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Research Article

A Land Use and Land Use Change Study of the Maltese Islands (1998-2012)

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Abstract. A thorough understanding of past spatial and temporal land use variations is critical for evaluating the effectiveness of land use policies and guiding future decisions towards sustainable management. Such knowledge places current land use trends in a historical context, allowing for better modeling of potential future scenarios. This study contributes to this understanding by providing two high-resolution datasets. The first dataset presents a fine spatial resolution land use map of Malta for 2012, with a minimum mapping unit (MMU) of 0.01 km^2. The second dataset offers a very fine spatial resolution map (MMU of 0.0005 km^2) that documents the spatial changes in artificial surfaces and the land uses they replaced between 1998 and 2012. The analysis shows that artificial surfaces in the Maltese Islands covered 48.13 km^2 in 1998, increasing by 4.68 km^2 to 52.81 km^2 by 2012. In 1998, 84% of these artificial surfaces were located within development zones (within scheme), 14% were found outside of combined development and environmental designations, and 2% within environmentally designated areas. Structure Plan policies during this period successfully confined 49% of new artificial surfaces within development zones. However, 48% of new artificial surfaces were constructed outside of development designations, and 3% were built within environmentally protected zones. These findings suggest that the Structure Plan's policy framework was only partially effective in containing urban expansion within designated areas, while environmental policies were more successful in curbing industrial and residential development within protected zones. New artificial surfaces during the study period primarily replaced agricultural land, both used (1.84 km^2) and abandoned (1.40 km^2), as well as semi-natural areas (0.43 km^2). This research highlights a misalignment between the intended objectives of land use policies and the actual land use changes observed over the 14-year period. It underscores the importance of acquiring detailed spatial and temporal data to inform national land use and resource management policies aimed at promoting sustainable land use. An accurate assessment of these variations is crucial for adjusting policy measures to achieve the desired outcomes in future land management efforts.

1 Introduction

1.1 Spatial and temporal variations of Maltese land use

A comprehensive understanding of spatial and temporal variations in land use from 1998 to 2012 is crucial for assessing the impact of land use policies and informing future strategies aimed at promoting sustainable land management. Such insights provide the necessary foundation for placing current land use trends within a historical framework, which in turn enables more accurate modeling of potential future land use scenarios.

Three primary datasets offer partial insights into the spatial and temporal dynamics of Maltese land use during this period: (1) the CORINE land cover data, (2) the MEPA (Malta Environment and Planning Authority) urban development maps, and (3) the spatial distribution and number of MEPA-issued development permits. These datasets, while valuable, each possess inherent limitations that restrict their ability to comprehensively capture land use changes over time.

The limitations of these datasets highlight the need for more detailed and higher-resolution data to fully assess land use dynamics and policy impacts in Malta. A more robust understanding of land use changes requires integrating these datasets with newer, more detailed mapping efforts, allowing for a more precise analysis of land use trends and their implications for sustainable development.

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1.1.1 CORINE Malta

The European Environment Agency's CORINE (Coordination of Information on the Environment) system, specifically the CORINE Land Cover (CLC), provides periodic assessments of land cover and land cover change across Europe. Utilizing a minimum mapping unit (MMU) of 25 hectares (0.25 km^2), the CLC is designed for monitoring large-scale land use changes. While this scale is suitable for broad regional analyses, it has limitations when applied to smaller territories with more intricate land use dynamics, such as the Maltese Islands.

According to CLC analyses, land cover changes in Malta were minimal, with a reported change of only 0.07% between 1990 and 2000, and no recorded changes between 2000 and 2012. Moreover, between 2006 and 2012, no changes were observed in urban areas, agricultural land, or natural cover (European Environment Agency [EEA], 2017, p. 61). However, these results are likely skewed by the CLC's relatively coarse spatial resolution, which fails to capture smaller-scale land use changes that are critical in highly urbanized and spatially constrained environments like Malta.

The inability of CLC data to detect such changes underscores its limitations for detailed, short-term land use monitoring in the Maltese context. To accurately assess land use dynamics, particularly in a setting characterized by rapid urban development and constrained land resources, a finer spatial resolution is necessary. Such detailed analysis is essential for informing land use policy, managing natural resources, and achieving sustainable development goals in Malta.

1.1.2 MEPA base maps and Local Plan maps

The MEPA (Malta Environment and Planning Authority) base maps were designed to represent various land use types across the Maltese Islands, capturing features such as road alignments, yards, stone structures, and built-up areas. These built-up areas were further categorized into hard buildings, soft buildings, and pavements. The maps offered a very fine spatial resolution, accurately delineating the spatial and areal distribution of land uses. However, updates to reflect de facto land use were conducted infrequently, particularly outside development zones (referred to as "within scheme" areas). While updates were more regularly applied to areas within development zones, land use in areas outside combined development and environmental designations often remained outdated, with older, no longer accurate land use classifications persisting.

This inconsistency in updates resulted in base maps that functioned as a mosaic of time-specific land use depictions, with many regions failing to reflect contemporary land use or built-up environments. Additionally, key data concerning the extent of development in 2000 and 2012 is not available, as confirmed by personal communication with MEPA (10 October 2016). Consequently, these maps do not provide a reliable or up-to-date representation of land use and therefore limit the ability to perform accurate spatial and temporal analyses of land use dynamics in the Maltese Islands.

1.1.3 Number and areal extent of permits

In parallel, trends in development applications and permits provide insight into the pressures exerted on land resources by the construction sector. For example, between 2010 and 2011, the number of permissions granted for new dwelling units decreased by 11%, from 4,444 to 3,955, with 83% of the permitted units being apartments (Malta Environment and Planning Authority [MEPA], 2011). Although this dataset provides valuable information on the volume and location of applications, it does not capture the associated changes in impermeable surfaces, which are critical for understanding the broader environmental and spatial impacts of development. Consequently, while these datasets offer some insights into development trends, they fall short of providing a comprehensive understanding of the changes in land use and associated impacts on land resources.

1.2 This study

The present study provides two distinct datasets that offer insights into land use in Malta. The first dataset is a high-resolution land use map for the year 2012, with a minimum mapping unit (MMU) of 0.01 km^2. This dataset offers a spatial resolution 25 times finer than that of the CORINE land cover inventory for the same period (which has an MMU of 0.25 km^2), thereby providing more detailed spatial information. The second dataset presents an even finer spatial resolution map, with an MMU of 0.0005 km^2, which captures land use changes from 1998 to 2012. This map specifically focuses on the transformation of artificial surfaces, defined here to include residential, industrial, port/airport, quarry, green urban areas, and greenhouse land uses (see Table 2 for detailed definitions). The resolution of this land use change analysis is significantly more refined than the 0.05 km^2 MMU of the CORINE land cover change dataset (http://land.copernicus.eu/pan-european/corine-land-cover), thus enabling a more precise assessment of spatial changes.

These datasets provide crucial insights into how national land use policies have influenced the spatial distribution and changes in land use over time. However, it is important to clarify that while this study documents land use change, it does not evaluate the legal status of any expansion in impermeable surfaces, such as whether such developments were legally permitted.

2 Maltese context

2.1 Socio-economic context of the period under consideration (1998-2012)

The period from 1998 to 2012 saw significant demographic and economic changes in Malta, which influenced land use dynamics. The population increased from 386,397 in 1998 to 421,364 in 2012, with population density rising from 1,223 to 1,333 persons per km^2, far exceeding the EU average of 117 persons per km^2 (National Statistics Office Malta, 2011).

Economically, Malta's gross value added grew by 69% between 1995 and 2004 and by 62% from 2004 to 2014, driven by a shift from agriculture, fisheries, and manufacturing to a service-based economy, particularly tourism, professional services, and information technology (Grech, 2015). Economic growth placed increasing pressure on land resources, particularly through real estate investment (Sustainable Development Directorate Malta, 2015).

2.2 Policy control on development during the period under consideration (1998-2012)

The 1992 Development Planning Act (DPA) (Cap. 356.) set out the legal framework for planning in Malta. The DPA presented a hierarchical system of development plans and planning policies on which decisions regarding land use change are based. Chief among these is the 1990 Structure Plan (SP) for the Maltese Islands. The SP established 320 policies providing strategic land use regulation at the national level (MEPA, 2004). The SP inter alia provided a strategic direction that guided Malta's development over a twenty-year period (1990-2010). The plan also sought to channel urban development activities into existing built-up areas (Ministry for Development and Infrastructure, 1990). On a strategic level, the SP divided the Maltese Islands into five broad categories: existing built-up areas, temporary provision scheme, primary development areas, non-urban areas and ODZ settlements. Each category consisted of policies that set out broad guidelines for development control. Site-specific development guidelines and policies were further elaborated upon in the individual Local Plans (LPs).

