# Landscape Restoration and Rehabilitation: A Geocultural Design Approach

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***Abstract*—The visual impact of open-pit mineral workings along sloping terrain generates conspicuous scars extending to the surrounding landscape. Such irreversible developments permanently alter the original landform. This is more pronounced in areas of high landscape value. The aim of this paper is to put forward the case for a contextual design of a restoration scheme grounded in the geophysical and cultural elements making up the landscape character and thus complimenting it. This is demonstrated through a case study of Gozo, a picturesque sister island of Malta, known as the island of Calypso after the legendary Homeric nymph, where such quarries have significant visual impact. Based on site contours derived from historical survey sheets and making reference to vernacular cultural features within the surroundings, a restoration and rehabilitation of a disused quarry based on a geocultural approach to landscape design was developed. Prior rehabilitated to sustainable agrarian parcels of land, the site contours were re-introduced together with field boundaries to pre-mineral operational status. This approach is a rational solution derived from rural vernacular architecture and ensures a landscape design solution which reinstates the scenic quality and the aesthetic experience of the area.**

***Index Terms*—Landscape restoration, landscape rehabilitation, geocultural landscape, design, visual impact, Gozo.**

## I. Introduction

Disused open-pit mining operations are a cause of negative impact on the surrounding environs [1]-[3]. They are intrusive on the existing geocultural environs. Indeed quarrying is an activity, so essential for the social well-being of the community, which is hostile and destructive towards the natural habitat of various species and the general environment. It is an irreversible development which impinges and depreciates the landscape value [4]. The restoration and rehabilitation of quarries involves making good for the damage generated by such operations through alterative re-use of the land. Visual impact is a paramount environmental concern such as in [5]. The significance of the scenic quality is nowadays recognised by the European Landscape Convention [6]. Quarrying impact in the Maltese islands, an archipelago of a group of low lying islands aligned in a North-West – South-East direction in the central Mediterranean, is no exception. Malta, the largest, is located 96 km south of Sicily and 290 km north of Africa. After mainland Malta, Gozo is the second largest island (Fig. 1). It has a long history of quarrying dating back to the Neolithic period. It supports Ġgantija megalithic temple complex, a World Heritage Site [7] dating to circa a millennium prior to the great pyramids of Egypt. The mineral extractive industry accounts for significant irreversible alterations to the island's topography [8].

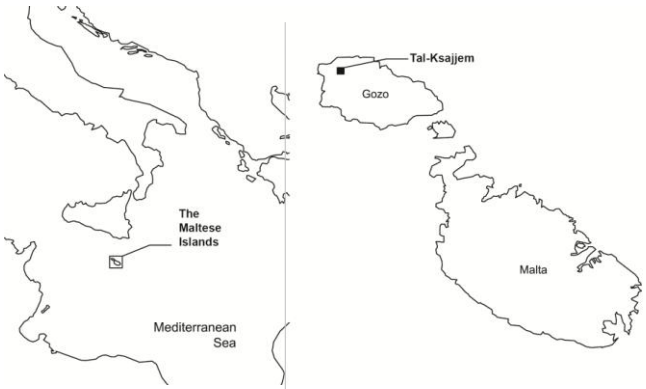


Fig. 1. The Maltese archipelago.

The geological sequence of the Maltese Islands is made up of five lithostratigraphic units. These, in chronological order, are Lower Coralline Limestone, Globigerina Limestone, Blue Clay, Greensand and Upper Coralline Limestone [9]. Industrial mineral extraction is through open-pit mining. Two types of quarries are present, hardstone extracted from Coralline Limestone formations, and softstone extracted from the lower stratum of the Globigerina Limestone formation [10]. The environmental contexts where these quarries are located are diametrically opposite: in mainland Malta, hardstone quarries are located along sides of natural valleys, which are thus highly visible, whilst softstone quarries are along a relatively horizontal terrain, rarely visible from the surrounding environs. In Gozo, hardstone quarries are either on plateaux or along the coast, with minimal visual impact, whilst softstone quarries are along sloping terrain with high visual impact.

