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TITOLO TESI / THESIS TITLE

The restoration and sustainable development of the traditional Aeolian Park of Lassithi plateau, Crete (Greece). Past, present, future.

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''Blowing Zeus'' [1]

[1] art creation for the purposes of this thesis by Maria Nikolaidi

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The restoration and sustainable development of the traditional Aeolian Park of Lassithi plateau, Crete (Greece). Past, present, future.

Demelis Nikolaos

Abstract

The Lassithi plateau, known in antiquity as the birthplace of Zeus, represents a unique agriculture-based socio-ecological system within the Mediterranean context, with the history of the settlement dating back to the Neolithic period (9ka BP). Once occupied by a shallow lake, this karstic depression (polje) has been used by the local population through time for timber production, herding and, more recently, irrigated agriculture. The study of the long-term evolution of this rural community is proposed to highlight in an historical perspective the introduction, functioning and shortcomings of one of the most impressive pre-industrial "renewable Aeolian energy" solutions experimented in agriculture within the Mediterranean context.

This study seeks to identify the reasons for land changes and historical agriculture practices able to transformed into future oriented tools for sustainability. To motivate the population of Lassithi to envision its own future and to achieve a common social goal. Furthermore, this study will spot light the opportunities for touristic alteration to provide special and unique ecological services based on the uniqueness of the area. The goal is to ensure the effectiveness of the socio-ecological system in terms of green, sustainable energy supply. It will explore new forms of human collaboration and policies for local society.

Keywords

land – change, socioeconomic conditions, smart rural development, social construction of technology, reuse of historical practices

GEOGRAPHY, CLIMATE and GEOLOGY of the LASITHI PLATEAU

Geographical location and infrastructure

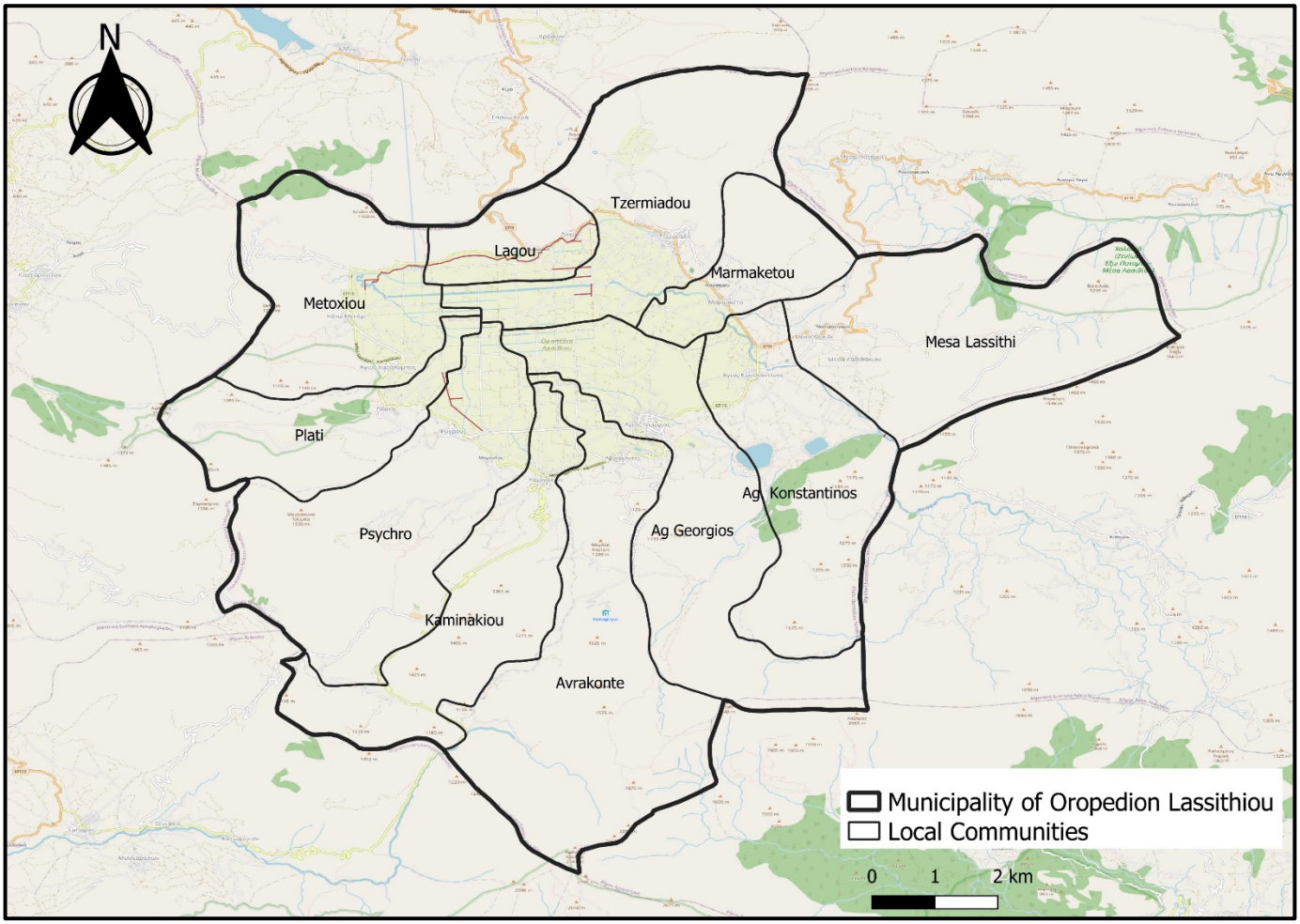
Lassithi plateau is situated in the interior of the eastern part of Crete, the largest of the Greek islands with a surface of 45km^2. The last major administrative reform ''Kallikratis Program'', Greek law 3852/2010, reduce the number of self-governing local administrative units (Hlepas & Getimis, 2011). New governance structure arose from the aforementioned law which divides Greek administration to decentralized agencies of national administration, secondary, regional-level self-governing entities, primary, local – level self – governing entities (Hlepas N.-K. , 2013). It brought upon the second major reform of the country's administrative divisions following the 1997 Kapodistrias reform (Chart).