LPs (Figure 1) provided local level interpretations of the national strategic policies set out in the SP. Five of these local plans were approved in 2006: the North Harbour Local Plan (NHLP), the North West Local Plan (NWLP), the Gozo and Comino Local Plan (GCLP), the Central Malta Local Plan (CMLP) and the South Malta Local Plan (SMLP). Two LPs had been approved in 1995 and 2002 respectively: Marsaxlokk Bay Local Plan (MBLP) and the Grand Harbour Local Plan (GHLP) (the latter was reviewed in view of Smart City development approved in 2007). The SP and LPs were supported by a set of supplementary planning guidance notes (planning policies) (MEPA, 2010). These LP indicated where development could take place and the criteria against which development proposals would be assessed by the previous Malta Environment and Planning Authority (MEPA), the designated competent authority. The main function of the LP was to guide development by seeking a sustainable balance between economic, social and environmental needs (MEPA, 2006, p. 1).

2.3 Environment designations aims

Malta's unique habitats and species are protected through various designations, including Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), Bird Sanctuaries, Nature Reserves, Special Areas of Conservation (SAC), and Special Protection Areas (SPA). By 2008, approximately 20% of Malta's land area was under some form of environmental protection.

It is important to note that environmentally designated sites are not a system of strict nature reserves where all human activities are excluded. Rather, these designations aim to ensure the sustainable management of natural areas, allowing for ecologically and economically viable human activities rather than enforcing strict exclusion zones.

3 Materials and Methods

3.1 Remote sensing versus visual interpretation of land use and land use change

Change detection, as defined by Singh (1989), is the process of identifying differences in a phenomenon by observing it at different times. While remote sensing (RS) data is widely used for land use change detection (Chen et al., 2012; Coops et al., 2006; Lunetta, 1999), its effectiveness depends on the object's spectral changes (Deer, 1995; Green et al., 1994; Jensen, 1983; Singh, 1989). Various change detection techniques and methods have been developed; however, the selection of the most appropriate change detection method is challenging (Lu et al., 2004).

Typically, a threshold value is applied in change detection algorithms to distinguish change from no-change. The technique, however, is beset by various issues, namely, the appropriate selection of threshold values identifying change (Jensen, 2005; Lu et al., 2004; Xian et al., 2009; Zuur et al., 2007). If threshold values are too low or high, areas of change may be mis-, under- or over- detected. Another key limitation affecting change detection techniques is the application of RS data sets of different spectral range. RS dataset consisting of different

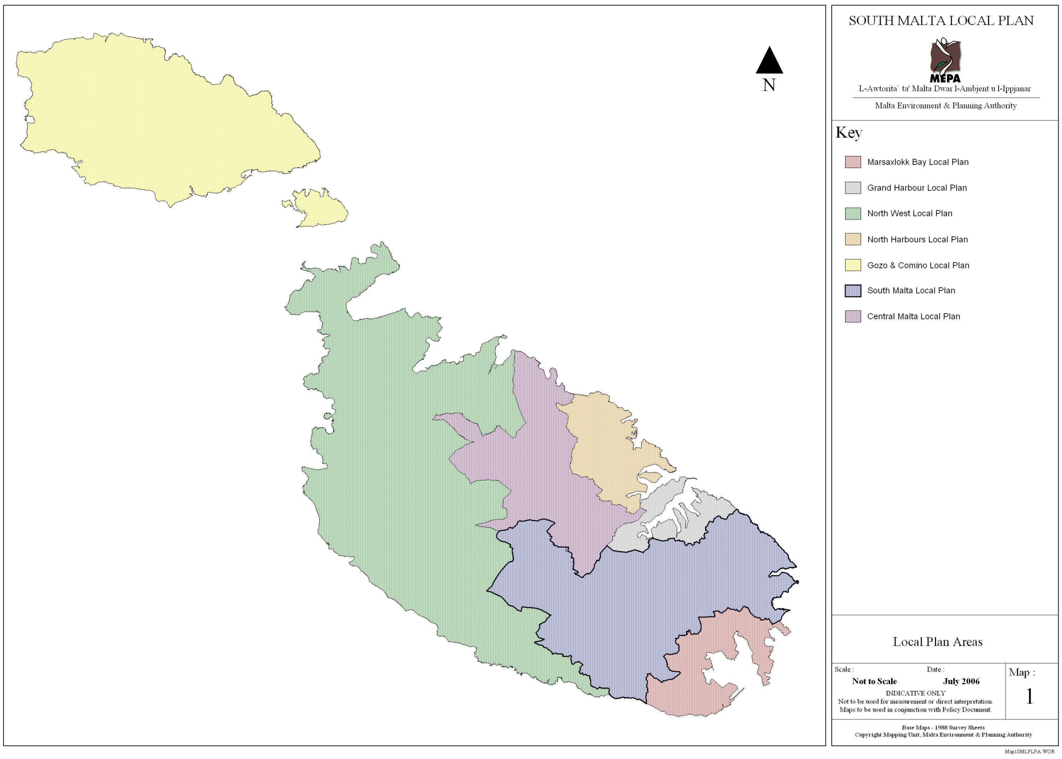

Figure 1: Map showing the distribution and extent of Local Plans.

spectral information raises questions about selecting classification algorithms and threshold values (Fung, 1992; Hussain et al., 2013). The classification of coarser resolution image will also overlook certain features, making a match to features observed in the finer scale remote sensing difficult. Different resolutions may also prevent an accurate overlay, further complicating change detection (Bontemps et al., 2008).

The available MEPA orthophoto datasets for 1998 and 2012 differ significantly in both spatial resolution and spectral range, with the 1998 dataset being coarser and having a lower spectral range than the 2012 dataset. Given these disparities, as well as the inherent limitations of remote sensing-based change detection methods, this study employed manual interpretation for land use assessment and change detection. Human operators were able to account for these variations and extract nuanced information that pixel-based methods often struggle to capture (Hussain et al., 2013).

3.2 Data used (1998 and 2012 orthophotos) and GIS software

Orthophoto datasets of the Maltese Islands were created from aerial imagery captured in 1998 and 2012. These orthophotos, geometrically corrected for topography, lens distortion, and camera tilt, allow for accurate measurement of distances and areas. Land use and land use changes were assessed using these orthophotos with the support of GIS software.

3.3 Land use and land use change detection methods

3.3.1 Study of land use 2012

The 2012 orthophoto data set was used to assess land use and land cover over the entirety of the Maltese Islands. A minimum mapping unit of $0.01km^2$ was established. The resulting land use map is distinct from previous land use maps for this period (2012) in that it combines various elements which, in previous maps, may have been individually focused upon, to the detriment of other key elements. The land use map presented in this study (i) applies a very fine spatial resolution, (ii) applies a consistent methodology in identifying land use across the Islands, (iii) assesses land use across the Islands at a fixed point in time (2012), and (iv) applies, where relevant, information from various other nationally recognised land use datasets to add land use and cover information that may be difficult to conclusively identify with the sole use of orthophoto images. Data sets that were referred to in the interpretation of land use are: MEPA Mapping Unit base maps, MEPA Ecosystems Management Unit terrestrial biota habitats, and MEPA Ecosystems Management Unit agricultural land. These data sets are based on site in-

Land use and reference number	Description
2.5: Abondoned and degraded arable land	The category includes agricultural areas that have been disused for an extended period of time and are vulnerable to soil erosion and degradation. Identifying features may include agricultural fields (i) predominantly occupied by steppe terrestrial habitat; (ii) not listed as Used Agricultural Area (UAA). (iii) clearly in state of abandon, distinguishing features may include: dilapidated rubble walls, gullying soil erosion etc. (iv) showing a colour difference compared to fields in use, (v) having undergone significant change in cover with the intent of changing overall area use (e.g. paving, entertainment areas, soil compaction) that increase the risk of land degradation.
3.4: Degraded semi-natural land	The category includes natural areas (steppe, garrigue, mixed forests, beaches, dunes and sand plains) that have been degraded through various human activities and are consequently vulnerable to soil erosion and degradation.
3.2.3.1: Steppe and garrigue	Steppe is characterised by herbaceous plants especially grasses; it is devoid of trees and mainly comprises annuals. During the dry season, steppe appears dry and impoverished because most plant species will, at the time, exist in the form of seeds. Garrigue is characterised by low-lying, usually aromatic and spiny woody shrubs that are resistant to drought and exposure. This habitat type often composed of kermes oak, lavender, thyme and white cistus. There may be a few isolated trees.
3.2.3.4: Maquis	Maquis generally consists of small oaks, oleasters, arbutus, lentiscus, junipers, briarwood and an understorey/undergrowth of cistus and low heathers.