Traditionally, quarries along relatively horizontal terrain were rehabilitated for agrarian use, mainly orchards; quarry floors were raised by infilling with inert waste to some metres lower that the surrounding natural topographical levels. According to the Mineral Subject Plan for the Maltese Islands [11], quarries have to reclaimed, once exhausted, for either of the following: agricultural land, commercial orchards, nature conservation uses and informal recreational/touristic facilities.

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## II. Background

### A. Geoculture and Landscape

It has long been recognised that anthropogenic landscapes should address aesthetic values and cultural requisites [12]-[14]. Most landscape restoration to quarries adopts mainly an ecological approach [15]-[20] or a geomorphological approach [21]-[23]. Other approaches have also been adopted such as in [24]-[27]. The ecological approach takes into account the context of the landscape, both natural [28], [29] and cultural [30], in full cognisance of the general public appeal to same [30]-[33].

The geocultural approach being proposed involves the replication of land form to original site contours whilst making use of the main cultural references in the landscape. The geology gives rise to existing topography which supports the natural and cultural heritage. The landscape transformation generated by open-pit mineral workings is re-transformed into a harmonious reconstruction of the landscape profile. It is an artificial landscape addressing the visual impact and after-use. A geocultural approach to landscape restoration ensures post-quarrying, geophysical and culturally sensitive sustainable landscaping design and planning. This leads to the reinstatement of the original landscape value of a given site. Landscape values bridge the gap between the geography and the sense of place [34]-[36].

### B. Study Area and Objectives

The purpose of this paper is to illustrate a restoration and rehabilitation proposal based on the main existing elements of the topography of the landscape, a design grounded in the geophysical parameters of the site and the cultural heritage features in its vicinity. These references are a useful source to develop a sustainable landscape restored to the original site profile and character. The environmental impacts of a disused softstone quarry at Tal-Ksajjem, within the limits of the village of GĦarb (coordinates: 36 °3'58" N and 14 °12'45" E), were assessed (Fig. 1, Fig. 2). The natural and rural character of Gozo was acknowledged through the Structure Plan for the Maltese Islands [37]. Nowadays, it is designated to become an ecological island [38]. The study area measured 1km diameter centred on the site, an area deemed sufficient for the island which measures 14.5km by 7.2km. The specific objectives were the following:

1) to establish the land-use within the study area to generate enough data for the analysis of the existing landscape character,
2) to identify the location(s) of particular feature(s) in the landscape scenery, plotting them and photographically record them, and
3) to propose a contextual landscape design concept which mitigate the existing visual impact.

### C. Study Context

The site under study, having an area of approximately 26,000m$^2$, formed part of a softstone quarry complex which mostly had been reclaimed back to agriculture. Such after-use is an environmental economic asset [39]. Situated in a location of high visual impact on the north-western fringe of the island, it is within the immediate vicinity of major topographic features, both natural and man-made. The significant physical feature is Wied il-Mielaħ dry valley system. Being one of the largest fluvial systems, it determines to a great extent the type of land use, namely terraced fields, some of which had fallen into disuse. The number of disused softstone quarries located on the lower slopes of the valley's flanks, at present reclaimed for agrarian use, indicates that the area has long been used for open pit mineral extraction.

The quarry is located on a major bend of the valley bed of Wied il-Mielaħ. From this point northwards, the valley meanders across a relatively open landscape characterised by gently rolling plains and dotted with mesa landforms and associated clay taluses. The landscape is heavily dissected by a number of dry valley systems. Most of the illegal, uncontrolled backfilling on site, a typical scenario triggered by disused quarries [40], was present at the time of the study.

## III. Research Methods

The evaluation of the site was undertaken through a desk study and ground surveys. The former, a semi-qualitative analysis, was based on official ordinance survey sheets, plotted at scale 1:2500, for the years 1957, 1968 and 1993, and the corresponding official aerial photographs (Table I).

