eligible to participate in this research. All participants needed to meet all the criteria (a - d) as outlined below:

- (A) Be of Maltese nationality.
- (B) Be between eighteen (18) and forty (40) years old.
- (C) Practice agriculture in Malta and/or Gozo.
- (D) Be involved in one or more of the activities listed below:
 - I production of crops and/or livestock as full/part time farmer,
 - II and/or as a subsistence farmer,
 - III and/or provides services related to agriculture,
 - IV and/or assist family members and/or friends in work related to agriculture.

Due to data protection regulations, it was not possible to obtain contact details of young farmers in Malta from entities such as the Department of Agriculture, the Paying Agency or the National Statistics Office (NSO). An

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#	Question	Replies
1	Are you a registered farmer with Jobsplus?	Yes/No
2	Are you registered with Jobsplus as a full time or part time farmer?	Full time/Part time
3	On average, how many hours do you spend working (in agriculture)	Number of hours
	per week?	
4	In which sector/s are you involved?	Various sectors
5	What level of education have you achieved so far?	Levels of education
6	Did you participate in any training (related to agriculture), over	Yes/No
	the past 5 years?	
7	From a scale of 1 to 5, do you think training can help you im-	5 being most positive,
	prove your operations as a young farmer?	1 being most negative
8	Does being a farmer allow you to have a good quality of life com-	Yes/No
	parable to young people working in other sectors?	
9	Briefly justify your answer for Q8.	
10	Do you use one or more social media platforms?	Yes/No
11	Do you use social media to market your goods/services?	Yes/No
12	How do you sell and market your own products/services?	Direct/Middlemen/Both
13	What percentage of goods/services do you sell	Percentage
	directly to the end consumer?	
14	Are you part of any producer group, co-operative, or organisation?	Yes/No
15	If the answer to Q14 was YES, kindly name the organisation/s.	
16	Have you benefited from any EU agricultural funds?	Yes/No
17	Have you applied for the EU-funded Young Farmer	Yes/No
	Measure (Measure 6.1)?	
18	From a scale of 5 to -5, can you rate your opinion about EU agri-	+5 as the most positive,
	cultural funds?	-5 as the most negative,
		0 is neutral in opinion.
19	In your opinion, what are the current opportunities for farming	
	in Malta?	
20	In your opinion, what major challenges do you face?	

Table 1: Questions used for data collection.

intricate search for young farmers was carried out using information available on the public domain, the social media, and personal contacts. The only public listing of young farmers was available on the EU funds government website having individuals who successfully qualified for sub-measure 6.1 funding under the Rural Development Plan for Malta 2014-2020 (Ministry for European Affairs and Equality [MEAE], 2023).

Through this list, which did not include contact details, individuals were searched for on social media platforms and through personal contacts. While a number of attempts were carried out to make contact, nevertheless, it was not always possible to obtain contact details or to get to know the beneficiaries.

The best method of finding and locating young farmers was through networking. The young farmers contacted during the initial stages of data collection indicated other young farmers who were either family members, friends, or collaborators. This snowball effect (T. P. Johnson, 2014) turned out to be beneficial since a preliminary list of over 300 young farmers was eventually drawn. Having such list allowed for a secondary selection to be drawn as well as a sufficiently enlarged pool of potential participants to meet the study's design requirements.

Furthermore secondary selection permitted balanced data collection from various categories of young farmers while avoiding data bias since one particular segment of young farmers could be featured more than others, or been missed. Achieving a fair balance in the range of responses, when possible, entailed the inclusion of participants depending on their gender, age, on whether they are registered as full-time, part-time farmers or non-registered, on the type of production in which they are involved and on whether they accessed EU funds at any time prior to this study.

Achieving overall balance amongst possible respondents was aimed for before contacting the young farmers. Obtaining data according to the criteria mentioned above, allowed for better targeting in terms of data collection. Including young farmers working under different conditions and circumstances is important for the purpose of this research to be able to generate a clear visual of how these young farmers are living and operating.