Comparison chart		
Reform name	**Kapodistrias**, 1998-2010	**Kallikratis**, 2011
Decentralized agencies national administration	**13 administrative districts** ("administrative regions",)	***7 administrative districts*** *("decentralized administrations",) headed by a general secretary appointed by the Minister of Interior.*
Secondary, regional-level self-governing entities	**51 prefectures** headed elected Prefect-Governor and governed Prefectural Council	***13 regions*** *subdivided into regional units , headed by a vice-regional governor*
primary, ***local -level self-governing entities***	***914 municipalities*** *subdivided* • *municipal districts* • *local districts* ***communities***	***25 municipalities*** *divided in:* • *municipal communities* • *local communities*

It consists a municipality composed by eleven (11) local communities and includes 20 villages (Map.1). It is surrounded by mountains, the highest of which is the Dikti (2148 asl), is one of three biggest mountain ranges of the island which is located south of the plateau. Transport network is divided into three categories: The main road

network, dirt roads and walking paths (Dimelli D., 2020). The main road connects the municipality with Agios Nikolaos and with Heraklion. The quality of the network is evaluated as adequate. The main axis road connects all the villages, which are located on the perimeter of the plateau, has a total length of 23 km and is essential for the commercial-tourist activities of the settlements develop. Due to the terrain the connection is easy and the quality of the network is evaluated as sufficient. Important for the development of the Municipality is the planned road connection of the new Kasteli airport with the Lassithi plateau. The secondary network with the dirt roads - rural roads has a local character and connects the zones of the agricultural holdings with the main road network. The main development parameter of the area is the walking path E4 which runs through it all Crete and crosses the municipality. In the Municipality of Oropedio there are important routes (eg Minoan path) which can be extended further by unifying more elements of the natural and cultural environment of the Municipality (Dimelli D., 2020).