Comparative aerial photography and the survey sheets were used:

1) to read the development planning history of the site and the surrounding land uses, and
2) to identify the extent of the landscape character of the area around the quarry.

The factors affecting the interpretation of aerial photos were the scale of the photograph, the shape and shadow of the site, associated features and tone. Difficulty in interpretation increased with decreasing scale. Ta' Pinu Sanctuary, a main touristic landmark, and the masonry bridge (Fig. 3) were the features which provided bearing to identify its location. Landscape features were selected on the basis of being typical to the area of study.

TABLE I: Ordinance Survey Sheets and Official Aerial Photographs Covering Site History

| Year | 1957 | | 1968 | | 1988 | | 1993 | |
|---|---|---|---|---|---|---|---|---|
| | S.S. | Photo | S.S. | Photo | S.S. | Photo | S.S. | Photo |
| Ref. Nos. | 6,7, 12,13 | 182 | 2891 | n.a. | 2891 | 65 | 2891 | 055, strip 50 296, strip 51 |
| Scale | 2500 | 8000 | 2500 | n.a. | 2500 | 15000 | 2500 | 4,000 |

S.S.: ordinance survey sheet; photo: official aerial photo; n.a.: not available.

Through quantitative assessment, the land uses were estimated to establish the elements making up the landscape. Where present in an explicit, consistent manner, they gave character to the landscape. The main features were identified, studied and evaluated to comprehend their inter-relationship and the pattern present in the landscape. Overlaying the various findings, a relationship between the physical components and the perceived sense of place associated with a given particular feature was established. Although ground surveys include an error in the interpretation and estimation of the superficial area for each land use, they were deemed sufficient for the purpose of this study.

## IV. Results

### A. Mapping Land Uses

Various erosion processes had modified the landscape into a number of mesa landforms and contiguous plains. These had been dissected by Wied il-Mielaħ. The most widespread land use was dryland agriculture. The morphology of the valley itself had been considerably modified by such activity. The sides of the valley had been transformed into successive levels of terraced fields. Upslope, the field sizes increased in proportion to the intensity of the actual agrarian activity. A number of smaller plots of land, particularly those in the immediate proximity of the site, were fallow and abandoned. Commercial activity in the area is limited to part-time farming practices with recreational activity focusing on hiking and leisure walks. Built development in the area is concentrated within the boundaries of the village of GĦarb and the hamlet of GĦammar. The land cover of the study was categorised into four: mineral workings, agrarian land, ecology and urban/semi-urban [41]. The various land uses are stated in Table II and plotted in Fig. 3. From the aerial photos it was evident that, in 1957, mineral extraction already covered half the present size of the quarry. By 1988, it was reclaimed back to agriculture. Although the 1993 aerial photos showed the site as being still cultivated for agricultural purposes, the south-western part had been infilled to the level of the adjacent public road.