The convergent design (Creswell & Clark, 2017) used in this study entailed the collection and analysis of qualitative and quantitative data simultaneously obtained from one questionnaire, yielding a single set of results. Previously referred to as concurrent or parallel design, the convergent design, enables the comparison and combination of results obtained from the investigation.

Inductive content analysis was carried out through systematic reading of a sample set of questionnaires, gradually establishing categories and numerical codes to be used for subsequent analysis of all materials (Martin & Hanington, 2012). All possible qualitative responses were identified and grouped under common themes, with a unique number allocated to each sub-theme. Such string-tonumerical conversions were crucial to be able to calculate the data scientifically.

2.2 Data analysis

Once all the data was inputted into the database, it was transferred into the IBM SPSS Statistics 27 software to allow a detailed analysis within specific parameters. This software platform, which offers advanced statistical analysis tools, allowed for different variables to be compared and combined in order to project the various trends and characteristics of the young farmers from whom data was collected.

The Chi Square test was used to determine possible associations between two categorical variables. According to Singhal and Kumar (2015) categorical data may be analysed through the Chi-square test which is a nonparametric test used to test the hypothesis of no association between two or more groups, population or criteria, and to test how likely the observed distribution of data corresponds with the expected distribution (ibid.).

3 Results and Discussion

3.1 Data collection methods

In this current study, the emerging traits of participants offer a glimpse of the key qualities that distinguish young farmers in Malta and Gozo. Due to the meticulous selection process previously outlined, these aspects are thought to be representative. The characteristics of such young farmers were assessed via a questionnaire that provided information on their lifestyle and their opinion on the opportunities and challenges they currently face.

During the data collection process, it was ensured that respondents felt comfortable in expressing themselves in colloquial language. Very often, a healthy discussion yielded more challenges and opportunities to be voiced and recorded on the questionnaire template. Although time consuming, the lengthy one-to-one meetings to obtain responses resulted in a large quantity of relevant information. There were very few instances when respondents did not provide any feedback. Most respondents provided multiple responses and tackled aspects which could be further analysed into categories.

Out of 202 questionnaires, 82.2% were collected during one-to-one meetings. The other 15.3% and 2.5% were collected via the ordinary postal system and via electronic mail, respectively. During this study it was found that the setting up of physical meetings, preferably on the farm,



Figure 1: The distribution of the 202 male and female respondents by age group.

gave young farmers flexibility and encouraged better expression of feelings and thoughts, rather than the other collection methods. However, a professional work ethic was maintained throughout data collection while keeping conversations in a colloquial form.

3.2 Characteristics of respondents

The population and structure of the farming population has been debated as one of the most worrying salient points for future reference. National statistics show that the farming population in Malta is ageing, and fewer young farmers are joining the workforce (ACS, 2018; EMCS Ltd, 2021; EC, 2020).

Considering the criteria mentioned in the previous section, gender and age provided the basis of the type of young farmers who participated in this study. Out of the 202 respondents, 171 were males and only 31 were females. This has been achieved notwithstanding the efforts made to recruit more female young farmers. Additionally, the majority within the female category (58.1%) are nonregistered which may well equate to non-remuneration. Figure 1 represents the distribution of male and female respondents by age group. This relates to recent results emerging in the thematic evaluation report about sub-measure 6.1 implemented in Malta, which states that around 82% of the beneficiaries are male while 18% are female (EMCS Ltd, 2021). Statistics available also indicate that 92% of farm holders are male while 7.9% are female (EC, 2021). The share of female young farmers is among the lowest in the EU (EC, 2020). Females in Malta are still generally associated with household duties and the rearing of children even though they might have a full-time or part-time job (Aquilina, 2015; European Institute of Gender Equality [EIGE], 2023).