Table 1: Land use class and distinguishing criteria for non CORINE land uses used in the Maltese 2012 land cover study. Descriptions for 3.2.3.1. and 3.2.3.4. are taken, in part, from CORINE.

vestigations and are therefore considered a reliable source of very fine-resolution data.

The land use classes (and their reference numbers) and the criteria used in distinguishing between various land uses follow those applied by the standard CORINE methodology (http://www.eea.europa.eu/publications/COR0-landcover). The land uses assessed follow: (1.1.1) continuous urban fabric, (1.1.2) discontinuous urban fabric, (1.2.1) industrial and commercial units, (1.2.2) road networks, (1.2.3) port areas, (1.2.4) airport areas, (1.3.1) mineral extraction, (1.3.2) dump sites, (1.3.3.) construction sites, (1.4.1) green urban areas, (1.4.2) sports and leisure, (2.1) arable land, (2.2) permanent corps, (3.1.3) mixed forests, (3.3.1) beaches, dunes and sand plains, (3.3.2) bare rock and (4.2.1) salt marshes. The number in from of the land uses are standard reference numbers applied in CORINE studies. In view of the finer spatial resolution assessed in this study, a number of land use classes were added that are not available in the CORINE land use framework. These are: (3.2.3.1) steppe and garrigue, (3.2.3.4) maquis, (3.4) degraded semi-natural, the three of which are subdivisions of the CORINE land use class 3.2.3 sclerophyllous vegetation; (2.5) abandoned and degraded arable land, a subdivision of the CORINE land use class 2.1 arable land. A description of identifying criteria for the above non-CORINE land use classes is provided below (Table 1).

3.3.2 Study on the change in artificial surfaces 1998-2012

The 1998 orthophotos were assessed in terms of presence of impermeable and/or man-made surfaces. The assessed impermeable surfaces and their descriptions are presented in Table 2. A minimum mapping unit of 0.0005km^2 was applied. Roads and road infrastructure are not included in the study and are therefore not mapped. Identifying and distinguishing criteria for the above listed impermeable surfaces are described in Table 2.

Once artificial surfaces were identified in the 1998 orthophotos, the 1998 artificial surfaces layer was overlain onto the 2012 orthophoto. Areas demonstrating an increase or decrease in artificial surfaces equal to or greater than 0.0005km^2 were identified as new polygons pertaining to an artificial surface class. The land use which was replaced by new (2012) artificial surfaces was identified from the 1998 orthophotos. The previous land use was categorised as: agricultural land, abandoned agricultural land turning into semi-natural or degraded land, natural land, quarry, dump, construction site, landscapes and gardens, and artificial land use that did not fulfil MMU in 1998 but expanded and in 2012 fulfilled MMU. In addition to the listed distinguishing criteria, contextual information

Land use and reference number	Description
1: Residential and Lodging (guest-houses and hotels)	Residential areas in city and village centres, around the edge of urban district centres, and certain urban districts in rural areas. These units consist of blocks of flats and groups of houses (not divided by roads), individual houses and residential gardens (with an area < $0.001km^2$). Due to the often similar nature of residential units (e.g. blocks of apartments), guesthouses and hotels, these three land use categories have been considered in the same land use category. This category of the nomenclature does not include scattered agricultural habitation (comprising agricultural building or shelters).
2: Industrial	Industrial complexes which demonstrate a footprint and plan layout that is atypical of residential units. Also includes associated landscaped areas and car parks which are predominantly artificially surfaced (cement, asphalt, tarmac) with minimal vegetation.
3: Ports or Airports	Ports: includes infrastructure of port areas, including dockyards and marinas. Industrial and commercial units located in immediate proximity should be singled out and defined as industrial or commercial units. Airport: includes airport installations: runways, buildings and associated land. Buildings (terminal buildings, hangars, workshops, warehouses, storage tanks), and associated spaces are included in the airport surface area.
4: Quarry	Areas with open-pit extraction of construction material (sandpits, quarries) or other minerals (open-cast mines) are included in this category. Rehabilitated quarries used for agricultural purposes fall under the appropriate agricultural cover category
6: Green urban area	Includes public parks, private green areas, and cemeteries with vegetation. The category also covers camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc.
21: Green houses	Have a highly discernible surface colour and overall rectangular plan layout.

Table 2: Land use class and distinguishing criteria used in the 1998-2012 land use study. When the integer before the class reference code is 1, it denotes land use in 1998, and 4 denotes land use in 2012.

and the spatial aspect of the real-world objects and their spatial relationships, along with their arrangements, were also considered when attributing an observed land use to a particular land use class. Despite a rigorous methodology and a strict adherence to the outlined criteria, one cannot definitively ensure a correct attribution of land use to either of the classes listed in Table 2; this is particularly the case for certain industrial and residential land uses. Having identified the spatial distribution and temporal change of artificial surfaces, national areas subject to particular land use policies pertinent to the year 2012 were overlain onto the combined 1998-2012 artificial surfaces map. National land use policy layers used in this study follow: (i) industrial schemes, (ii) development zone and rationalisation scheme, (iii) outside development zone (ODZ) category 1, 2 and 3 settlement scheme, (iv) Environmental AEI, SSI, Beaches, TPA, Historical trees, (v) SAC national, (vi) SAC international and (vii) SPA. These policy designations have been divided into two categories of similar overall land use policy aims and objectives. The first category is termed "within planning designations" and consists of areas within the development zone, rationalisation, most UCA, ODZ category 1, 2 and 3 settlements and Industrial schemes. The second category is termed "combined environment protected areas" and consist of Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA). Areas outside the above listed schemes are classed under a third category that has been termed "outside combined development and environmental designations".

4 Results

4.1 Study of land use 2012

In 2012, land use in the Maltese Islands (Figure 2) was dominated by agricultural land in either of the following forms: arable land (52%), abandoned and degraded arable land (3%) and permanent crops (1%). Impermeable surfaces, which include continuous and discontinuous urban fabric, industrial and commercial units, port and airport areas, and construction sites, take up (24%) of the Maltese Islands. Natural and semi-natural areas cover 19% of the Islands; such areas include steppe and garrigue, degraded semi-natural areas, bare rock, maquis, mixed forests, salt marshes and beaches (Table 3).