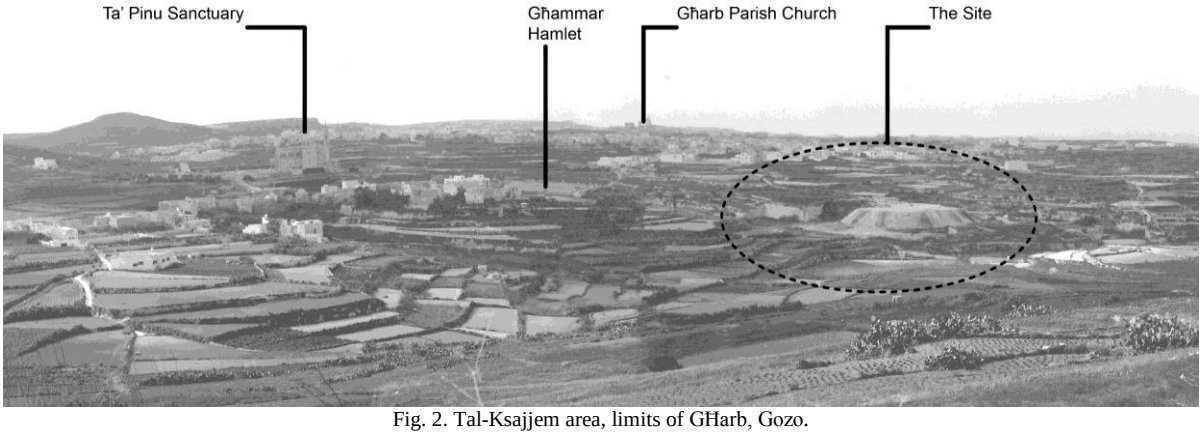


Fig. 2. Tal-Ksajjem area, limits of GĦarb, Gozo.

TABLE II: Land Uses within the Study Area

| Land Use Type | Area ($m^2$) | Percentage (%)* |
|---|---|---|
| Mineral workings | | |
| The site | 025,976 | 03.3% |
| Reclaimed quarries | 016,636 | 02.1% |
| Agrarian land | | |
| Cultivated | 608,530 | 77.5% |
| Abandoned | 072,090 | 09.2% |
| Scraped tracts | 002,919 | 00.4% |
| Ecology | | |
| Valley Bed | 013,134 | 01.7% |
| Disturbed ground | 001,167 | 00.1% |
| Degraded garigue | 001,459 | 00.2% |
| Urban/Semi-urban | | |
| Settlement | 023,349 | 03.0% |
| Main access routes | 008,756 | 01.1% |
| Roads | 011,383 | 01.4% |

* Percentage was calculated as a fraction of the total study area.

### B. Geological and Hydrological Considerations

Gozo is composed of tertiary succession of limestones with intervening strata of marls and clays stacked in a simple horizontal fashion [42]. Quaternary deposits capping the whole succession are limited. The succession dates to the Oligo-Miocene age [43]. Different lithologies give rise to contrasting landscapes with the more compact limestone formations giving rise to sharp drops and flat barren plateaux often eroded by karstic action. On the other hand, the marls form a gently rolling landscape whilst the clays are often cultivated by way of terraced fields which characterise most of the Gozitan countryside. The lithostratigraphic outcrops within the study area are the three distinct members of the Globigerina Limestone Formation: the Upper, the Middle and the Lower. The quarry extracts the Lower Globigerina limestone, locally known as franka. This industrial mineral has been quarried for the erection of building engineering structures since time immemorial [44], [45].

Located within the hydrological catchment of Wied il-Mielaħ, the geological setting excludes all possibilities that one encounters springs which surge from the perched aquifer, on top of the Blue Clay [46]. The only one present is the Mean Sea Level Aquifer; its potentiometric surface occurs around sea level with a flow pattern directed predominantly towards the coastline.

### C. Pedological and Ecological Considerations

The predominant type of agriculture is dryland farming. The main agricultural crops are sulla, wheat and barley, legumes and some spring potatoes [47]. The average field size is about 500 to 1000$m^2$. Most of the rubble walls had fallen into disrepair with a concurrent increase in soil erosion. Using Kubiena classification, surface soil sampling and analysis indicated the presence of Xerorendzina soil, San Biagio Series [47]. Typical topsoil and subsoil depths of San Biagio profiles in Western Gozo are about 20cm and 55cm respectively [48].

The vegetation of the study area was typical of communities associated with disturbed ground and consisted of resilient species characterised by rapid growth and high fecundity [49]. Such species were favoured in disturbed habitats since they react to changing ecological conditions more swiftly than large, slow-growing ones. All the recorded species on disturbed ground were not listed in the Red Data

Book [50]. The community of the valley bed was terrestrial rather than aquatic with all present species not listed in the Red Data Book. The exception is Carlina involucrata, a species of restricted distribution in the Mediterranean region [49]. Construction of dams along the floor of the valley led to the accumulation of silt, permitting the invasion by terrestrial species which gradually displaced the freshwater ones characteristic of this habitat.