The biggest village on the plateau is Tzermiádo (637 habitants in 2011), which is the capital of municipality and the basis of the Farmers' Cooperative of the plateau (ENOSEIS) along with the cheese factory, which includes 300 registered members. Municipality's educational infrastructures are 3 kindergartens, 2 primary schools, 2 high school and 1 technical school. Beside that a health center at capital and 2 regional clinics were recorded in the settlements of Psychro and Agios Georgios. In the study area there are no big industrial units neither industrial zone along with their activities, in addition, there are small units within the boundaries of settlements that constitute the secondary production sector. The businesses are local with a low level of organization developed by the members of a family. Also, there is a municipal slaughterhouse which has been rented by a meat company. The municipality also registers blacksmiths, carpenters and machine shops. The main problems in these units are the lack of mechanical equipment and the high cost of transportation of raw materials due to the distance from the production sites (Dimelli D., 2020). Despite the network and its condition plateau is still considered as a remote area.



Map.1 Administration boundaries

Geology

Geomorphology

The relief of the area is a valley almost flat, with the exception of two hills near Agios Georgios in the South East of the plateau. Its altitude varies between 850m asl in the south-east and about 811m asl in the north-west. The mountain range has important morphological peculiarities: steep peaks, gorges, plateaus, springs, valleys, forests, torrents and a large number of sinkholes that grow on the strongly karstic limestone bedrock of the area. In this geographical environment, Lassithi Plateau is a distinct ecosystem, in terms of geomorphology a karst polje, created by aqueous solvent processes on the tectonic trench of the area, is the largest of the 25 plateaus that exist

on the island of Crete. Its shape is an irregular ellipse with a large axis of about 9 km and a small 5 and is surrounded everywhere by mountains that contribute to the drainage of water by sinkholes. Around the plateau are the peaks located at North Selena (1539 asl), at West, Afentis (1588 asl), Louloudaki (1163 asl), at East Katharos (1564 asl), Varsami (1545 asl) and to South Spathi (2148asl).