The population and structure of the farming population has been debated as one of the most worrying salient points for future reference. National statistics show that the farming population in Malta is ageing, and fewer young

Region	Frequency	Percentage
Malta North	127	62.9 %
Malta South	51	25.2 %
Gozo	24	11.9 %

Table 2: The distribution of 202 respondents (18-40 years old) by region in Malta and Gozo as a sample of the 1239 young farmers in 2020.

farmers are joining the workforce (ACS, 2018; EMCS Ltd, 2021; EC, 2020). Regardless of gender, various instances were encountered throughout this research and previously through work experience when established farmers might not consider their children as workers, but simply pro bona helpers. This may be associated with the reluctance of older farmers to retire, which has been identified as one of the obstacles by 42% of beneficiaries of sub-measure 6.1 (EMCS Ltd, 2021). Four different age groups were categorised considering the age range between 18 and 40 years. During data collection, it was deemed necessary to include young farmers having different ages to obtain a balanced sample regarding their age group. In fact, a minimum of 37 responses from the 18-25 years age group and a maximum of 57 young farmers falling in the age group of 36 to 40 years were obtained. The largest number of males (48) were found in the 36-40 age group, whereas the largest number of females (13) belongs to the 26-30 age group. It is a known fact within local rural communities that parents encourage their children to further their studies to access a job within another sector and with less hardship (ACS, 2018). Nonetheless, this research provided opportunity to encounter young farmers who chose to work in agriculture despite their parents discouraging them, because they consider such work as a way of life.

Table 2 indicates that most of the respondents live in the north-western part of Malta (62%), followed by 25% located in the south-eastern part of Malta and 11.9% in Gozo. This concurs with the geographical distribution of farmland and fields which are mainly prominent in the north-western region of the island of Malta. This grouping was adopted following the composition of Local Action Groups formed according to the LEADER approach of the Rural Development Policy (MEAE, 2023)

Another important characteristic of these young farmers is their job status. This study reveals that most participants are registered full-timers (42.1%), 25.7% are part-timers, and 32.2% are non-registered. Through this study, it was revealed that job status is, to some extent, an age-related factor. The largest share of non-registered young farmers (48.6%) is within the 18-25 age bracket.

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In which main sector are you involved?				
Main sector	Frequency	Percentage		
Fruits and vegetables	65	32.2 %		
Dairy/Beef cattle	47	23.3 %		
Sheep and goats	13	6.4 %		
Gardening/Landscaping	10	5.0 %		
Swine	9	4.5 %		
Beekeeping	8	4.0 %		
Olive cultivation	7	3.5 %		
Subsistence Farming	7	3.5 %		
Broilers	5	2.5 %		
Floriculture	4	2.0 %		
Rubble wall restoration	4	2.0 %		
Rabbitry	3	1.5 %		
Ploughing/Harvesting	3	1.5 %		
Egg layers	3	1.5 %		
Arboriculture	3	1.5 %		
Viticulture	2	1.0 %		
Organic Farming	2	1.0 %		
Hydroponics	2	1.0 %		
Ornamentals	2	1.0 %		
Micro greens	1	0.5 %		
Nursery management	1	0.5 %		
Processing	1	0.5 %		

Table 3: The distribution of 202 respondents (18-40 years old) by region in Malta and Gozo as a sample of the 1239 young farmers in 2020.

In other age-brackets analysed, especially that of the 26-30 age bracket, non-registered work is considerably high when compared to registered employment. In such situations, these participants are involved in another gainful employment and help around with their parent's farm business 'after office hours'. The term 'part-timer' is not equate to the number of working hours. A good number (30.8%) of part-timers participating in this research work between 21 and 40 hours per week, and another 30.8% of part-timers work 41 to 80 hours a week, thus working more than the regular 40-hour week associated with a full-time job. Therefore, a part-timer could be more committed than one would think, by spending a substantial number of hours working on a farm.