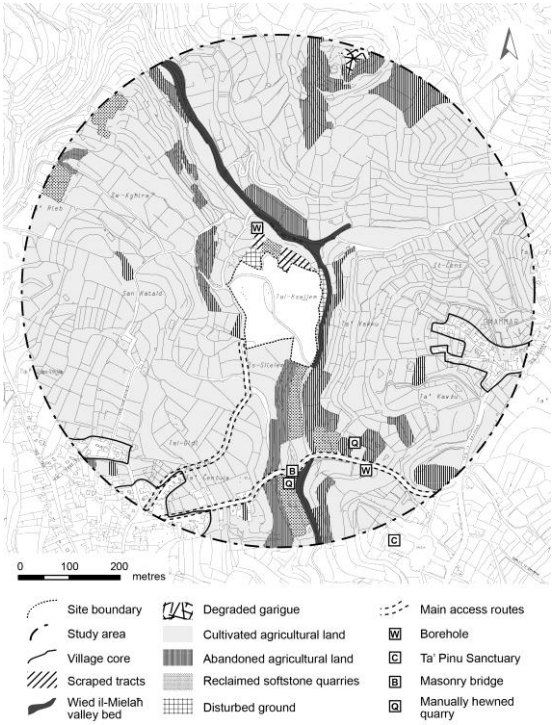


Fig. 3. Land-use map.

Parts of the valley system surrounding the site had suffered substantial environmental and visual degradation. These were worsened by the presence of a run-down access route to the site passing along the valley bed. Other sources of anthropogenic disturbance included dumping of construction waste, spillage of vehicle fuel, leaching of agricultural effluent, construction of dams and entry of alien species into the community.

### D. Cultural Heritage Landscape

Wied il-Mielaħ is a single geo-physical context in which a number of anthropogenic interventions through time have contributed to the current cultural landscape [51]. Two historical and cultural landscape features are agriculture and softstone quarries. Agricultural assets are represented by the rubble walls and terraced field systems. Traditionally, given the barren land character of the Maltese islands, terraced fields were formed by covering such land with soil which was retained on site by means of dry-stone rubble walls [52]. Industrial archaeology is represented by a series of shallow and deep quarries. The absence of mechanised cutting marks raises the cultural value of these manmade features [51]. Among these assets there are two old quarries, manually hewned, located along the access route which runs over the masonry bridge.

Although not scheduled, Tal-Ksajjem quarry has a significant landscape value and is of local landscape importance. In spite of weathering, the quarry faces were conspicuous and visible from as far off as Ta' Gordan Hill, 1km North-East of the site. Absence of clear management policies and the lack of an acceptable visually sensitive rehabilitation design for the after-use of mineral operations were evident in the picturesque topography of the site.

## V. Discussion

### A. Assessment of Environmental Impacts

The main characteristics of the study area are land form, land use, elements in the landscape and site access. Site levels ranged from 67m to circa 80m above mean sea level. When viewed from Ta' Gordan Hill, a popular location with both local and foreign tourists, the site disrupts the harmonious continuity in the terraced, natural landforms. The principal land use is agriculture; terraced fields dominate the landscape. The cultural assets typical of the study area relate to vernacular rural constructions which are protected through the Rubble Walls and Rural Structures Conservation and Maintenance (Amendment) Regulations [53]. Rubble walls are the main elements of the landscape scenery. These regulations specifically define a rubble wall as a dry stone wall, built in loose unhewned or rough-dressed stones. It further states that such a wall has to stand by gravity and friction and without the use of mortar.

The significance of the hydrogeology of the area is highlighted by the presence of a pumping station situated close to Triq ta' Wied il-Mielaħ. As an ideal aquitard, the Lower Globigerina Limestone can act as a buffer to delay the migration of pollutants from the surface to the Mean Sea Level Aquifer. The wells in the vicinity of the site are vulnerable to pollutants dumped during land filling. Groundwater pollution might have lead to health risks to the community residing at GĦarb. Furthermore, losses in water production translate into additional public expense to replace it through other sources. In addition to being detrimental to the flora and fauna in the valley habitat, pollutants might also seep into the adjacent watercourse and end flowing over the Lower Coralline inlier further down the valley, and thus reaching the aquifer at a faster rate.

