AGROECOLOGY AND SUSTAINABLE FOOD SYSTEMS
https://doi.org/10.1080/21683565.2024.2325150

Taylor & Francis
Taylor & Francis Group

OPEN ACCESS Check for updates

Early eco-agrarian adaptations in Malta

George Attard[a], Charles Dalli[b], and Anthony Meli[c]

[a]Institute of Earth Systems, Department of Rural Sciences and Food Systems, University of Malta, Msida, Malta; [b]Department of History, University of Malta, Msida, Malta; [c]Argotti Botanic Gardens & Resource Centre, University of Malta, Msida, Malta

ABSTRACT

Indigenous knowledge is generated at a local level and is unique in its culture and society. The Maltese rural landscape, being one of the most anthropomorphic in the world, describes a wealth of indigenous knowledge on how to thrive in arid conditions on land that is barren of soil. The most visible features of the present landscape are the characteristic field terraces with their dry rubble wall containment that in most cases represent the boundary wall of man-made "Campi Artificiali." These features constitute an inestimable rural attribute that has facilitated human habitation of the islands. Additionally, distinctive water harvesting and dryland cultivation techniques were also employed by Maltese farmers to sustain a living in an often-arid environment. Recognizing the importance of indigenous knowledge and locally developed technologies can facilitate the cost-effectiveness of development or conservation interventions.

KEYWORDS

Malta; indigenous technology; soil; water; agriculture

SUSTAINABLE DEVELOPMENT GOALS

SDG 1: No poverty; SDG 2: Zero hunger; SDG 13: Climate action; SDG 12: Responsible consumption and production; SDG 15: Life on land

Introduction

Evidence of human occupation on the Maltese islands can be traced back to about 7900 cal BP. Historical remains give evidence of the presence of agrarian societies inhabiting the Maltese archipelago dating back to these early years. Marriner et al. (2012) indicate that the earliest palynological evidence suggests that anthropogenic clearance with fire and grazing had started before 7,300 cal BP. Remnants of degraded woodland and impoverished maquis have mostly survived in inaccessible areas and garigue expanses predominate on limestone outcrops.

Primavera et al. (2017) in their evaluation of Bronze Age cropping and harvesting strategies in Apulia, South-Eastern Italy, indicate that climate was a major influence in Middle Bronze Age whilst social factors predominated in the Late Bronze Age and the cultivated crops were those that adapted to 'eco-geography and climate through the millennia with cold weather in late winter, decreased springtime rainfall and high temperatures

CONTACT George Attard george.attard@um.edu.mt Institute of Earth Systems, Department of Rural Sciences and Food Systems, University of Malta, Msida, MSD 2080, Malta

in summer influencing the cereals and pulses that were cultivated. The later development of silos utilized for edible tree fruit storage recovered was considered an adaptation strategy to safeguard against crop failure.

Carroll et al., (2012), in their evaluation of Holocene climates and human impact in the Maltese Islands indicate ‘deforestation from Pinus-Cupressaceae woodland in the early Neolithic, and although it initially was sparse, cereal agriculture was established by 7800 cal BP. and seems to have persisted. Observed increases in cereal pollen around 5800 cal BP. indicated a shift from mixed farming to arable agriculture. It is also sustained that agriculture was experiencing a crisis at around 4300 cal BP. toward the end of the Neolithic era due to aridity.

Gambin et al., (2016), indicate that from about 4450 cal BP the landscape became more exposed and fires, soil erosion, and grazing activity were increasing, while climatic instability between 4600 and 3700 cal BP resulted in decreased summer moisture. The landscape was still partly open during the early Roman occupation period though at this time the increase in olive trees and cultivated crops was noticeable. This period was also marked by reduced precipitation and an increase in fires. This conformed to sites in southern Italy and the drier period in the Mediterranean. Throughout man’s occupation, the Maltese islands changed little in shape and size, however, the occurrence of serious soil erosion, witnessed by bare rock and silted inlets, indicates that land surface activities have not been all that beneficial. Soil loss was considerable even before 1000 B.C., as evidenced by the dominance of grass and low herbs and the limited presence of pines and cultivated olives (Trump 1990, 18 & 90). The loss of the Judas tree, hawthorn, and ash – linked to the intensification of farming practices in the earlier Neolithic period, further supports the changes associated with the advent of man and farming in the Maltese islands (Blouet 1992, 22).

Malta has a long history of olive cultivation dating back to about 2700 cal BP when olive trees were introduced by the Phoenicians. They were extended throughout the Roman and Byzantine periods. When the Arabs arrived in the 1100 Cal BP olive plantations and trees were destroyed to make way for the cultivation of cumin, cotton plantations, and citrus groves. However, following the expulsion of the Saracens in 930 cal BP, by the 15th century Malta had once again become an olive oil exporter, yet at the beginning of the 18th century the Spanish demand for cotton saw the destruction of some 80,000 olive trees that were replaced with cotton (Borg 1922, 98).