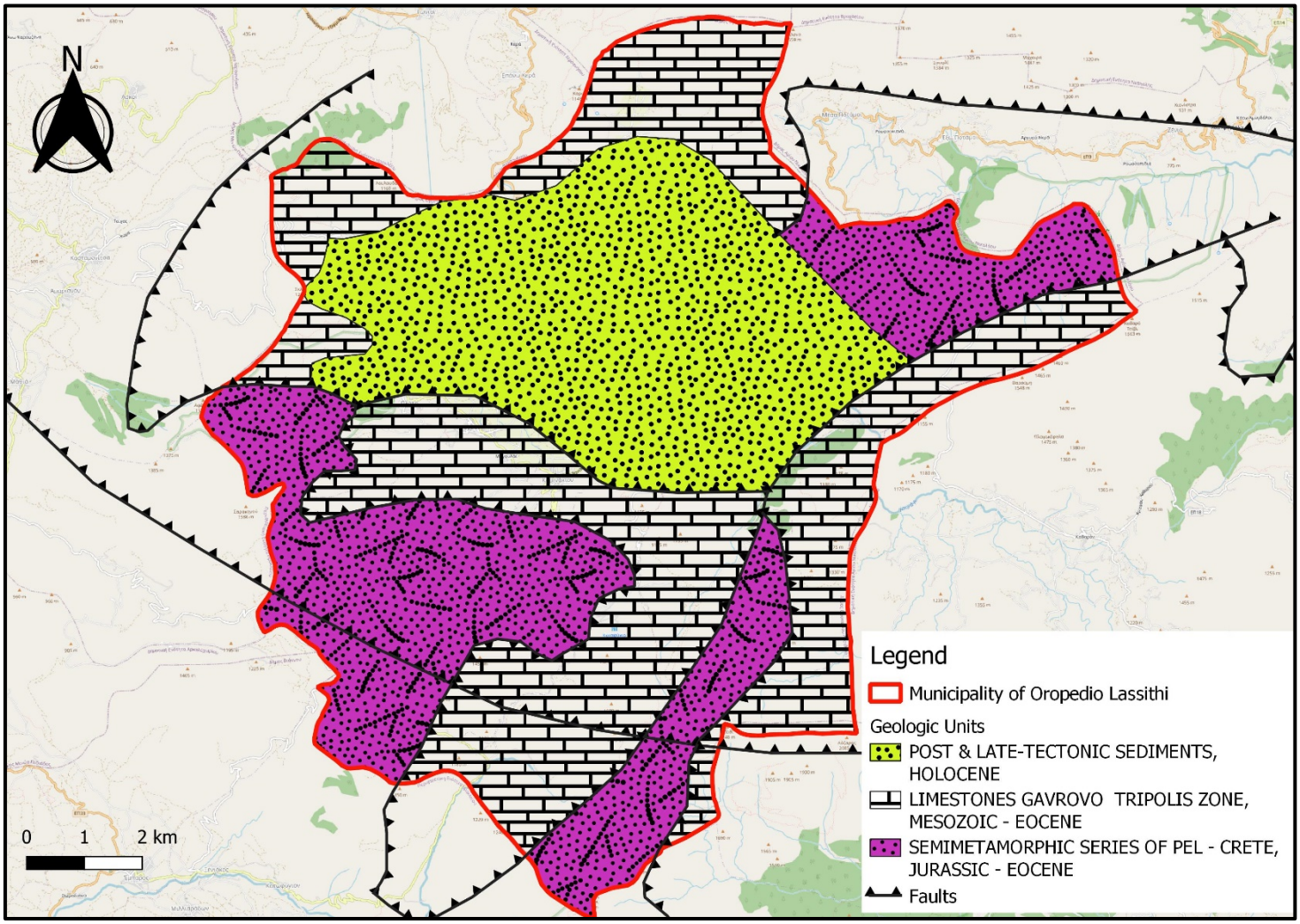
Geological Formations

There are many scientific publications related to the geology of the study area (Seidel, 1978, (Fitrolakis, PhD Thesis Dissertation, 1980) (Alexopoulos A. , 1990), , The impact of the geological structure of the western piemonts of Lassithiotika mountains on the hydrogeological conditions of the area and the development of karstic forms and caves, 1993-94) & (Alexopoulos A. , On the Geological and Hydrogeological conditions between Malia, Mohos, Potamia and Limenas Hersonissou, 2001), (Bouloukakis, 1999.). The study area is characterized by the presence of successive thrust sheets (tectonic zones). The pre-neogene basement consists of the Plattenkalk series (or Kriti-Mani unit), the Phyllite-Quartzite series and the formations of Tripolis and Pindos zone. Younger rocks are: the Neogene deposits and the Quaternary clastic sediments

Geological Formations Lassithi Plateau

The Lasithi plateau, including the Katharo plateau, covers an area of 129.2 km^2 . The low-land area of the plateau (45 km^2) is covered by alluvial deposits (loose clay to silt and clay to sand alluvial deposits 10 m thick, with mean slope is 12.7% (Voudouris, 2007) while according to (Papakonstantinou A. & Kritsotakis, 2010) is estimated to be greater than 30m. From drilling data carried out in the area of the NW part of the Lassithi Plateau for the Aposelemi dam construction project, it appears that the thickness of the alluvial deposits reaches approximately 30m (A.T.E., SOIL ENGINEERS – RESEARCH, 2006). It is pointed out that this thickness related geographically with the end of the plain of the Lassithi Plateau, near the surface appearance of the limestone formations. Therefore, the thickness of the alluvial alluvium in the innermost parts of the plain may appear even greater. The bedrock of the alluvial alluvium of the plain are mainly the formations of the Tripoli zone (Triadic-Jurassic

limestones, Cretaceous limestones and locally in the southern part of the flysch) and often the formations of the phyllite-quartz series (Map.2).



Map.2. Geological Formations

Tectonic Structures

Fault zones

Studies (Papakonstantinou A. & Kritsotakis, 2010), based on data derived from seismotectonic map (I.G.M.E ,scale 1: 500,000) (Fitrolakis, Contribution to the geological research of Crete, 1978) (Fitrolakis, PhD Thesis Dissertation, 1980) about the geological structure, report the existence of three groups of neotectonic structures (Pleistocene-Holocene age) in the wider area. In the third group, faults of

general direction ENE – WSW to E-W are identified. These include the most important fault zone of Selena - Louloudaki - Krasi - Kastamonitsa (or otherwise Nipiditou - Tichou - Krasi or simply ruptured zone of Selena) (Papakonstantinou A. & Kritsotakis, 2010)˙ (Sotiropoulos & Associates, 2013, pp. A88-A91.) ˙ (Vogiatzi, 2020), which created the polje of Lassithi (Map.2).