Western Gozo is rich in dryland farming as the clayey soils would not permit an irrigation regime. Thus, opting for the reclaimed site to be used for such farming was a suitable option which merged with the rest of the landscape. Soil is barren of vegetation during the dry summer months and hence increases the likelihood of soil erosion by wind. The situation is worsened by the heavy autumn rain. Field terracing, contour cultivation and rapid vegetation establishment, reduce erosion. San Biagio Series, the soil likely to have been present on site prior to the commencement of mineral extraction operations, was used in the soil profile of the restored site in order to preserve the surrounding area's homogenous pedology.

Impacts arising from the rehabilitation scheme were minimised by i) relocation of excess construction waste away from the valley system, ii) removal of the existing access road along the valley floor, iii) careful storage of any potential contaminant and iv) selection of native vegetation for landscaping purposes. Excess construction waste arising from

the proposed rehabilitation was disposed of in a designated location approved by the planning regulator. The disturbance arising from the disposal of waste favours the growth of opportunistic annuals, both native and alien, with consequent displacement of native species.

Visible cultural features relating to mineral operations, such as quarry marks, should be recorded prior to being buried under the proposed restoration. One, low cost recording approach is through photogrammetric methods that would allow eventual reconstitution of data. From a geocultural landscape perspective, the major concern in the restoration and rehabilitation of Tal-Ksajjem quarry was its visual impact. On such a touristic and ecological island, the quarry has degraded the aesthetic experience that visitors enjoy.

### *B. Restoration Proposal*

The design considerations for landscape restoration are given in Table III. It involved infilling with inert building construction waste and reclaiming the site for agriculture purposes. Where data regarding site contours, terracing and fields boundaries was available from survey sheets, it was incorporated into the design proposal (Fig. 4); where absent, the position of contours and field boundaries were designed through extrapolating the information contained in the survey sheets and aerial photographs. Since the location is along a slope, fields usually follow the natural contours of the land. Where data was not available, field sizes were kept in the range of the average present within the study area, namely 500 to 1000m$^2$. Such sizes are more effective against soil erosion.

No aerial photographs prior 1957 are available. The 1957 survey sheet does not distinguish between original terracing and scrapped land. In either case, it is indicative of the natural topographical layout of the site. Thus, this survey sheet was used as the conceptual layout of the proposed rehabilitation scheme.

The 1968 survey sheet was used to identify the contours of the land and their respective position above mean sea level. A typical vernacular wall along the valley bed of Wied il-Mielaħ, part of which had collapsed, had been used to develop the design of the rubble walls used in the restoration scheme (Fig. 5)

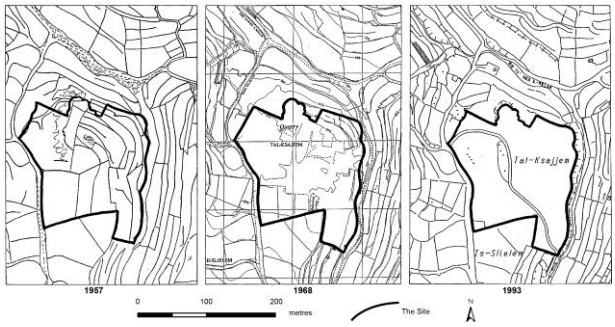


Fig. 4. Ordinance survey sheets covering the site at Tal-Ksajjem.

The proposed phasing of the restoration profile involved five stages. Each stage, together with the activity involved and the recommended intervention is stated in Table IV. The restored site has three distinct divisions which, starting from the lowest, are the inert fill, subsoil and topsoil. For sustaining the restored profile, the proposed after-use was agrarian activity. Vegetation reduces risk of soil erosion. The rubble walls had to be regularly maintained both for maximum soil preservation and for aesthetic reasons. The restored profile of the site and a visual of same are shown in Fig. 6 and Fig. 7 respectively.