Effectively, the Maltese ecosystems have been exploited since the arrival of Neolithic man, ultimately carving out a distinctive character. As a result of years of human ingenuity and toil, the Maltese rural landscape is one of the most anthropomorphic in the world leading to a gradual accumulation of indigenous technological knowhow that now forms an integral part of the culture and history of the Maltese in their struggles to thrive under the harsh semi-arid conditions of Malta. This knowledge is a result of human efforts invested over centuries in trial and error and keen observation that gradually accumulated into a systematic body of information acquired through experience, informal experiment, and intimate understanding of the local conditions. However, with the introduction of modern technology into agriculture young farmers are oblivious to these ingenious ancient but sustainable know-how. The level of knowledge about the Maltese indigenous land husbandry technology involving aspects of soil and water conservation are slowly disappearing. It is increasingly recognized in countries that have like Malta experienced similar situations that the need to study and appreciate the approaches and strategies of these indigenous technology has been expressed since the early 1980s (Critchley, Reij, and Willcocks 1994). Indeed, indigenous knowledge practices are at high risk of becoming extinct due to a rapidly changing environment and a fast pacing economic, political, and cultural changes on a global scale.

Research in this area is confined to published material dating back a few centuries. A reassessment of these techniques, coupled with proper maintenance of the remaining agricultural areas, should be central to any discussion on sustainable Maltese agriculture. The scope of this review is to promote the Maltese indigenous land husbandry practices in aspects of soil and water and to bring them back into context to act as a suitable starting point for the development of appropriate and sustainable technologies for land husbandry in Malta and elsewhere having similar geophysical properties.

Indigenous knowledge

Indigenous knowledge systems, relative to agriculture, can be described as knowledge pools that develop over time as a cultural or ethnic group strives to meet subsistence goals in a particular ecological setting. To address agricultural production challenges, astute observations of the local environment leading to a gradual accumulation of information that is passed on through generations and thereby fine-tuned into a system of understanding natural resources management and the relevant ecological processes. The particular sets of circumstances of the Maltese islands where agriculture has to thrive within the semi-arid conditions, relying mostly on rain for irrigation since no surface water is available and the fact that the shallow soils are prone to water and wind erosion, has led to the evolution of homegrown technologies to mitigate against these particular sets of circumstances. In the second decade of the last century, Dawson Shepherd rightly remarked that more than a passing glance was necessary to appreciate agriculture in the Maltese islands. To the uninitiated, lack of vegetation and livestock was the first apparent feature, but after familiarization with the semi-arid environment, intensive farming practices emerged. The dry-farming technology derived from the long experience of Maltese farmers exacted a minimum of two crops with the aid of hand-watering even when winter rainfall was limited (Dawson Shepherd 1920, 1 & 12).

Since low water resources limit arable production; and through moisture conservation, crop/plant performance is improved, techniques attach a high priority to the capture of rainfall. Precipitation is gathered and diverted into subterranean wells or cisterns to store this precious resource for use during dry periods. The need to cultivate crops on lands that are mostly covered with thin layers of soil implies paramount priorities for the need to preserve and maintain this rooting/growing medium. With the presence of an over-abundant availability of stones, ingenious techniques were developed to "dispose" of them in ways that also promoted soil conservation. Pressure to increase cultivation within a context of a shortage of arable land prompted the evolution of unique techniques aimed at transforming barren land into productive utilizable agricultural areas. However, an important underlying factor for the development of indigenous technology is land tenure security and the desire to maximize one's resources to improve livelihood. The ensemble of these processes leads to the development of knowledge systems that are particular to people living in that particular land. The most visible features of the present Maltese landscape are the characteristic field terraces with their dry rubble wall containment. Less visible are the small irrigation canals hewn out of blocks of limestone to form a dense network of water distribution relying solely on gravity. Even less noticeable are the "Campi Artificiali."

Soils for land reclamation

Maltese soils are of a soft calcareous nature usually found to be very shallow sitting on the bedrock of two kinds and are classified as anthropogenic (artificial/manmade) or naturally occurring. Chetcuti et al. (1992) state that the artificial cultivable soils were either manufactured by man or as also described by Professor Carlo Giacinto in 1811, by the collection of soil from different locations and carting it away to be deposited directly on the rock surface to cover and reclaim barren tracts of land or to rehabilitate unused quarries.

In the discussion on Malta's development problems and economic prospects, Crist (1956) states that in Malta "Soil is above price, more precious than rubies." and refers to the "Red Soil Law" which at the time was probably unique in the word. The Fertile Soil Preservation Ordinance was enacted on 8th January 1935 to protect cultivatable soil present on building sites. This Act which is still in force today, imposes that soil from all building sites must, under the directions and supervision of the Director of Agriculture, be removed and deposited in places for agricultural use. The whole rural landscape shows evidence of considerable translocation of topsoil and regolith and the frequent mixing of soil with other materials.