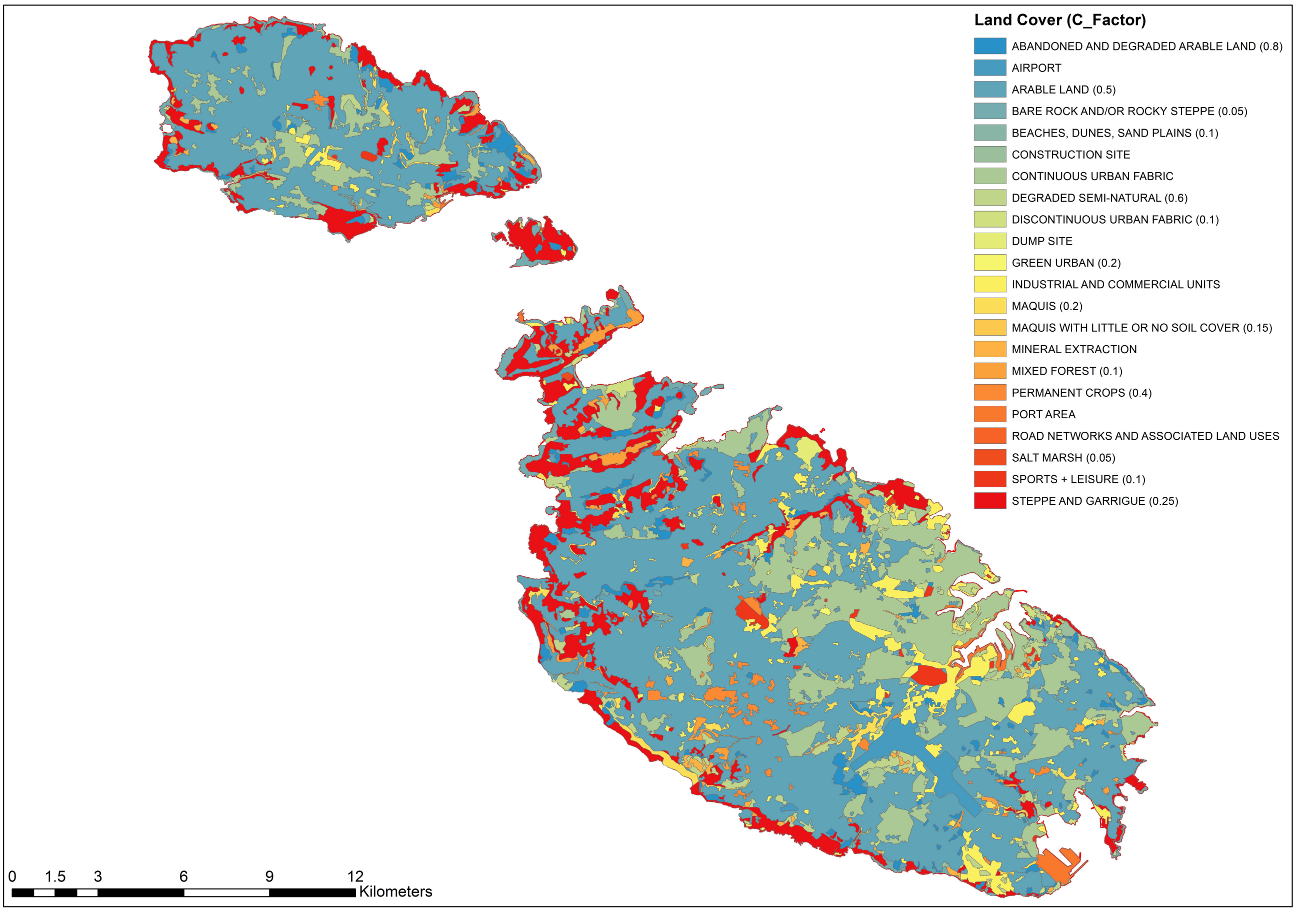

Figure 2: Detailed map showing spatial distribution of land use and land cover in the Maltese Islands for the year 2012.

Land use class	CORINE Ref. code	Area [km^2] Malta 2012	Land use [% of total MT land area]
Arable land	21	164.50	52.11
Permanent crops	22	2.91	0.92
Abandoned and degraded arable land	(25)	9.56	3.03
Degraded semi-natural land	(34)	7.42	2.35
Continuous urban fabric	111	53.09	16.82
Discontinuous urban fabric	112	3.34	1.06
Industrial and commercial units	121	12.83	4.07
Port areas	123	1.96	0.62
Airport areas	124	3.86	1.22
Mineral extraction	131	2.09	0.66
Dump sites	132	0.60	0.19
Construction sites	133	0.28	0.09
Green urban areas	141	0.26	0.08
Sports and leisure	142	1.95	0.62
Mixed forests	313	4.20	1.33
Beaches, dunes, and sand plains	332	0.12	0.04
Bare rock (and rocky steppe)	421	5.75	1.82
Salt marshes	421	0.15	0.05
Steppe and garrigue	(3231)	36.01	11.41
Maquis	(3234)	4.78	1.51

Table 3: Land use class, their total area (km^2) in 2012 and their respective land area relative to total Maltese terrestrial land area.

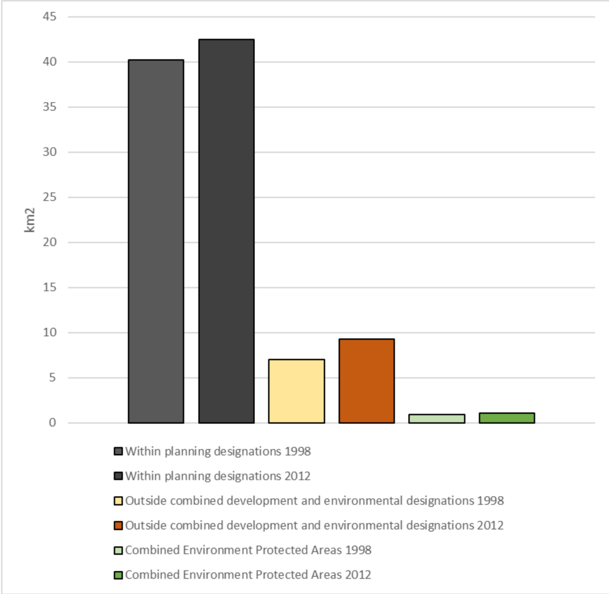

Figure 3: Graph showing the footprint (km^2) occupied by artificial surfaces observed in 1998 and 2012 as well as their distribution within planning designations, within combined environment protected areas and outside combined development and environmental designations.

4.2 Change in artificial surfaces 1998-2012

4.2.1 Study on the change in artificial surfaces 1998-2012

Results of change in artificial surfaces, and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces in the Maltese Islands amounted to 48.13km^2 in 1998 and increased by 4.68km^2 to a total of 52.81km^2 in 2012. Artificial surfaces observed in 1998 were predominantly concentrated within scheme (84%), and are also present outside combined development and environmental designations (14%) and in environmentally designated zones (2%). Expansion of new artificial surfaces between 1998 and 2012 amounted to 4.68km^2 (Table 4) Structure Plan policies were successful in confining 49% of new artificial surfaces within scheme. However, 48% of new artificial surfaces were constructed outside combined development and environmental designations and 3% of new artificial surfaces were constructed within environmentally designated zones (Figure 3).

New 2012 artificial surfaces were predominantly constructed on and replace agricultural surfaces used agricultural areas (39% of 2012 new surfaces) and abandoned agricultural areas (30% of 2012 new surfaces). A total of 0.54km^2 (or 12% of new 2012 artificial surfaces) are land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of

	Artificial surfaces 1998 (km^2)			New artificial surfaces built between 1998 and 2012 (km^2)			Artificial surfaces 2012 (km^2)		
Local Plan	Planning designations	Outside designations	Environment areas	Planning designations	Outside designations	Environment areas	Planning designations	Outside designations	Environment areas
MSLP	10.51	2.97	0.155	0.55	0.68	0.005	11.06	3.65	0.16
CZLP	9.79	1.03	0.032	0.53	0.28	0.007	10.32	1.31	0.039
GCLP	5.39	0.59	0.145	0.32	0.33	0.025	5.71	0.92	0.17
NHLP	6.14	0.11	0.074	0.35	0.09	0.01	6.49	0.2	0.084
NWLP	4.72	1.47	0.452	0.39	0.55	0.091	5.11	2.02	0.543
GHLP	2.76	0.43	0.005	0.1	0.01	0.003	2.86	0.44	0.008
MBLP	0.92	0.38	0.055	0.03	0.33	0.001	0.95	0.71	0.056
Sum	40.23	6.98	0.92	2.27	2.27	0.14	42.50	9.25	1.06
%	84	15	2	48	48	3	80	18	2
Total		48.13			4.68			52.81	

Table 4: Change in artificial surfaces across the Maltese local plans categorizes into areas within planning designations, areas within combined environment protected areas, and areas outside combined development and environmental designations.

the particular artificial land use.

A closer look at changes in land covered for residential and industrial artificial surface shows that between 1998 and 2012 residential areas increase by 1.89km^2 and industrial areas increased by 1.87km^2. Most new residential areas were accommodated within planning designations (81%), however, more than half of the new industrial areas (59%) were developed outside the planning designations (Table 5).

4.2.2 Withing planning designations

The following section presents land use change that took place within the development zone, rationalisation, most UCA, ODZ category 1, 2 and 3 settlements and Industrial Schemes. The land use change results for combined planning designations may be less than the individually summed designations (sections 3.2.2.2, 3.2.2.3 and 3.2.2.4); this is since a number of planning designations overlap.