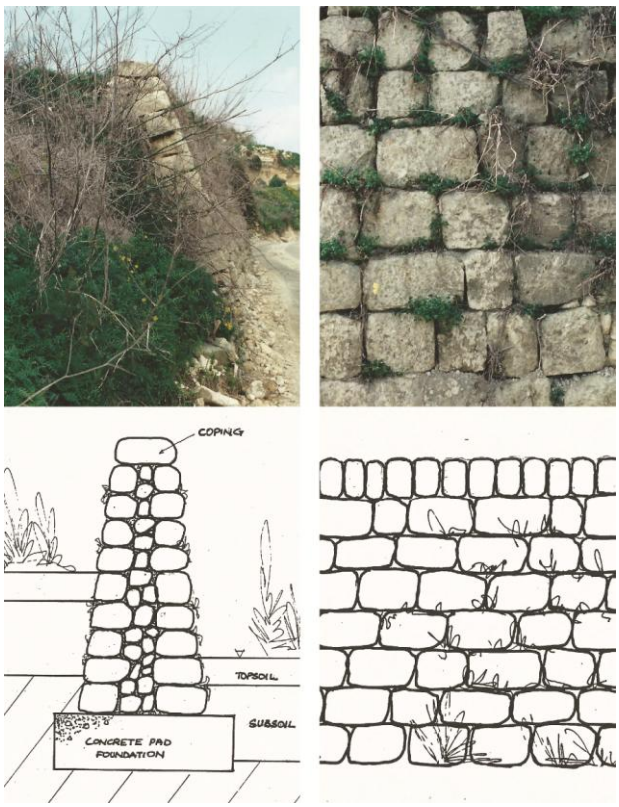


Fig. 5. Section (top left) and elevation (top, right) of a typical rubble wall along the valley bed of Wied il-Mielaħ. These were used to prepare the respective section (bottom, left) and elevation (bottom, right) respectively.

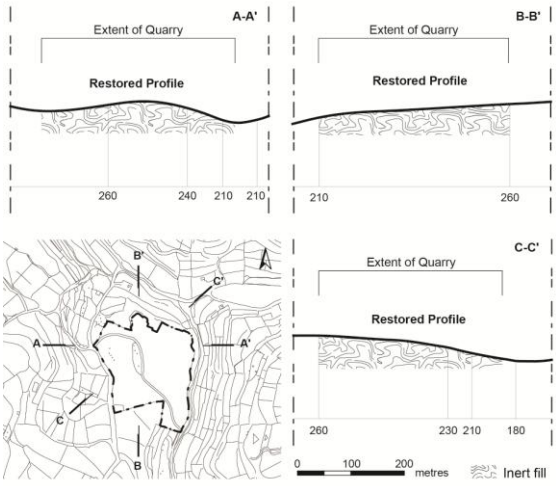


Fig. 6. Profile design of the restoration landscape.

Fig. 7. Visual of the restored landscape.

Assessment of water and land pollution through environmental audit of the restored phase is an important consideration [54]. Given the high porosity of the restored site, preventive measures against leaching of substances into the aquifer were recommended to minimise the risk of pollution of ground water from agrarian and allied activities. Irrigation techniques were limited to the drip-type. Another recommended measure was the adoption of organic farming techniques. The public perception of organic farming at the time was that it promotes the cultivation of plants and agricultural products without making use of pesticides and/or chemicals, thus generating confidence of healthier relation between farmers, consumers and the environment [55].