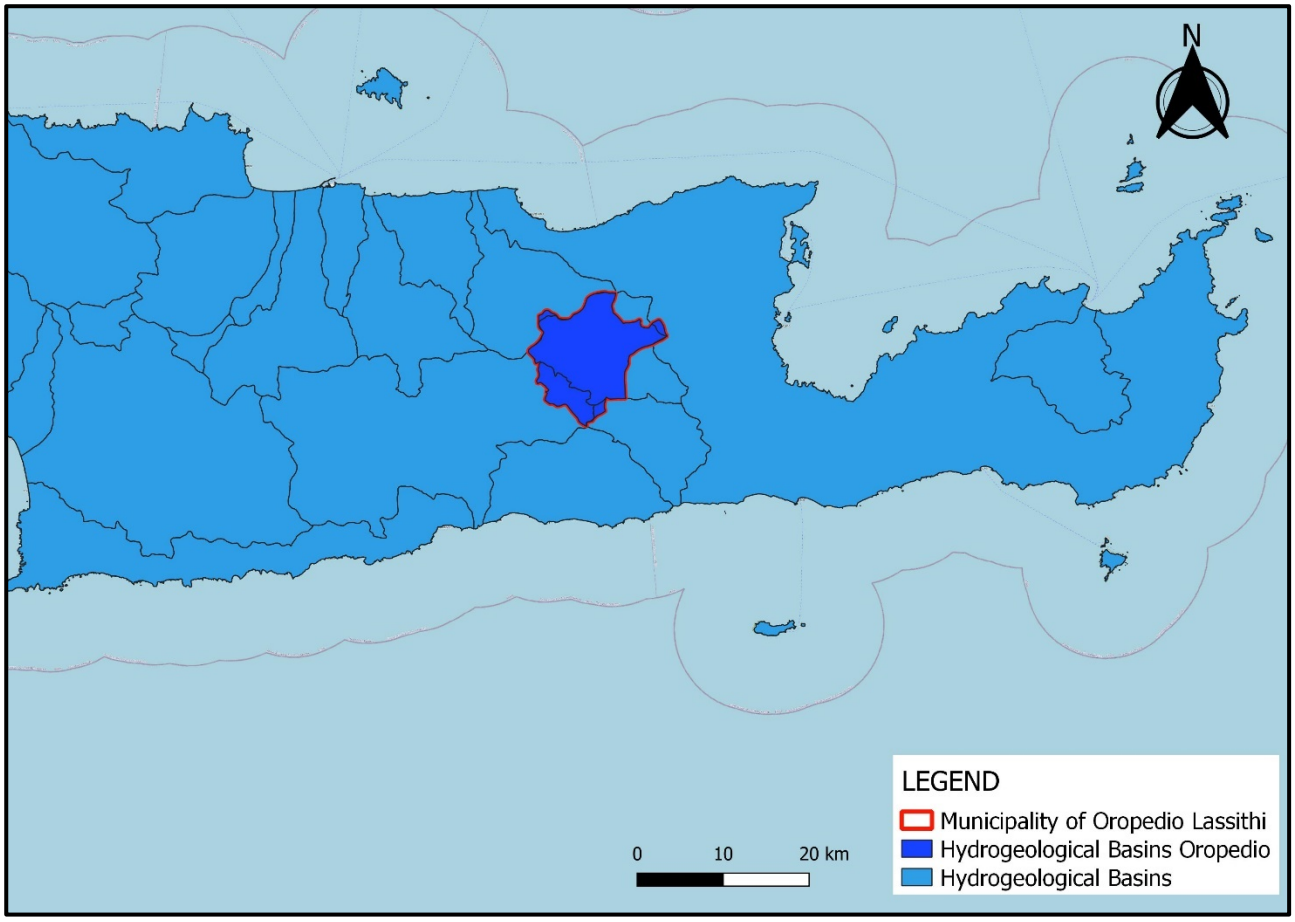
Hydrogeology

Hydrolithology

From a hydrolithological point of view, the limestone formations of the alpine background of the area are characterized as water permeable formations, due to the phenomena of intense karstification and tectonics that occur in places. High to moderate water permeability is estimated to characterize the limestone formations of the Tripoli area, and moderate to low the Plattenkalk limestones of the native series particularly limited flow of water exclusively within discontinuities or selective circulation within their mass. Their impermeable nature ensures airtight conditions to the reservoir, as water penetrate due to karstification phenomena (ENVECO S.A, 2018) (Voudouris, 2007).The alluvial deposits that cover the plain of the Lassithi Plateau are estimated to be characterized by fluctuating permeability, due to the variety of porosity of the formations that constitute them. Thus, in the places where the sandy composition prevails, they are generally characterized as water permeable formation, while in places where the aluminous silty composition prevails, their permeability is estimated to be particularly low.