Results of change in artificial surfaces (Figure 4) and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces within planning designations amounted to 40.24km^2 in 1998 and increased by 2.27km^2 to a total of 42.51km^2 in 2012 (81% of 2012 total artificial surfaces of the Maltese Islands). In 1998, artificial surfaces within planning designations are predominantly residential (35.01km^2) and industrial (4.75km^2) (Table 4). Between 1998 and 2012 residential areas increase by 1.53km^2 and industrial areas increased by 0.70km^2 (Table 5). New 2012 artificial surfaces were predominantly constructed on and replace abandoned agricultural areas (41% of 2012 new surfaces) and used agricultural areas (40% of 2012 new surfaces). A total of 9% of new 2012 artificial surfaces are land uses that were below the

		Artificial surface (km^2)	Artificial surfaces increase (1998 to 2012) (km^2)
WITHIN PLANNING DESIGNATIONS	1998 Residential	35.01	
	2012 Residential	36.54	1.53
	1998 Industrial	4.75	
	2012 Industrial	5.44	1.53
COMBINED ENVIRONMENT PROTECTED AREAS	1998 Residential	0.47	
	2012 Residential	0.51	0.04
	1998 Industrial	0.22	
	2012 Industrial	0.28	0.06
OUTSIDE COMBINED DEVELOPMENT AND ENVIRONMENTAL DESIGNATIONS	1998 Residential	1.78	
	2012 Residential	2.11	0.33
	1998 Industrial	3.56	
	2012 Industrial	4.67	1.10
ACROSS ALL MALTESE ISLANDS	1998 Residential	37.26	
	2012 Residential	39.15	1.89
	1998 Industrial	8.52	
	2012 Industrial	10.39	1.87

Table 5: Changes in land covered for residential and industrial artificial surface.

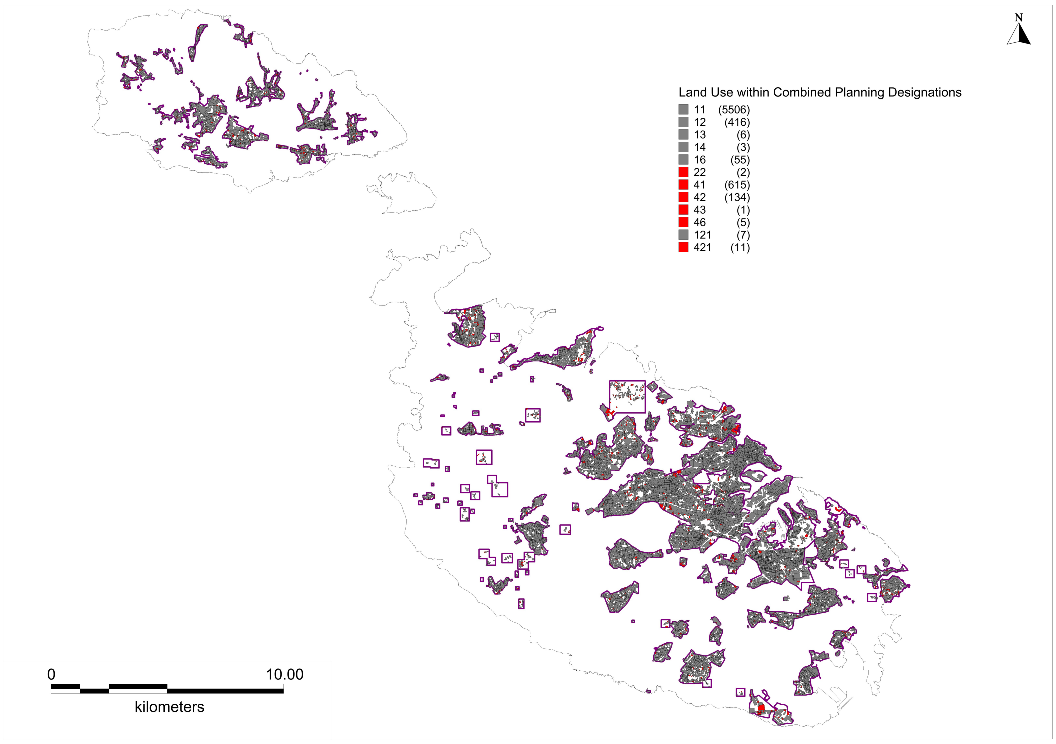

Figure 4: Detailed map showing spatial distribution of areas within planning designations (violet). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3).

MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

4.2.3 Combined Environment Protected Areas

The following section presents land use change that took place within Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA).

Results of change in artificial surfaces (Figure 5), and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces within environment protected areas amounted to 0.92km^2 in 1998 and increased by 0.14km^{2}2 to a total of 1.06km^2 in 2012 (2% of 2012 total artificial surfaces of the Maltese Islands) (Table 4). In 1998, artificial surfaces within environment protected areas are predominantly residential (0.47km^2 or 51% of artificial surfaces in 1998) and industrial (0.22km^2 or 24% of artificial surfaces in 1998). Between 1998 and 2012 industrial areas increased by 0.06km^2 (49% of total new 2012 artificial surface) and residential areas increase by 0.04km^2 (26% of total new 2012 artificial surface) (Table 5).

4.2.4 Outside combined development and environmental designations

The following section presents land use change that took place outside policy categories termed “within planning designations” and “combined environment protected areas”. The outside combined developed and environmental designations therefore consist of policy areas not covered by development zone, rationalisation, and most UCA, Outside Development Zone (ODZ) category settlements, Industrial schemes, Areas of Ecological Importance (AEI), Sites of Scientific Importance (SSI), beaches, Tree Protected Areas (TPA), historical trees, Special Areas of Conservation (SAC) and Special Protected Areas (SPA).

Results of change in artificial surfaces (Figure 6) and land uses preceding new 2012 artificial surfaces are presented in the Appendix. A highlight of key results follows. Artificial surfaces outside planning and environmental designations amounted to 6.98km^2 in 1998 and increased by 2.27km^2 to a total of 9.25km^2 in 2012 (18% of 2012 total artificial surfaces of the Maltese Islands) (Table 4). In 1998, artificial surfaces within planning designations are predominantly industrial (3.56km^2 or 51% of artificial surfaces in 1998) and residential (1.78km^2 or

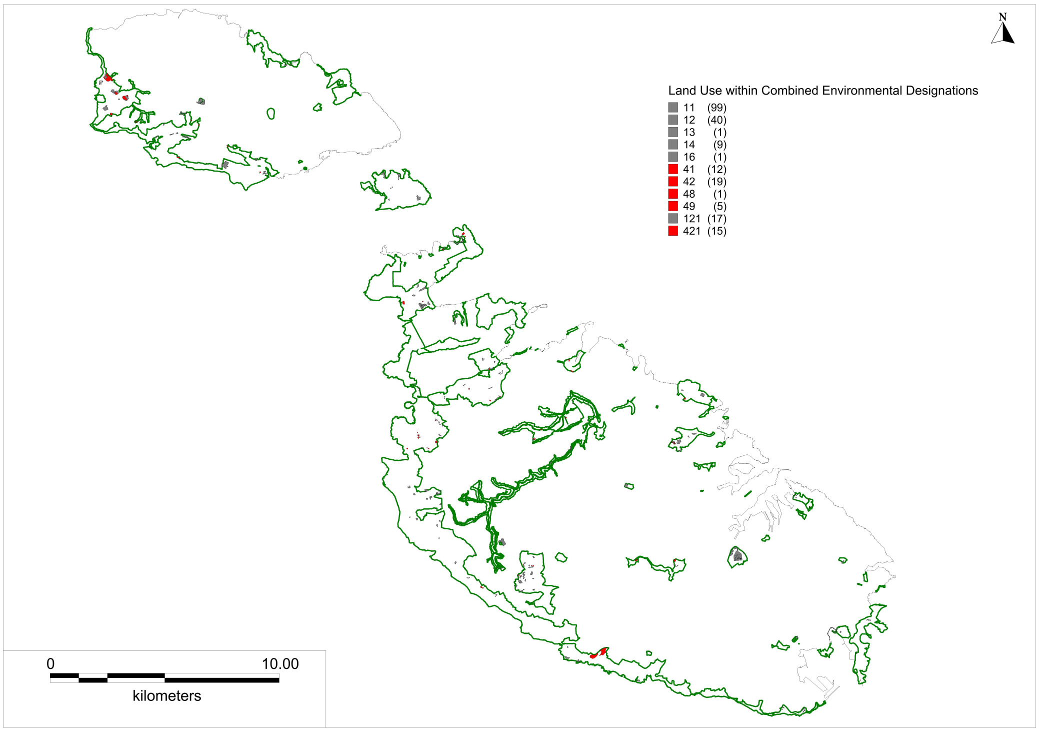

Figure 5: Detailed map showing spatial distribution of combined environment protected areas (green). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3).