The first documented reference to the movement of soil for land reclamation is found in the 1524 report drafted by eight commissioners and presented to Grand Master l'Isle Adam on the suitability of Malta as a base for the Knights of Saint John. Bosio (1602) summarized the content of the report on matters in Malta and included a word-to-word quote from the report. The following extracts are of relevance: "That Malta, ...was but an arid rock, covered many places with sand, and in a few with a light scattering of earth brought from the neighbouring continent, or Sicily; that it had neither river, nor rivulet, nor spring, nor any other fresh water for the most part, save rain preserved in tanks or cisterns, except few wells, rather brackish; that it produced a little grain, not half enough of anything to feed the scanty population . . . . ; that as to Gozo it was too little, though, in comparison of Malta, fertile and pleasant." This is the first time that the importation of soil is encountered as a documented reference.

The challenge posed by the remark of the commissioners of 1524, namely that the fields of Malta were created with imported soil, deserves historical evaluation. While it is conceded that the commissioners may have reported local feedback, evidence from the later Middle Ages would seem to contradict the commissioners' assertion. The discussion of late medieval agriculture by Wettinger (1982) does not document any substantial importation of soils from abroad. A limited amount of Sicilian soil may have reached the islands as ballast on trading ships before 1500. This possibility was noted by Ballou (1893, 64). Several authors continued to repeat the assertion of the 1524 report without verification. In the eighteenth century, Count Ciantar (1772, 425–7) took them to task, even identifying Maltese *Laniet* as the source of local *terra rossa*. As noted below, Lang (1960, 18) put the matter to rest.

One has to keep in mind that the 1524 report had a political agenda, relating to the proposed settlement of the Hospitaller knights in the Maltese islands. Thus, while the commissioners of 1524 painted a picture of an arid archipelago, Quintinus (1536) described the islands as irrigated with springs and dotted with fruit trees and rose gardens. Fifteenth-century records go some way to support Quintinus, notably concerning local viticulture, which laid greater demand for land, water, and labor than the widespread cultivation of cotton and cumin.

According to Murray (1890), Maltese country folks were known to collect any loose residue from rocks, cracks, crevices, and potholes, to spread on their fields. He describes the red clayey, whitish marly, and grayish type of soils found on various limestone bedrock, and, on these grounds, states that there is no basis for the widespread belief that soil was imported into the islands in past times and hence discards the notion. In the report entitled Agriculture in

Malta penned by Dawson Shepherd (1920), the author comments on the fact that the idea of soil importation from Sicily to cover the bare rock was firmly fixed in the mentality of people beyond the Maltese shores. He alluded to the fact that Malta imported pozzolana from Sicily in open barges. Pozzolana is a fine, sandy volcanic ash, originally discovered and dug in Italy at Pozzuoli in the region around Vesuvius, but later found in all the volcanic areas of Italy. When finely ground and mixed with lime, pozzolana creates a hydraulic cement and can be used as a strong mortar. It was used chiefly to render flat roofs of dwellings to channel rainwater toward a collection point to darn into a subterranean reservoir and to render the same reservoirs to prevent any water loss due to leaks. Coincidentally pozzolana comes in various colors: black, white, gray, and red, similar to hues found in Maltese soils. Hence tourists, on seeing barges heaped with pozzolana coming from Italy probably promulgated the idea that soil importation was an ongoing activity. The idea of the importation of soil continued to prevail well into the 1960s (Lang 1960). It is also worth noting that engineer Osbert Chadwick contributes to the subject in Murray (1890) to further disprove the hypothesis of soil importation.

A pre-modern technology

There is, on the contrary, good evidence of land improvement, including some indications as stipulated in land tenancy contracts. These concessions would occasionally set out conditions, including the building or rebuilding of surrounding walls, the excavation of cisterns, and the removal of stones. Moreover, public acts record how public wastelands and pastures were granted to private holders who converted them into cotton-growing fields, while prominent landlords expropriated public common lands through enclosures (Wettinger 1982, 10–11, 31–33).

The toponymic evidence from pre-modern Malta and Gozo documents the prevalent use of terms, frequently of Arab origin, to refer to every field and strip of land (Wettinger 2000). Zerafa (1838: xviii-xix) documented the word *ktaien* (Malt. Ktajjen) used by Maltese farmers to refer to man-made ridges in the valleys to contain soil deposits through water courses and facilitate the creation of fruit plantations. No doubt these practices refer to the construction of *campi artificiali* (as noted below).

Formation of new man-made soils

The technology behind the transformation of barren land into arable areas goes beyond the simple translocation of soil from one site to another as described by Giacinto (1811). A unique technique employed in the creation of new soils is described by Hennen (1830). This manuscript gives great details on how the Maltese of the period labored to manufacture new soil thereby transforming barren rock into productive fields. Since the bedrock of the Maltese islands is made up of various types of soft limestone, the Maltese soon realized that it can be crumbled and crushed into a fine matrix just by using hand tools. The farmers took advantage of this, and after breaking down stones, the crumbled powder was mixed with other suitable substrates that were previously collected. Any organic matter would eventually be incorporated to start the soil formation process and supply fertilizer nutrients. According to MacGill (1839) at the time, every rural dwelling had ground-floor level quarters for animals with an adjacent dung room to receive all of the animal manure plus litter and any other organic waste generated by the household. In addition to this, other organic scraps collected from the seashores, streets, and markets were collected and also incorporated to form an artificial soil, which, in the course of two or three years, under proper culture, yielded adequately.