Hydrogeological Basins

The above descripted hydrolithological structure depicts and estimates the boundaries of groundwater systems (or hydrogeological basins) in the study area (Map.3).



Map3: Hydrological basins of Study area

Two types of hydrogeological basins are formed: alluvial (porous aqueous systems) and karstic. The porous alluvial deposits of the Lassithi Plateau are an alluvial hydrogeological basin, which shows lateral transfusions with its neighboring karst basins.

Karst hydrogeological basins are of particular importance for the study area, those that are mainly part of the Plateau area consist of the karst basin of the Western Dikti (west) (ENVECO S.A, 2018).

According to Voudouris et al. (2007), the carbonate formations of the wider area host aquifers at various altitude levels, which often communicate with each other. Also, in several cases, the communication of the water of the limestone formations with the sea water is favored (Voudouris, 2007). The Plattenkalk limestones, the carbonate formations of the Tripoli area, as well as the marly limestones of Neogene are

estimated to have particularly important aquifers (Voudouris, 2007) and to transport significant amounts of water within their mass. The movement of water within the mass of carbonate formations is determined by the shape of the karst complex, as well as by any variety of tectonic structures encountered, such as discontinuities, cracks and folds. Also, a very important parameter that determines and controls the flow of groundwater is the presence of impermeable formations of the Phyllite-Quartzite Series. Due to their stratigraphic location, phyllite and quartz formations are the impenetrable bedrock of carbonate formations in the Tripoli area. In places where the contact of the formations (limestones with Phyllite-Quartzite) is observed on the surface and the morphology allows it, karst contact sources are formed. (Voudouris, 2007)

Hydrogeological Regime

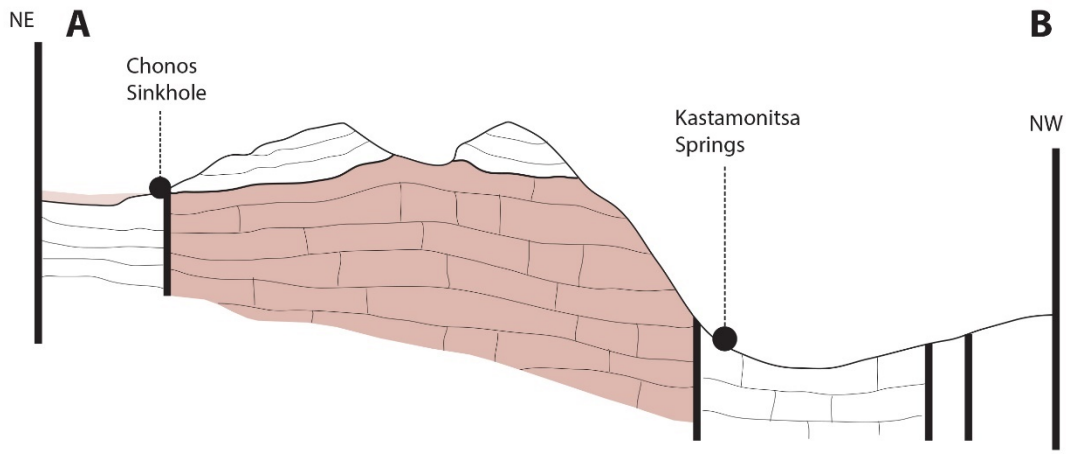
The highly developed karst system of the wider area of the Lassithi Plateau, appears as a very important hydrogeological parameter for the area. In the past decades, the function of this karst complex had been an important object of investigation of the Greek (and not only) scientific community.

The water capacity of the area has been investigated both based on the water balance at the level of hydrological river basins (Koutsogiannis, 2003) and from a hydrogeological point of view, in the form of water balance investigation at the water level basins (Voudouris, 2007).