Generally, young farmers are involved in one or more sectors. However, these are mainly engaged in one of the following sectors: fruit and vegetable sector (53.5%), followed by the dairy and beef sector (28.2%) and subsistence farming (21.3%), amongst others. Since multiple responses were collected regarding sectors in which the respondents are involved, further analysis was carried out to identify which are the primary and most important sectors in which the young farmers operate. Table 3 illustrates the main sectors in which the 202 respondents

	Count	Percentage
Improved marketing	33	17.4 %
Increase the demand for	32	16.8 %
local products		
EU funding	32	16.8 %
Increased awareness about	31	16.3 %
local food systems		
Direct sales	28	14.7 %
Demand for local and fresh	26	13.7 %
produce increased		
Diversification	26	13.7 %
Doing a job/hobby you love/like	25	13.2 %
Developments of niche products	24	12.6 %
Training opportunities	24	12.6 %

Table 4: The ten most common opportunities within the agri-cultural sector identified by young farmers replying to the questionnaire.

were involved at the time. In spite of this fine-tuning, the fruits and vegetable sector remains the most prominent (65 young farmers), followed by the dairy and beef cattle sector (47 young farmers). Overall, young farmers mentioned twenty-two different sectors. This goes in accordance with the National Agricultural Policy 2018-2028, which states that the production of fruits and vegetables and dairy milk are the two major sectors. There is a significant correlation between the main sector and the employment status of these young farmers. 44.6% of young farmers in the fruit and vegetable sector and 72.30% of young farmers in the dairy sector, are full-timers. Today young farmers are also diversifying in their services, such as landscaping and rubble wall restoration. The increase in urbanisation has also created a need for more landscaping services in dwellings located in urban areas (ACS, 2018). Additionally, the increase in demand for skilled persons who can restore and build traditional rubble walls is due to EU funding available for non-productive investments (EU Funding, 2018), but also due to the increase in road works and new dwellings being constructed all over the islands (Zerafa, 2020).

The respondents were further categorised by farm type. The largest number of respondents (50.5%) carry out activities related to horticulture, while 40.1% carry out work on livestock farms. A fraction of young farmers (9.4%) work on mixed farms, meaning that they grow crops as well as rear livestock.

3.3 Opportunities

Respondents were asked to identify opportunities in an open-ended question. The variety of opportunity have been recorded and analysed. The respondents (n = 202) mentioned a total of 774 opportunities. The ten most

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Figure 2: The themes and their respective responses for the opportunities expressed by the young farmers.

common opportunities identified by the young farmers, are listed in Table 4, having 'improved marketing' as the most frequently mentioned (17.4%), together with the 'increased demand for local products' (16.8%) and 'EU funding' (16.8%).

Subsequently, all the opportunities mentioned have been further categorised into themes (n = 18). Figure 2 shows the themes and their respective responses. Opportunities which fall into the theme of positive lifestyle associated with farming (14.86%) has been deemed the most important for young farmers, followed by diversification (13.95%) and marketing (13.05%). Recent opinion pieces about local agriculture often depict the sector as a dying one with little hope and possibilities to revive the workforce (Carabott, 2017; Depares, 2019). Young farmers responded wholeheartedly about what opportunities exist giving a clear message about what needs to be done for their work and local agriculture to improve. Most of the issues mentioned are listed in the National Agricultural Policy 2018 – 2028 (ACS, 2018). Improved marketing, for instance, remains one of the most crucial needs when selling agricultural produce (EC, 2020). This need has for long been highlighted (Stockdale, 1934), however necessary action throughout the years seems to be lacking. Most locally produced horticultural and meat products lack sufficient grading, packaging, and branding. This made it increasingly difficult for consumers to identify and choose local products, making way to possible food fraud from happening at the point of sale. Cachia (2015) examines the rationale behind food fraud as a criminal offense suggesting that specific food fraud legislation is necessary.