The following is a synopsis of the technique employed for the manufacture of new man-made soil: heaps of smaller stones were gradually crushed using hand tools such as hammers or mallets and broken into pieces of smaller size and crushed to manufacture the new soil substrate. Any soil and other loose material were collected and added to the substrate. This would include greensand and clay either found as substrates or outcrops. Before spreading on the ground, projecting rocks were removed and the surface leveled off as much as possible and covered with a layer of crushed stones and regolith at about 30 cm deep. When the surface is leveled off, a layer of the newly manufactured soil substrate (pulverized stones) is placed on top and mixed with the stones layer. This second layer is spread to a depth of about 30–45 cm and spread over the whole field, followed by a stratum of dung and an additional layer of the new soil substrate.

Alternatively, the leveled site is covered with a layer of previously collected soil that had accumulated due to erosion as sediments at the bottom of valleys, followed with a dressing of compost or manure, and finished off with the spreading of a second bed of earth.

Initially, the edaphological properties of this newly formed artificial soil would be low and would have yet to be developed and mature. The transformation from a complex of crushed stone, dust, and organic matter to the formation of a structured soil requires time to cure, develop, and gradually acquire its yielding potential. The rubble walls that are usually found surrounding fields, apart from acting as a physical support to stabilize the field, also complement the conditions required to favor soil formation by allowing for the cultivation of crops and retaining soil moisture. Over successive cropping seasons, the accumulation of organic input from crop residues (roots, stubble, etc.), and the application of natural fertilizers and compost will gradually build up and enhance the profile and characteristics of this new soil. Under proper management, the maturation of the soil's edaphological characteristics will improve the fertility of the man-made artificial soil.

Farming implements

Farming implements, although suited to local conditions, involved considerable hand labor (Figure 1). The wooden iron-shod plow constituted the main tillage implement and small cultivators were unknown. Livestock and a crude romblu attachment were used for threshing. The local variety of cow was still a draught animal, not efficient for good milk or meat production (Dawson Shepherd 1920, 10–11).

In 1930, Azzoppardi noted that farmers who lived exclusively off the production from their holdings were relatively few and also led a very simple life. As their children grew older, they were assigned light work such as potato seeding, and when over 18 years, they participated in the more arduous farm duties. Girls carried out the same light duties as boys, but when adults either went to town to work as maids or helped in the housework or worked in the fields (Azzopardi 1930, 94–96).

A day in the life of a farmer would entail a very early start, with work already starting by sunrise in the fields, after the hearing of Mass. Farmers not living in a farmhouse close to their holdings would resort to a donkey and cart for the transport of tools and children. A half-hour break was taken around nine o'clock and at midday, an hour's rest was provided in winter and two hours in

Figure 1. Hand implements. Source: Azzopardi (1930)

Figure 2. Animal-drawn implements. Source: Azzopardi (1930)

summer. Engaged workers would remain till sundown, while farm proprietors would continue working till almost nighttime. It was not unusual for farmers harvesting cereals to sleep over their stacked hay (Azzopardi 1930, 96–97).

Bowen-Jones, Dewdney, and Fisher (1961, 321–322) observed that the plow, hoe, sickle, and harrow used in the Maltese islands were typically Mediterranean. The animal-drawn plows (Figure 2) had no cutting edges on their steel tips and ridging together with furrow inversion was restricted except in cases when a modified version that had a movable double moldboard was resorted to. Usage of these traditional implements, however, had started to decline due to increased availability of import substitutes. Farmers with accessible fields were contracting tractor-operated plowing, while those with smaller and less approachable holdings sometimes hired or purchased rotary cultivators. The particular attraction of the cultivator was that while it could till six tumoli (1 tumolo = 0.1124 hectare) in one day, an animal-drawn plow could only cover between two and three tumoli while using solely a hoe, one could just work a tumolo.