25% of artificial surfaces in 1998) (Table 5). Between 1998 and 2012 industrial areas increased by 1.1km^2 (49% of total new 2012 artificial surface) and residential areas increase by 0.33km^2 (15% of total new 2012 artificial surface). New industrial development associated/directly neighbouring the Malta Freeport area (located outside combined development and environmental designations in the south east of Malta) totals 0.237km^2 and is classed as industrial, not ports and airports; this area has falls within the Marsaxlokk Bay Local Plan (MBLP). New 2012 artificial surfaces were predominantly constructed on and replace used agricultural areas 0.94km^2 (42% of 2012 new surfaces) and abandoned agricultural areas 0.48km^2 (21% of 2012 new surfaces). A total of 0.27km^2 (or 12% of new 2012 artificial surfaces) are land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

5 Discussion

5.1 Total change in artificial surfaces 1998 and 2012

The analysis shows that artificial surfaces in the Maltese Islands covered 48.13 km^2 in 1998, increasing by 4.68 km^2 to 52.81 km^2 by 2012. In 1998, 84% of these artificial surfaces were located within development zones (within scheme), 14% were found outside of combined development and environmental designations, and 2% within environmentally designated areas (Table 4). Between 1998 and 2012, a total of 2.27 km^2 of new artificial surfaces were constructed within designated development zones, an additional 2.27 km^2 were developed outside combined development and environmental designations, and 0.14 km^2 were built within environmentally protected zones.

The MSLP ranks first in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 1.23km^2; 0.55km^2 located within scheme, 0.68km^2 located outside combined development and environmental designations and 0.005km^2 within environment protected areas (Table 4). The MSLP is the LP with the greatest increase in artificial surfaces within scheme and outside combined development and environmental designations. While MSLP covers 20% of the Maltese terrestrial territory, it accommodated 25% of all new artificial surfaces.

The NWLP ranks second in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 1.03km^2; 0.39km^2 located within scheme, 0.55km^2 located out-

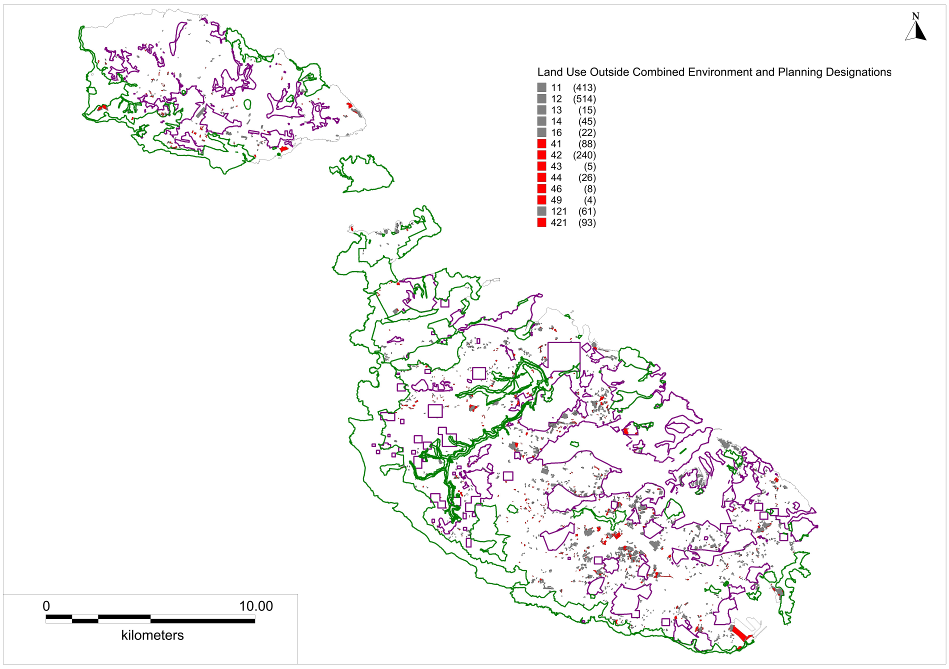

Figure 6: Detailed map showing spatial distribution of outside development zone (areas between combined environment protected areas (green) and areas within planning designations (violet)). Artificial surfaces present in 1998 are shown in grey while new artificial surfaces recorded in 1998-2012 land use change study are marked as red. Table (top right of figure) refers to land use classes used in the Maltese 1998-2012 land cover study (Table 3). Note: new industrial development associated/directly neighbouring the Malta Freeport area (south east of Malta) totals 0.237km^2 and is classed as industrial not ports and airports; this area has falls within the Marsaxlokk Bay Local Plan (MBLP).

side combined development and environmental designations and 0.091km^2 within environment protected areas (Table 4). The NWLP ranks first in terms of land use change within environment protected areas.

The CZLP ranks third in terms of new artificial surfaces established by the year 2012 across the Maltese Islands. Total new development amounts to 0.81km^2; 0.53km^2 located within scheme, 0.28km^2 located outside combined development and environmental designations and 0.007km^2 within environment protected areas (Table 4).

It is worth noting that four of the seven LP demonstrate a growth (1998-2012) of artificial surfaces that is greater outside combined development and environmental designations (ODZ) than within development schemes (WS); MBLP (WS 0.03km^2; ODZ 0.33km^2), NWLP (WS 0.39km^2; ODZ 0.55km^2) MSLP (WS 0.55km^2; ODZ 0.68km^2) and GCLP (WS 0.32km^2; ODZ 0.33km^2). It is important to note that new industrial development associated/directly neighbouring the Malta Freeport area (south east of Malta) totals 0.237km^2 and is classed as industrial, not ports and airports; this area has falls within the MBLP. Three of the seven LP demonstrate a growth of artificial surfaces that is greater within development scheme than outside combined development and environmental designations; GHLP (0.1 WS 0.10km^2; ODZ 0.01km^2), NHLP (0.26 WS 0.35km^2; ODZ 0.09km^2), CZLP (0.52 WS 0.53km^2; ODZ 0.28km^2).

5.1.1 Policy control

The Structure Plan aims to provide strategic direction and context to guide both government and private sector development in Malta over a twenty-year period (1990–2010) (Sustainable Development Directorate Malta, 2015). The structure plan's central goal is "to use land and buildings efficiently and consequently to channel urban development activity into existing built-up areas particularly through rehabilitation and upgrading of urban areas thus constraining further inroads into undeveloped land". On a strategic long term level, the Structure Plan divides Maltese settlements into five broad categories, i.e. existing built-up areas, temporary provision scheme, primary development areas, non-urban areas and ODZ settlements. Each of these categories is typified by key policy which sets out broad guidelines for development control.

Category: Existing Built-up Areas A key objective of the Structure Plan is to promote a significant portion of future urban development within existing built-up areas while maintaining and enhancing their environmental quality. This strategy seeks to minimize the development footprint on undeveloped land beyond these areas (Ministry for Development and Infrastructure, 1990, p. 35, Policies SET 1–7). To achieve this, the Structure Plan, along with local plans, will enforce stringent controls over development throughout the Islands, ensuring that proposed developments do not adversely affect existing or planned adjacent uses (Ministry for Development and Infrastructure, 1990, p. 40, Policies BEN 1–4).

Category: Non-Urban areas This section outlines key policies from the Structure Plan regarding land use within and outside combined development and environmental designations. Policy SET 11 facilitates development in existing built-up areas, temporary provision areas, and primary development areas, as delineated in the Structure Plan. Conversely, it prohibits any form of urban development outside these designated areas (Ministry for Development and Infrastructure, 1990, p.38, Policy SET 11). While the Structure Plan upholds a strict prohibition on the urbanization of non-urban areas, it acknowledges the necessity of certain built structures, such as farmhouses, parking facilities, and control buildings, which are considered appropriate within the non-urban landscape. Nonetheless, the establishment of such structures will be regulated to preserve and enhance the environmental quality of the countryside (Ministry for Development and Infrastructure, 1990, p. 41, Policy BEN 5).