Funds for processing and marketing have been made

available since Malta's accession to the EU (Rural Development Department, 2004), but small producers have found it difficult to implement proper marketing actions due to limited packaging and labelling. Economies of scale (Duffy, 2009) may discourage the use of machinery, but being part of a co-operative or producer organisation can help overcome this barrier (EC, 2020). Costs related to compliance of standardised systems and quality labels can be spread amongst producers by reducing individual initial investments (Meybeck & Redfern, 2014).

Marketing aspects need to be improved at farm and national level (ACS, 2018). This proved to be effective in other countries (Gregoric et al., 2018; Pujara, 2016). Young farmers are using branding and online methods, particularly social media platforms, to market their produce directly to consumers and retail outlets. This was one of the lessons learned through the COVID-19 pandemic situation. Direct sales (14.7%) are identified as an opportunity, and respondents were satisfied with the response obtained through social media.

Two young farmers switched from part-time to fulltime farming due to the potential profits gained. Another young farmer started producing niche products from a small patch of land owned by a family member. Marketing can greatly improve the sales of produce and is a real opportunity to tap into when products are produced according to market demands. In parallel to the marketing aspect, a good number of young farmers feel that the need to increase the demand for local products is on the rise (16.8% of cases). The drive from consumers to purchase local products is probably due to several reasons, such as value, freshness, and taste.

Over recent years, there have been several marketing



Figure 3: The themes and their respective responses for the challenges expressed by the young farmers.

campaigns, including those driven by individual farmers, authorities, and NGOs (Parliamentary secretariat for the EU Presidency and EU funds, 2015). Young farmers feel that knowledge about how they produce food needs to be conveyed on to consumers, and this can be achieved through marketing. The EU funded "Investments in agricultural holdings" measure (Managing Authority, Parliamentary Secretary for European Funds and Social Dialogue, 2018), has always been popular amongst farmers, ranking 'funding' at 16.8% in the opportunities list identified by respondents. Other opportunities identified in relation to production were diversification and development of value-added niche products (Malta Profile, 2017). Diversification can happen both in terms of goods and services provided, and success stories of local farmers who diversified their offerings need to be promoted to set a positive example to others.

Research can only be achieved through research to develop new products (da Silva et al., 2009). This research could be supported by academic and vocational educational institutions who can provide the theoretical background necessary to create new products (European Centre for the Development of Vocational Training [CEDEFOP], 2020). Young farmers identified training as an opportunity (12.6%), likely because they value the positive outcomes that may emerge from further education. Projects supporting training and research involving young farmers could create further opportunities giving more scope for the future generation of farmers in Malta. Despite claims about farming as a dwindling profession, young farmers are showing interest in improving the current situation.

As stated earlier, Improved marketing has been deemed

to be the most important opportunity (17.4%). For this reason, it is being acknowledged that sales and marketing are important aspects for young farmers, which have been studied further as per Table 5.

Sales and marketing methods have been studied in terms of how produce is marketed and sold, be it directly, through the middlemen or both. Six respondents claimed that they did not sell any of their produce thus meaning they can be classified as subsistence farmers. The Chi Square test was used to investigate the association between two categorical variables. The null hypothesis specifies that there is no association between the two categorical variables and is accepted if the p-value exceeds the 0.05 level of significance. The alternative hypothesis specifies that there is a significant relationship between the two variables and is accepted if the p value is less than the 0.05 criterion.

Results in Table 5 show that 43.1% of the respondents do not market and sell their own produce thus depending entirely on the middlemen, while 25.2% market and sell between 76 and 100% of their produce. The percentage of direct sales by those who sell directly to consumers is significant. Since the *p*-value (p < 0.001) is much lower than our chosen significance level (0.05), we conclude that there is a strong association between the percentage of direct sales and the way young farmers market their goods and services ($\chi^2(12) = 280.82, p < 0.001$).