Soil fertility

Since antiquity land stewardship has incorporated the use of organic matter in the creation of new soils and to maintain and improve soil fertility. Davy (1842a,b) comments that "The perfect knowledge and the free use of manure is one of the most important features of Maltese farming." In the pre-1800 one would assume that most of the organic matter would be chiefly composed of vegetative matter and green manure, with the addition of some animal manure in the form of bedding utilized for goats, sheep, and rabbits. Post 1800, the importation and fattening of store cattle increased to meet the needs of the British forces for beef. Thus, more animal manure was available for spreading and consequently available for fertilization. Davy (1842a,b) noted that the manure used was mainly stable and farm-yard dung; no composts, no mineral, fossil, or other fertilizers, had up to then been employed. Organic manure can stimulate the gradual transformation of dust from pulverized stones into a conglomerate of soil. This concept is again mentioned by Castagna (1865) who remarks that the Maltese farmer had a good grasp on the role of organic manure in maintaining soil structure and fertility. He states that fresh uncured manure was more sought after than the dried type, due to its long-lasting capacity of warming the soil and increasing soil aggregation. The use of dried manure was utilized as a top dressing every year. He narrates that, to obtain fresh manure, as soon as the dung was collected from the barns, it was immediately spread on the soil; and the soil will support a crop of grain followed by a crop of sulla (*Hedysarium coronarium*), widan (*Scorpiurus muricatus*) or beans. Castagna (1865) tabulates that cattle manure was best suited for the red (ħamri) and white (bajdani) type of soils, while that of the horse, donkey, or mules was used on clay soils. Urine was also highly prized as a fertilizer, so much so that the barn floors were sloped to collect the liquid portion into a trough so that when mixed with bedding and dung it would help to make a better fertilizer.

Crop rotation

Once the man-made soil is ready for planting, a traditional crop rotation program was implemented (Hennen 1830). In the first two years, the crops of choice were melons (an excellent fruit, which is preserved during the winter, and distinguished by the name of Maltese melons) and cucumbers that were cultivated with the occasional application of small amounts of dung. The decaying process of the manure and vegetable remains improved soil structure and its overall fertility. In the third year, the ground was plowed and planted with grain crops, the stubble was left in the fields while the straw was used as fodder for ruminant animals. This was the process employed to gradually develop and mature the man-made soil and establish this artificial soil into a state of cultivation.

Once the edaphological properties were established, the land was never permitted to rest but was worked continuously without fallow. Wheat, barley, cotton, cumin, potatoes, beans, pulses and peas, vetches, sulla, melons, pumpkins, marrows, onions, maize, tomatoes, saffron, and various vegetable varieties constituted the main dry-farming crops. Wheat was sown every alternate year with barley and sulla at around November. The barley was gathered in May, whilst wheat and sulla were harvested in June. After this crop, the fields were sown with cotton, melons, cumin, sesame, and other seeds. Occasionally, peas, beans, and other leguminous plants were planted instead of barley (Table 1) to replenish soil fertility through the symbiotic association that exists with

Table 1. Early twentieth-century crop rotations.

	Four Year Rotation
Year 1	Spring crop potatoes planted in January; summer fallow; winter crop potatoes planted in September/October.
Year 2	Spring fallow; cotton sown in April/May and picked in September–November.
Year 3	Winter and spring legumes - vetches and pulse beans; summer fallow.
Year 4	Wheat sown until December.
	Cyclic Crop Variation - I
Cycle 1	Spring crop potatoes planted in January; summer fallow.
Cycle 2	Green barley from November to February; cumin; summer fallow.
Cycle 3	Sulla sown on cumin stubble or barley stubble.
Cycle 4	Wheat.
	Cyclic Crop Variation - II
Cycle 1	Spring crop potatoes planted in January; summer fallow.
Cycle 2	Green barley from September to March; summer fallow.
Cycle 3	Sulla or beans, to April–May.
Cycle 4	Wheat.

Source: Dawson Shepherd (1920).

microorganisms which fix atmospheric nitrogen and make it available to the host and other crops by a process known as biological nitrogen fixation (BNF).

Irrigated land was rarely left fallow, with marrows, potatoes, and tomatoes being the most common types of irrigated crops (Dawson Shepherd 1920, 12–13).

Rainwater harvesting

Since most of the land is rain-fed, the lack of available fresh water for irrigation has long been recognized as one of the major limitations for agriculture and hence human survival. Precipitation is limited and highly variable from year to year, with a predominance of rainfall during October. This pattern of precipitation provides moisture during a period when demand for crops is relatively low, i.e., when the rate of plant growth is at its slowest. Conversely, when the potential for plant growth is high, natural moisture is almost completely absent. The severe scarcity of this natural resource has encouraged successive generations to be as creative as possible in harvesting rainwater for use at a later stage when crop water demands are at their peak.

Besides toponymic evidence, recent archaeological studies by Buhagiar (2016) have hypothesized how water harvesting technology contributed to the formation of the rural landscape. Perched aquifer gallery systems datable to pre-modern times exploited areas of local blue clay and upper coralline limestone. Buhagiar (2006) notes that since antiquity water stored above the Blue Clay deposits was recognized as a readily accessible resource. Furthermore, particular areas with Blue Clay stratification created perennial water sources, and wells and water galleries were dug into Upper Coralline or Greensand strata to tap the underlying water source. Water was transported to nearby fields by a network of stone canals. Vertical shafts in galleries were also resorted to and animal-driven water-lifting devices such as the noria or sienja were eventually adopted. Buhagiar adds that the water galleries are tentatively dated to the Arab occupation of the island when new horticultural improvements were introduced (2008).