5.1.2 Policy control

The above discussed Structure Plan policies were successful in confining 49% (2.27km^2) of new 1998-2012 artificial surfaces within scheme, and limiting new impermeable surfaces to 3% (0.14km^2) within environmentally designated zones. Despite this, 48% (2.27km^2) were constructed outside combined development and environmental designations (Table 4). Given these results, it appears that the implementation of the SP policies faced challenges, and the associated aims and objectives may not have been fully realized.

The Structure Plan's strategy was translated into seven Local Plans and a number of supplementary planning policies. The Strategic Plan for Environment and Development (2015) references the State of the Environment Reports and suggests that the implementation of these policies over the past two decades has played a role in managing urban sprawl within the defined development boundaries. However, despite these reported achievements, ongoing efforts are necessary to address the persistent demand for development and further ensure the effective containment of urban sprawl (Sustainable Development Directorate Malta, 2015).

5.2 How much and in what proportions is agricultural, forest and other semi-natural and natural land being taken for urban and other artificial land development? What are the drivers of uptake for urban and other artificial land development?

New (1998-2012) artificial surfaces across the Maltese Islands are primarily associated with the following land uses: residential land uses 1.89km^2, industrial land uses 1.87km^2, free port/airport 0.3km^2 and green houses 0.3km^2. New artificial surfaces within scheme typically pertain to residential (1.53km^2), industrial (0.70km^2) and green urban (0.013km^2) land uses. New artificial surfaces outside combined development and environmental designations are predominantly industrial (1.10km^2), followed by residential (0.33km^2) and airport (0.3km^2) associated land uses (Table 5). New artificial surfaces within environment protected areas are associated with industrial (0.06km^2), green house (0.04km^2) and residential (0.04km^2) land uses (Appendix).

New 2012 artificial surfaces across the Maltese Islands were predominantly constructed on and replace used agricultural areas 1.84km^2 (35% of 2012 new surfaces) and abandoned agricultural areas 1.40km^2 (27% of 2012 new surfaces), and 0.43km^2 (8% of new 2012 artificial surfaces) replaced semi-natural areas. A total of 0.54km^2 (10% of new 2012 artificial surfaces) were land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

5.3 How does this compare to EU

The CORINE Land Cover analysis for 2000, 2006, and 2012 provides insights into land cover trends across European countries over 12 years. The data reveal that artificial areas experienced the most significant increase among all categories, both in net area and percentage change (EEA, 2017, p. 17). Specifically, artificial areas rose from 207,498 km^2 in 2000 to 218,295 km^2 in 2012, marking a 5.2% increase. The drivers behind this growth have evolved; since 1990, residential sprawl has declined while economic sprawl and urban management have gained prominence. From 2000 to 2006, the rise in artificial surfaces was attributed primarily to housing, services, and recreation (43%), followed by construction sites (21%) and industrial/commercial sites (16%) (EEA, 2019). In the Maltese Islands, residential areas increased by 41%, and industrial areas by 40% during the study period (1998-2012). Notably, the rise in artificial surfaces related to industrial sites is particularly pronounced in Malta, while the increase in residential areas mirrors trends in the broader European Union. However, it is important to note that the European classification includes recreational surfaces, which are not accounted for in Malta's classification.

The analysis also indicates a decline in agricultural land due to urbanization, land abandonment, and conversion to pastures (EEA, 2017, p. 17). Across the EU, arable land and permanent crop areas decreased from 1,409,012 km^2 in 2000 to 1,401,769 km^2 in 2012, a reduction of 0.5%. From 2000 to 2006, artificial surfaces expanded by 5,486 km^2, with prior land uses comprising arable land or permanent crops (46%), forests and transitional woodland shrub (13%), and natural grassland, heathland, and sclerophyllous vegetation (7.3%). In Malta, the new artificial surfaces constructed by 2012 predominantly replaced agricultural land (39%), abandoned agricultural areas (30%), and previously unclassified land (12%), indicating a significant footprint expansion of artificial land use. These findings suggest that agricultural surfaces in both the European Union and the Maltese Islands are increasingly being converted to artificial uses.

5.4 Way forward

The second goal of the Structure Plan emphasizes the efficient use of land and buildings, directing urban development into existing built-up areas through the rehabilitation and upgrading of urban zones, thereby minimizing encroachment into undeveloped land. Although the national land use policy outlines adequate aims and objectives, enforcement has often been lacking. It is proposed that the cumulative approval of "exceptional" applications, along with instances of unlawful construction, may have significantly impeded the realization of these goals. Future research could assess the prevalence of unlawful expansions and identify the types of development that require closer scrutiny within Maltese local plans.

The Structure Plan aims to limit urban land expansion while accommodating economic development, housing, and community needs through more effective use of existing urban areas. A national analysis could help identify dilapidated, unused, and underutilized structures, offering opportunities for regeneration and reuse rather than further consuming undeveloped land. The Environment Report (MEPA, 2010) highlights that Malta's high urban land cover, driven by population density, raises concerns about land use efficiency. This high urbanization rate is particularly notable in light of the 2005 Census, which revealed that 22% of residential properties were permanently vacant, with an additional 5% classified as temporarily vacant second homes (MEPA, 2010; Vakili-Zad & Hoekstra, 2011). This trend also extends to commercial and industrial sectors (MEPA, 2010). Vakili-Zad and Hoekstra 2011 suggest that a prevailing 'homeownership culture' may lead to an oversupply of properties built for investment rather than genuine housing needs. This points to considerable potential for enhancing land use efficiency, especially given the current oversupply of residential, commercial, and industrial spaces. Investigating the potential of incentives to optimize land use efficiency warrants further study (MEPA, 2010).

The Strategic Plan for Environment and Development (SPED) (2015) supersedes the Structure Plan originally published in 1990 and adopted in 1992, establishing a long-term spatial strategy for development and environmental protection, with 2020 as the first review milestone. This new plan aligns with national policies, integrating social, economic, and environmental objectives (Sustainable Development Directorate Malta, 2015). This research has revealed discrepancies between land use policy aims and actual land use changes over the fifteen-year period from 1998 to 2012. Understanding the spatial and temporal variations in land use in the Maltese Islands is essential for guiding national resource management and land use policy towards sustainable management practices.

6 Conclusions

The areal extent of artificial surfaces in the Maltese Islands in the year 1998 was of 48.16km^2. Artificial surfaces observed in 1998 were predominantly concentrated within scheme (83%), and are also present outside combined development and environmental designations (15%) and in environmentally designated zones (2%). Expansion of new artificial surfaces between 1998 and 2012 amounted to 4.68km^2. Newly constructed artificial surfaces were observed within scheme (49%), outside combined development and environmental designations (48%) and in environmentally designated zones (3%). It is worth noting that four of the seven LP demonstrate a growth (1998-2012) of artificial surfaces that is greater outside combined development and environmental designations than within schemes. New 2012 artificial surfaces across the Maltese Islands were predominantly constructed on and replace used agricultural areas 1.84km^2 (35% of 2012 new surfaces) and abandoned agricultural areas 1.40km^2 (27% of 2012 new surfaces), and 0.43km^2 (8% of new 2012 artificial surfaces) replaced semi-natural areas. A total of 0.54km^2 (10% of new 2012 artificial surfaces) were land uses that were below the MMU in 1998 and in 2012 fulfilled the MMU; this implies an increase in footprint of the particular artificial land use.

The purpose of the Structure Plan was to inter alia "to provide a strategic direction and context to guide both Government and the private sector in matters concerning Malta's development over twenty years (1990-2010)" (Sustainable Development Directorate Malta, 2015).

The structure plan had three central goals amongst which is "to use land and buildings efficiently and consequently to channel urban development activity into existing built-up areas particularly through rehabilitation and upgrading of urban areas thus constraining further inroads into undeveloped land". Various SP policies relate to land use within and outside combined development and environmental designations. In particular, SP Policy SET 11 prohibits any form of urban development outside existing and committed built-up areas (Ministry for Development and Infrastructure, 1990, p. 38, Policy SET 11).

Results indicate that SP policies were successful in confining 49% (2.27km^2) of new 1998-2012 artificial surfaces within scheme, and limiting new impermeable surfaces to 3% (0.14km^2) within environmentally designated zones. Despite this, 48% (2.26km^2) of new 1998-2012 artificial surfaces were constructed outside combined development and environmental designations. Results indicate that the SP policy sets were only partly successful in confining and channelling urban development activity into existing built-up areas (within scheme). Close to half (48%) of the new 1998-2012 artificial surfaces were developed outside combined development and environmental designations. By comparison, environmental policy was successful in limiting industrial and residential growth in environmentally protected sites.