3.4 Challenges

Challenges identified by respondents have addressed an open-ended question in the questionnaire. A total of 1028 responses have been collected from 202 young farmers. All the different challenges highlighted have been listed

How do you sell and market your own products/services?							
			Direct Sales	Middlemen	Both	No Sales	Totals
What percentage	0 %	Count	0	81	0	6	87
of goods/services		Percentage	0.0 %	98.8 %	0.0 %	100.0 %	43.1 %
do you sell	1-25 %	Count	2	1	31	0	34
directly to the		Percentage	5.6 %	1.2 %	39.7 %	0.0 %	16.8 %
end customer?	26-50 %	Count	1	0	19	0	20
		Percentage	2.8 %	0.0 %	24.4 %	0.0 %	9.9 %
	51-75 %	Count	0	0	10	0	10
		Percentage	0.0 %	0.0 %	12.8 %	0.0 %	5.0 %
	76-100 %	Count	33	0	18	0	51
		Percentage	91.7 %	0.0 %	23.1 %	0.0 %	25.2 %
Total		Count	36	82	78	6	202
		Percentage	100.0 %	100.0 %	100.0 %	100.0 %	100.0 %

Table 5: Different sales channels in relation to direct sales (as a percentage) to the end user. $\chi^2(12) = 280.82$, p < 0.001

and analysed. A list of the ten most mentioned challenges have been included in Table 6. Among these ten most popular challenges are the harsh competition that exists (7.30%), the costs of production (5.40%), and climatic factors (5.20%) Subsequently, the different challenges were organised into catagorised themes (n = 20). Resources (14.69%), market issues (10.80%) and authorities (10.70%) are the three most common themes.

The insular nature of the Maltese Islands poses significant challenges to all farmers, as competition from producers outside Malta is a real threat (ACS, 2018; MEAE, 2023). Since Malta became a member of the EU, trade barriers have been removed, making it advantageous to local sellers. Additionally, bilateral agreements with the EU enabled third countries¹ to trade with Member States (Hervé, 2020). Local consumers are still price conscious due to the low minimum wage. Policy makers argue that Maltese farmers need to focus on adding value and focusing on niche products rather than competing on price (ACS, 2018; EC, 2020). The purchasing of agricultural products from outside Malta is a reality that cannot be changed due to the free trade policy of the EU (EC, 2024).

Transport costs associated with agricultural inputs and lack of bargaining power from individual farmers result in a significant increase in prices. Although 45.3% of the utilised agricultural land in Malta is dedicated to fodder crop cultivation, Malta is still dependent on high quantities of imported feeds. The European Commission (2020) has suggested exploring the cultivation of protein and fodder crops. The National Agricultural Policy 2018-2028 suggests further experimentation of crops such as alfalfa, vetches, maize, corn, and sorghum. Young farmers are caught in a situation where it is easier to bring over produce to Malta and difficult to sell produce abroad due to the large quantities available and competitive prices.

Additionally, this is due to the conservative mentality of older farmers (ACS, 2018). The lack of resources as a challenge is the most common theme identified in published reports describing the current situation of agriculture in Malta. The lack of basic resources such as land or buildings, in the case of livestock farms, is a major challenge for young farmers (ACS, 2018; EC, 2020). These challenges include high costs and lack of availability of agricultural inputs, as well as lack of trained personnel and professional services. The strong opinion of young farmers regarding the lack of resources concurs with statements in academic literature and official reports about the role of agriculture in the Maltese Islands (Attard, 2009).

In the livestock sector, the lack of veterinarians working with farm animals is a concern expressed by many farmers. This issue has been flagged in a DG SANTE report (EC, 2020) and Debono (2009) in a newspaper article. Young livestock farmers have alleged that they have to deal with complicated births and illnesses on their own due to lack of veterinary support, resources, and professional personnel. Local farms are managed by families with limited financial resources (ACS, 2018), and farmers have resorted to hiring migrants to help in day-to-day duties on farms (Debono, 2009). However, migrants may leave Malta to join their families or seek better employment in other European countries.