Most of the techniques utilized to make use of gravity, channeling runoff, and draining water from fields into underground holding reservoirs usually located at the lowest point of the property or else through channels on the surface of the bedrock leading to the reservoir to drain and direct the flow of excess water into the subterranean holding facility. These reservoirs were either dug by hand or else using naturally occurring depressions or man-made cavities, as in the case of shallow disused quarries, to be roofed over and in most cases have the sides plastered with a coat of pozzolana to stop any water loss due to leakages. An adequate review of locally developed solutions for rainwater harvesting and irrigation systems was reviewed by Attard and Azzopardi (2005).

Passive irrigation

An ingenious locally developed technology that offers a solution for delivering moisture to plants even under the arid Maltese environment is through the principle of passive irrigation. The physical properties of the soft globigerina parent rock allow it to absorb and retain water. Murray (1890) takes note that Globigerina Limestone will absorb about one-fourth of its weight in water in 24 hours. Davy (1842a,b) notes that while the surface appears perfectly arid, this soft rocky surface readily absorbs and retains moisture at a considerable depth only to release it slowly during dry periods. While the Globigerina Limestone can be compared to a sponge, capable of holding vast quantities of rainwater, the presence of an intricate capillary network channels water against gravity, up from the deep toward the rock surface. This phenomenon creates a huge challenge for the building industry to overcome in providing dwellings with a dry living environment (Buhagiar 2007), but a blessing for agriculture in that the ascending dampness can be utilized as a source of passive irrigation water. It is due to this phenomenon that specific indigenous technology was developed that passively provides crop irrigation water.

Davy (1842a,b) describes that the rock surface that was to eventually be covered with soil was furrowed, at intervals, 2–5 cm deep. In so doing, the root balls being close to the scarred sides have access to the moisture present in the rock channels. Hence, the combination of night dew together with the dampness that emerges from the porous rock provided enough water in the form of passive irrigation to yield a harvest of crops from land with no access to traditional sources of irrigation water. This may be the rationale behind why some of the older generation farmers refer to certain fields as being "BLATA FRISKA," meaning soil sitting on a cool rock.

In time, the groves become encrusted with a calcium deposit (calcrete) which acts as a barrier that greatly reduces the capacity for the translocation of this water, a common practice, at least during the early 1800s, was to remove the soil once every ten years to re-expose the rock surface and the process of re-furrowing or re-grooving is repeated to clear the thick crust buildup to the depth of 3 cm or so to reopen the scars on the bedrock.

A modification to the above process, but still exploiting the same principle, consists of trench-like excavations carved into the bare rock on the barren stretches of the garigue landscape (Borg 1922). These trenches were shaped as troughs, filled with soil that was most probably collected from shallow deposits in the vicinity, and finally planted with vines. It is considered a modification and adaptation of technology in that while functioning to contain the sparse soil resource, it also acts as minute terrace pockets that also trap runoff rainwater. Borg (1922) records that in places that contained friable rock, trough-like ditches 1.5 to 2 meters long, 1 meter deep, and 0.5 meters wide were excavated with a pickax, filled in with the same broken material and two vines with a basketful of red earth planted in each trough. This technique, which in a way can also be perceived as a unique attempt of alley cropping is a sustainable approach for the production of grapes from an otherwise barren and soilless landscape. Davy (1842a,b), attributes the discovery of this technology that takes advantage of the rock base's unique geological property as being the most important contribution to Maltese agriculture.

Rubble walls

On many of the hills and rising grounds the fields are enclosed with stone walls, vernacular known as "ħitan tas-sejjieħ," a predominant and integral feature of the Maltese rural landscape, reflecting the history, knowledge, and skill of ancestral agrarian societies. These dry-stone walls employ great skills since they are built entirely without any use of bonding aggregate, cement, or mortar. Davy (1842a,b) gives a brief account of the technique of rubble wall building: The large stones were rudely dressed and utilized to construct the rubble wall five to six feet high at the bottom of the slope, behind which smaller stones were laid down to level off the depression directly behind the wall and to act as a sieve to release water pressure and act as a drain. After a rubble wall was built, the space created between the wall and the slope was refilled with the soil that was either previously removed or with newly manufactured soil substrate.

More recently, Ellul (2005) presents a comprehensive study of the various techniques employed in the building of rubble walls in Malta. In general, the type of wall built and its construction techniques depends on the topography and natural resources available in the surrounding area. It is common knowledge that terraced landscapes retard or even block soil erosion. Normally terraces are supported by rubble walls, and their integrity is of utmost importance. If not maintained and left to degrade, they will break down causing erosion paths that are not predictable in direction or dimension. The rubble walls, apart from retaining soil in place, also define the field and just as importantly delineate the property boundary and hence defines the ownership limits.