This research reveals a significant discrepancy between the objectives of land use policy and the actual changes in land use that occurred over a fifteen-year period (1998-2012). A precise understanding of the spatial and temporal variations in land use across the Maltese Islands is crucial. This information should inform and guide national resource management and land use policies, ultimately facilitating sustainable land management practices.

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Appendix

WITHIN PLANNING DESIGNATIONS

Local Plan	**CZLP**	**GCLP**	**GHLP**	**MSLP**	**MBLP**	**NHLP**	**NWLP**		
Land use	km^2	km^2	km^2	km^2	km^2	km^2	km^2	Sum land use class (km^2)	
1998 Residential	8.8724	4.9394	1.7467	8.8525	0.8370	5.4975	4.2633	35.0088	
1998 Industrial	0.8263	0.4318	0.8827	1.5909	0.0736	0.5392	0.4005	4.7449	
1998 Port/Airport	0.0000	0.0000	0.0513	0.0011	0.0000	0.0000	0.0000	0.0524	
1998 Quarry	0.0193	0.0000	0.0000	0.0000	0.0000	0.0013	0.0094	0.0300	
1998 Green Urban	0.0645	0.0185	0.0748	0.0733	0.0119	0.1041	0.0232	0.3702	
2012 Residential, new	0.3488	0.2953	0.0222	0.2986	0.0252	0.0252	0.2490	1.5273	
2012 Industrial, new	0.1753	0.0278	0.0707	0.2403	0.0014	0.0632	0.1191	0.6977	
2012 Port/Airport, new	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0036	
2012 Quarry, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Green Urban, new	0.0000	0.0000	0.0047	0.0077	0.0000	0.0000	0.0008	0.0132	
2012 Agricultural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Semi natural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
1998 Green house	0.0054	0.0000	0.0000	0.0000	0.0000	0.0000	0.0235	0.0289	
2012 Green house, new	0.0037	0.0000	0.0000	0.0000	0.0000	0.0000	0.0200	0.0237	
Tot. (1998+2012) dev. in LP (km^2)	10.3157	5.7129	2.8566	11.0644	0.9491	6.4934	5.1087	tot. (1998+2012) dev. (km^2)	**42.50**
Tot. 2012 dev. in LP (km^2)	0.5278	0.3231	0.1012	0.5465	0.0266	0.3514	0.3889	tot. 2012 dev. (km^2)	2.27
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.2330	0.1426	0.0447	0.2412	0.0118	0.1551	0.1717		
LP tot. 2012 dev./ LP (km^2/km^2)	0.0159	0.0047	0.0127	0.0687	0.0021	0.0246	0.0034		
Rate 2012 dec (km^2/yr-1)	0.0377	0.0231	0.0072	0.0390	0.0019	0.0251	0.0278		

COMBINED ENVIRONMENT PROTEXTED AREAS

Local Plan	**CZLP**	**GCLP**	**GHLP**	**MSLP**	**MBLP**	**NHLP**	**NWLP**		
Land use	km^2	km^2	km^2	km^2	km^2	km^2	km^2	Sum land use class (km^2)	
1998 Residential	0.0225	0.0043	0.0045	0.1285	0.352	0.0057	0.2673	0.4681	
1998 Industrial	0.0068	0.0390	0.0000	0.0266	0.0000	0.0414	0.1017	0.2155	
1998 Port/Airport	0.0000	0.0000	0.0000	0.0000	0.0197	0.0000	0.0000	0.0197	
1998 Quarry	0.0000	0.1025	0.0000	0.0000	0.0000	0.0241	0.0458	0.1723	
1998 Green Urban	0.0000	0.0000	0.0008	0.0000	0.0000	0.0000	0.0000	0.0008	
2012 Residential, new	0.0000	0.0116	0.0000	0.0052	0.0000	0.0000	0.0203	0.0371	
2012 Industrial, new	0.0068	0.0129	0.0030	0.0000	0.0007	0.0102	0.0312	0.0649	
2012 Port/Airport, new	0.0000	0.0000	0.0036	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Quarry, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Green Urban, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Agricultural landfill, new	0.0000	0.0076	0.0000	0.0000	0.0000	0.0000	0.0000	0.0076	
2012 Semi natural landfill, new	0.0000	0.0954	0.0000	0.0000	0.0000	0.0000	0.0997	0.1951	
1998 Green house	0.0029	0.0000	0.0000	0.0000	0.0000	0.0027	0.0364	0.0419	
2012 Green house, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0399	0.0399	
Tot. (1998+2012) dev. in LP (km^2)	0.0389	0.1704	0.0083	0.1603	0.0557	0.0841	0.5425	tot. (1998+2012) dev. (km^2)	**1.06**
Tot. 2012 dev. in LP (km^2)	0.0068	0.0246	0.0030	0.0052	0.0007	0.0102	0.0914	tot. 2012 dev. (km^2)	0.14
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.0198	0.0713	0.0088	0.0151	0.0021	0.0295	0.2651		
LP tot. 2012 dev./ LP (km^2/km^2)	0.0002	0.0004	0.0004	0.0007	0.0001	0.0007	0.0008		
Rate 2012 dec (km^2/yr-1)	0.0005	0.0018	0.0002	0.0004	0.0001	0.0007	0.0065		

OUTSIDE COMBINED DEVELOPMENT AND ENVIRONMENTAL DESIGNATIONS

Local Plan	**CZLP**	**GCLP**	**GHLP**	**MSLP**	**MBLP**	**NHLP**	**NWLP**		
Land use	km^2	km^2	km^2	km^2	km^2	km^2	km^2	Sum land use class (km^2)	
1998 Residential	0.3342	0.1493	0.1367	0.4734	0.1330	0.0666	0.4893	1.7825	
1998 Industrial	0.6029	0.2177	0.1632	1.6769	0.1964	0.0460	0.6590	3.5621	
1998 Port/Airport	0.0000	0.0230	0.0277	0.0194	0.0486	0.0000	0.0069	0.1256	
1998 Quarry	0.0544	0.0911	0.0000	0.7258	0.0000	0.0000	0.1021	0.9734	
1998 Green Urban	0.0148	0.0034	0.1024	0.0294	0.0093	0.0017	0.0877	0.2487	
2012 Residential, new	0.0406	0.0798	0.0000	0.0585	0.0159	0.0589	0.0765	0.3302	
2012 Industrial, new	0.2113	0.1640	0.0014	0.3966	0.0721	0.0185	0.2402	1.1042	
2012 Port/Airport, new	0.0000	0.0000	0.0000	0.0460	0.2373	0.0000	0.0177	0.3009	
2012 Quarry, new	0.0021	0.0603	0.0000	0.0989	0.0000	0.0000	0.0664	0.2278	
2012 Green Urban, new	0.0039	0.0000	0.0069	0.0367	0.0000	0.0073	0.0000	0.0548	
2012 Agricultural landfill, new	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	
2012 Semi natural landfill, new	0.0000	0.0512	0.0000	0.0000	0.0000	0.0000	0.0214	0.0726	
1998 Green house	0.0308	0.1111	0.0000	0.0475	0.0000	0.0000	0.1212	0.3106	
2012 Green house, new	0.0169	0.0253	0.0000	0.0445	0.0015	0.0000	0.1518	0.2400	
Tot. (1998+2012) dev. in LP (km^2)	1.3119	0.9249	0.4383	3.6536	0.7141	0.1990	2.0189	tot. (1998+2012) dev. (km^2)	**9.25**
Tot. 2012 dev. in LP (km^2)	0.2748	0.3293	0.0083	0.6812	0.3268	0.0847	0.5527	tot. 2012 dev. (km^2)	2.27
LP tot. 2012 dev./ MT tot. 2012 dev. (proportion)	0.1179	0.1413	0.0036	0.2923	0.1402	0.0364	0.2372		
LP tot. 2012 dev./ LP (km^2/km^2)	0.0083	0.0048	0.0010	0.0857	0.0264	0.0059	0.0048		
Rate 2012 dec (km^2/yr-1)	0.0196	0.0235	0.0006	0.0487	0.0233	0.0061	0.0395		