TABLE III: DESIGN CONSIDERATIONS FOR LANDSCAPE RESTORATION

| Parameter | Existing Considerations | Proposed Considerations |
|---|---|---|
| Land use | Dryland agriculture predominates | Restore site back to agrarian uses to typical field sizes of 500 to 1000m$^2$ |
| Geology | Lower Globigerina Limestone outcrops on site | Photographically record quarry faces prior to land filling |
| Hydrogeology | Lower Globigerina Limestone is an aquitard which delays percolation to mean sea level aquifer | Compacted inert waste construction material helps retarding percolation to the quarry base and to the adjacent watercourse |
| Pedology | Xerorendzina soil (San Biagio Series); typical depth of topsoil and subsoil are 20cm and 50cm respectively | Topsoil and subsoil profiles will be reconstructed to the average current depths existing in fields within the study area. Soils (San Biagio Series) will be utilised |
| Ecology | Wied il-Mielaħ system, one of the largest fluvial systems on the island, bounds the site | Introduce native vegetation to help consolidate the reconstructed soil levels and prevent infilled material reaching the valley bed |
| Cultural heritage | Rubble walls, protected at law, are the predominant vernacular cultural heritage within the study area | Reconstructed rubble walls in traditional construction technique to complement the existing geocultural landscape |
| Visual impact | Site located in a panoramic landscape | Reconstructed rubble walls, whilst serving as retaining structures, will visually compliment the surrounding environs of significant landscape value |

TABLE IV: PHASING OF THE RESTORATION PROFILE

| | Activity | Recommended Intervention |
|---|---|---|
| Phase 1 | Filling the quarry with inert fill material | Fill compacted to prevent subsidence, decrease porosity and permeability, and increase capacity of fill on site; fill is to be to the levels indicated |
| Phase 2 | Compaction of inert material to original contour level less depth of subsoil and topsoil | At top of fill, cast concrete strip foundation and erect a random dry-stone rubble walls along the established and/or designed location of field boundaries; place the subsoil simultaneously on the lower sides of the terraces |
| Phase 3 | Subsoil placed on the compacted inert material to a depth of about 55cm | Use of earth moving equipment; the lower sides of the terraces should be stabilised by stonework; these should be constructed simultaneously with subsoil deposition |
| Phase 4 | Topsoil placed on the subsoil to a depth of about 20cm and levelled | Use of scrapers is recommended for this purpose; contour cultivation by rotary cultivator soon after post levelling of the topsoil minimises erosion; if serious compaction problems are noted, deep tillage is recommended |
| Phase 5 | Vegetation rapidly carried out to act as an effective protection against soil erosion | A temporary cover of seeded grass holds the soil until dryland farming; vegetation binds soil particles together, breaks the raindrop impact, and prevents wind erosion when soil moisture content is low |

## VI. CONCLUSION

This paper attempted to identify a design methodology and outline a contextual restoration proposal for beneficial, sustainable after-use whilst mitigating the significant visual scar in the landscape generated by the quarry operations. It put forward a case for the restoration and rehabilitation of a disused quarry, effectively a prototype for similar natural and cultural landscape settings.

The restoration and rehabilitation of Tal-Ksajjem quarry is a case study which illustrates the applicability and suitability of this approach. The restored and rehabilitated site is a contextual architectural landform solution for a terraced, highly visible landscape with rural vernacular heritage features. The restored site and the consequent visual impact emerged from the link between the physical components and the perceived sense of place of the particular, predominant element present in the landscape, terraced fields. They were re-established, and boundaries to same re-introduced, along the site contours existing prior commencement of mineral operations. Dry stone masonry rubble walls were introduced both for aesthetic and functional, soil retaining reasons. The restoration proposal was grounded in the geophysical and cultural heritage contexts of the site. It reflected the landscape character of the area thus balancing out the existing negative landscape and visual impacts; as intended, it enhanced the site, once infilled, and re-established continuity with the surrounding landscaping. Reinstatement to agrarian after-use reaps economic benefit which ensures that this continuity is maintained.

The restoration and rehabilitation of disturbed, originally terraced, natural topography, effectively involving the reconstruction of the original site profile, reinstates the landscape value of the site. Given the agrarian nature of the physical geographical context, the geocultural design approach leads not only to visually restoring the landform but serves also to an aesthetical, complimentary rehabilitation of the site for beneficial after-use.

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