Campi artificiali

The appearance of cultivated hills where every field is contained by stone walls and each terrace holds about one meter of soil, reflects human ability and skills. Every declivity was transformed into a succession of such terraces, often small and narrow, at times more similar to steps rather than fields. A significant proportion of the cultivated fields probably falls within the category of land formed through human effort and labor, better known as "Campi Artificiali," which was first described by Professor Carlo Giacinto in a monograph published in 1811. An array of the above technologies was utilized in combinations that best suited the particular site, nonetheless, although relatively simple, they are very labor intensive (Azzopardi 1930). The width of these parapets or hanging grounds was determined by the greater or lesser acclivity of the hill. The construction of the enclosing rubble walls (Figure 3) offered protection against erosion and the intrusion of livestock.

The process of converting barren land into arable surfaces allowed survival through food security (Figure 4). However, as mentioned previously, an

Figure 3. Creating a field base. Source: Azzopardi (1930)

Figure 4. A new campo articificiale. Source: Azzopardi (1930)

important underlying factor for the development of indigenous technology and its implementation is land tenure security and the desire to maximize one's resources to improve livelihood. This is captured by Crowe (1853) that gives the following account: "Having mustered a few pounds, the Maltese purchases a square portion of what is rock; he falls to work upon it with his pickaxe, and with all the implements and aids required in working a quarry. During this operation he carefully saves and puts together every particle of what might be called earth, and, having excavated his plot of ground to a certain depth, he deposits at the bottom the larger blocks of stone, and over them layers of the finer and the finer, until he has nothing to strew upon the surface but the red earth, that he has gleaned, and sifted, and cherished, as never soil was. To this he adds all the refuse he can procure, the road sweepings, spare earth, or the semblance of earth, from other spots: and at last, he is the owner of a field, surrounded with stone walls, and bearing a marvelous succession of crops."

Conclusion

The Maltese were the most industrious people, who through their attained understanding of their environment have succeeded in managing to convert barren parts of the island into productive artificial land. Such structures are still visible to this day. Agricultural fields, with their conglomeration of rubble walls, terraces, and fields have become part of the Maltese landscape. The numerous stone walls, which cover the face of the country, may be said to be a work of necessity, as well as of use. A continued system of labor inputs has not only rendered the land surface capable of tillage but even made it fertile through the establishment of well-managed agroecosystems despite harsh climatic conditions. Apart from contributing to the Maltese economy, this process has knit a complex interaction between natural vegetation, geology, soils, hydrology, crops, water/land management, and socio-economic aspects and has been going on since the advent of man.

The first humans that arrived had to adapt to new environmental conditions, but the consequent exposure of the landscape and increased frequency of fire and erosion, whether due to climate change or otherwise, indicate a strategy to adapt and exploit land resources to support domesticated plants and animals. The conversion and construction of parcels of arable land is the living testimony of the will to survive.

The intimate relationship that the Maltese farmer developed with his land has cultured an in-depth understanding of the physics of the Maltese landscape. Nature, experience, and practice have selected the best technology suited for the Maltese Territory to promote multifunctional landscapes and conservation, and effectively provide environmental services in maintaining sustainable soils. This has led to hands-on knowledge of where to plant what, where, and when.

In appraising soil and water conservation, consideration of indigenous methods of soil and moisture conservation provides a better adaptation to physical and climatic parameters. Water harvesting, storage, and seepage control techniques aimed toward conservation are particularly effective as they are locally available, relatively cheap, and less destructive to local environments. The survival of the agricultural landscape has shown that the interconnectedness of man with his enviroment can result in positive long-term interaction. Understanding the strength and weaknesses of indigenous conservation practices that have stood the test of time could provide useful insight to develop land and water management strategies. Indigenous technology can, and should, assist as the starting point for the sustainable development of agroecological conservation programs of a region.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

No funding was requested or awarded to prepare this paper.

Author contributions

Conceptualization, G.A. and T.M.; methodology, G.A and T.M; writing – original draft preparation, G.A, C.D. and T.M.; writing – review and editing, G.A and T.M.; visualization, G.A.;. All authors have read and agreed to the published version of the manuscript.

References

Attard, G., and E. Azzopardi. 2005. An overview of irrigation system performance on the island of Malta. *Options Méditerranéennes* 52:165–72.

Azzopardi, A. 1930. L'Agricoltura e gli Agricoltori di Malta. R.Istituto Superiore Agrario, Portici, Gabinetto di Economia Rurale dissertation.

Ballou, M. M. 1893. *The story of Malta*. Boston and New York: The Riverside Press.

Blouet, B. 1992. *The story of Malta*. Valletta: Progress Press.

Borg, J. 1922. *Cultivation and diseases of fruit trees in the Maltese Islands*. Malta: Government Printing Office.

Bosio, G. 1602. Auteur Du Texte. Dell' Istoria Della Sacra Religione Et Illustrissima Militia Di San Giovanni Giorosolimitano Di Jacomo Bosio, (volume 3 page 30,31). Facciotti.

Bowen-Jones, H., J. C. Dewdney, and W. B. Fisher. 1961. *Malta, background for development*. Durham College: Department of Geography.