Climatic factors are the third most common challenge identified by young farmers in Malta (Galdies, 2011). Long periods of drought and anomalies such as strong winds, hailstorms, and heat waves are affecting agriculture in a direct manner (European Environment Agency

 $^{^1\}text{A}$ "third country" refers to any country that is not a member of the European Union.

	Count	Percentage	Percentage
			of cases
Harsh competition	75	7.3 %	37.5 %
Costs of production	56	5.4 %	28.0 %
Climatic factors	53	5.2 %	26.5 %
Low profit margins	49	4.8 %	24.5 %
Pests and diseases	43	4.2 %	21.5 %
Work life balance	30	2.9 %	15.0 %
is difficult			
Beaurocracy	28	2.7 %	14.0 %
Lack of professional	28	2.7 %	14.0 %
services			
Limited resources	27	2.6 %	13.5 %
available			
Lack of assistance	26	2.5 %	13.0 %
from authorties			

Table 6: The ten most mentioned challenges by the 202 youngrespondents.

[EEA], 2023; Galdies & Galdies, 2016). Damages mentioned by young farmers include loss of livestock due to extreme heat temperatures, infestations caused by pests and diseases, and damage to farm structures such as greenhouses when strong winds prevail. The lack of resources, market issues, and authorities are the three most relevant themes identified by young farmers. The availability and cost of resources has been indirectly mentioned earlier, while the second most important theme related to market issues includes food fraud, harsh competition, and market volatility. These issues are widely acknowledged by policy makers (ACS, 2018) and the farming community alike.

Producers need to improve their standards in grading, packaging, and labelling to make local products easily identifiable by consumers (ACS, 2018; EC, 2020). Effective monitoring and enforcement from authorities is necessary to tackle the challenges mentioned. Farmers acknowledge that consumers may opt for local products if quality and price are advantageous, but their products do not stand out from the rest. This lack of traceability creates a risk of food fraud at sales point. The third most important theme regarding challenges is about local authorities, which include bureaucracy, lack of assistance, co-ordination and accountability, complicated and expensive permitting processes, as well as lack of political vision.

Data collected from young farmers showed that those who are pro-active within the sector are encountering a multitude of obstacles leading to time-wasting and unnecessary costs. The Planning Authority, the Environment and Resources Authority, and the Lands Department were mentioned multiple times by young farmers who vented their frustration regarding situations encountered during

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the permitting process and land transfer issues. EU funding applications and paperwork involved during the implementation of investment projects were also mentioned as matters discouraging farmers from applying again (EMCS Ltd, 2021). The National Agricultural Policy 2018-2028 refers to the need to reduce bureaucracy and implementation costs, but few references are made to this issue in other official and academic texts. Bezzina et al. (2017) outlines that bureaucracy has become a 'buzz word' and that such perception is weakening the good work done by public administration.

Local NGOs have raised their concerns about bureaucracy and various organisations taking a leading role as farmer representatives have called for an increase in efficiency across all departments on which farmers are dependent (Carabott, 2021; Young Friends of the Earth, 2023). Initiatives that increase efficiency across all administrative sections would lead to win-win situations for policy makers and the operators. Adopting a targetoriented approach can improve the motivation of producers within the sector while maximising resource efficiency. The policy also envisages to reward genuine farmers through a point system for certain policy measures (ACS, 2018).

4 Conclusions

This study was based on a questionnaire that was aimed at encouraging young farmers to voice their ideas freely about their experiences on the current agricultural situation in Malta. Apart from the quantitative demographic information, which characterises this section of the population, information on challenges and opportunities, raised by young farmers, constituted the qualitative aspect of this study. The overwhelming volume of responses and the justifications offered indicated a great degree of interest among respondents. The three most significant theme opportunities include positive lifestyle, the need to diversify production and marketing, whereas the three most significant unconstructive themes were the availability and cost of resources, together with issues pertaining to the market and the authorities. This study sets a baseline to policy makers, funding agencies, farmers organisations and authorities to understand better the situation of young farmers and the future of agriculture in Malta.

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