Buhagiar, K. 2006. Water management in Medieval and Early Modern Malta. In *Malta in the Hybleans, the Hybleans in Malta: Malta negli Iblei, gli Iblei a Malta*, ed. A. Bonanno and P. Militello, 259–67. Palermo: Officina di Studi Medievali.

Buhagiar, K. 2016. The tal-Callus and Simblija estates at Wied ir-Rum and Wied Hazrun (Malta): an enigma resolved.

Buhagiar, V. 2007. Technical improvement of housing envelopes in Malta in cost C16, improving the quality of existing urban building envelopes.

Carroll, F. A., C. O. Hunt, P. J. Schembri, and A. Bonanno. 2012. Holocene climate change, vegetation history and human impact in the Central Mediterranean: Evidence from the Maltese Islands. *Quaternary Science Reviews* 52:24–40.

Castagna, P. P. 1865. Lis Storja ta Malta bil Gzejer Tahha, 3 volumes 2nd edition, Stamperia ta C. Busuttil, Valletta, 1890.

Chetcuti, D., A. Buhagiar, P. J. Schembri, and F. Ventura. 1992. *The climate of the Maltese Islands: A review*. Malta: Malta University Press.

Ciantar, C. G. A. 1772. *Malta illustrate ovvero descrizione di Malta isola del mare Siciliano ed Adriatico, Vol 1*. Malta: Stamperia del Palazzo.

Crist, R. E. 1956. Malta: development problems and economic prospects. *The American Journal of Economics and Sociology* 15 (4):369–381. doi:10.1111/j.1536-7150.1956.tb00131.x.

Critchley, W. R. S., C. Reij, and T. J. Willcocks. 1994. Indigenous soil and water conservation: A review of the state of knowledge and prospects for building on traditions. *Land Degradation and Development* 5 (4):293–314. doi:10.1002/ldr.3400050406.

Crowe, E. E. 1853. *The Greek and the Turk: Or powers and prospects in the levant*. Whitefish, MT: Kessinger Publishing.

Davy, J. 1842a. Notes and observations on the Ionian Islands and Malta. London, Smith, Elder & Co., Cornhill. Volume 1 (2 volumes).

Davy, J. 1842b. *Notes and observations on the Ionian Islands and Malta with some remarks on Constantinople and Turkey, and on the system of quarantine as at present conducted*. London: Institute of Neohellenic Research.

Dawson Shepherd, J. 1920. A report on agriculture in Malta. Malta.

Ellul, E. 2005. “Il-Hitan Tas-Sejjieh” published by Klabb Kotba Maltin
Gambin, B., V. Andrieu-Ponel, F. Médail, N. Marriner, O. Peyron, V. Montade, T. Gambin, C. Morhange, D. Belkacem, and M. Djamali. 2016. 7300 years of vegetation history and climate for NW Malta: A holocene perspective. *Climate of the Past* 12 (2):273–97.
Giacinto, C., (Carmelitano). 1811. *Saggio di Agricoltura per le isole di Malta e Gozo Roma*. Italy: Nabu Press.
Hennen, J. 1830. Sketches of the medical topography of the Mediterranean; comprising an account of Gibraltar, the Ionian Islands, and Malta. To which is prefixed a sketch of a plan for memoirs on medical topography. By J. Hennen. . . Edited by his son, J. Hennen.
Lang, D. M. 1960. Soils of Malta and Gozo. *Soils of Malta and Gozo.*, (29).
MacGill, T. 1839. A handbook, or guide, for strangers visiting Malta.
Marriner, N., T. Gambin, M. Djmali, C. Morhange, and M. Spiteri. 2012. Geoarchaeology of the burmarrad ria and early holocene human impacts in western Malta. *Palaeogeography, Palaeoclimatology, Palaeoecology* 339-341:52–65. doi:10.1016/j.palaeo.2012.04.022.
Murray, J. 1890. The Maltese islands, with special reference to their geological structure. *Scottish Geographical Magazine* 6 (9):449–88. doi:10.1080/14702549008554551.
Primavera, M., C. D’Oronzo, I. M. Muntoni, F. Radina, and G. Fiorentino. 2017. Environment, crops and harvesting strategies during the II millennium BC: Resilience and adaptation in socio-economic systems of Bronze Age communities in Apulia (SE Italy). *Quaternary International* 436:83–95. doi:10.1016/j.quaint.2015.05.070.
Quintinus, J. 1536. *Insulae Melitae Descriptio. Apud Seb*. Lyon: Gryphium.
Trump, D. H. 1990. *Malta an archeological Guide*. Malta: Progress Press.
Wettinger, G. 1982. Agriculture in Malta in the late Middle Ages. Proceedings of History Week 1981. The Malta Historical Society: Malta. 1–48
Wettinger, G. 2000. *Placenames of the Maltese Islands, ca. 1300-1800*. San Gwann Malta: PEG.
Zerafa, S. 1838. *Discorso sulla storia fisica di Malta e sue adiacenze*. Malta: Tipografia F. Naudi.