In the Lassithi Plateau, the surface runoff (up to flooding from time to time) of the river Chavgas is discharged into the sinkholes at Chonos, in the NW part of the Plateau. The sinkholes of the Chonos site are located within the Triassic -Jurassic carbonate formations of the Tripoli zone. According to Voudouris et al. (2007), the maximum drainage capacity of the Chonos sinkhole is 10-12 m^3 / sec.

The water entering them flows through the karst forms of the limestone formation, with the main determining factor of the movement being the complex structure of the karst system. In places where the phyllite-quartzite series is the underlying formation, its impenetrable character often determines the movement of groundwater. In places

where triadic-Jurassic limestones come in contact with other karstic carbonate formations, groundwater movement may continue along with them. During its course, the groundwater supply's karstic aquifers of various altitude positions. It is estimated that a significant amount of groundwater that penetrates into the Triadic-Jurassic limestones (via the Chonos sinkhole) is discharged near the site of Kastamonitsa, in the form of the homonymous karst springs of Kastamonitsa, Agios Georgios (Koutsogiannis, 2003) (Marinos, 2010) (Tsakiris, 2006) (Voudouris, 2007).



Creator: Demelis Nikolaos (Geological section, Chonos to Kastamonitsa (Voudouris et al., 2007).

Eventually, water from the surface runoff of the Lassithi Plateau ends up, after a complex underground route, enriching the surface runoff of the river Aposelemis. According to all the data, a percentage of the surface runoff of the Aposelemis basin already comes from the basin of the Lassithi Plateau'', a hypothesis which confirmed this communication channel between the hydrological basins of Oropedio and Aposelemis was documented, through the sinkholes of the Chonos and the karst springs.

Hydraulic Communication of Plateau & Aposelemis Basins

The scientific research proved with various methods and approaches the existence of hydraulic communication between the basin of the Lassithi Plateau and the basin of Aposelemi.

The hydraulic communication was confirmed by on-site tracing experiments carried out in the area by the I.G.M.E., in the year 2003 (ENVECO S.A, 2018) (Tsakiris, 2006).Also, (Tsakiris, 2006) studied the interconnection between the two basins using deterministic and fuzzy approaches. Voudouris (Voudouris, 2007) report an unpublished technical report of complementary tracing experiments by the I.G.M.E. in the year 2006, which prove hydraulic communication between the Lassithi Plateau (Chonos sinkhole) and the karst aquifers of the whole mountain Dikti, up to the newborn aquifers of the Thrapsano area.

Climate & Meteorological Characteristics

Climate

The wider study area exhibits a Mediterranean climate, which is characterized by mild winters and fairly hot and dry summers ((Ministry of Environment & Energy - Special Secretariat for Water, 2017) (Voudouris, 2007) (Vogiatzi, 2020). Representative meteorological data for the study area are the recorded measurements of the meteorological stations (M.S) of Heraklion, Kastelli (National Meteorology Service, N.M.S. & National Observatory of Athens, NOA) and Tzermiado (National Meteorology Service, N.M.S.), as well as the M.S station of Avdou (Land Reclamation Service, L.R.S). The meteorological station (M.S.) of Heraklion is estimated to be representative of the area of the coastal area of the island, of Avdou of the intermediate area (based on different altitude) and of Tzermiado as representative of the area of the Lassithi Plateau. Tables 1 and 2 give values of rainfall height (mm) and temperatures (^{o}C) of the aforementioned stations in the study area.

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Rainfall (mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Heraklion (1955-1997)	90,1	67,6	58,2	28,5	14,2	3,5	1,0	0,6	17,7	64,9	59,0	77,9	483,2
Heraklion (2006-2017)	92,7	65,6	39,6	18,5	12,3	1,4	0,02	2,7	15,8	72,5	51,0	95,6	467,7
Avdou (1964-1998)	149,1	118,7	105,1	45,5	23,3	10,4	1,7	1,3	23,6	75,4	114,0	132,2	800,3
Tzermiado (1975-1992)	206,7	200,2	146,4	69,5	32,8	12,2	3,1	2,6	26,3	99,5	143,1	240,8	1183,2

Temperature (σε °C)

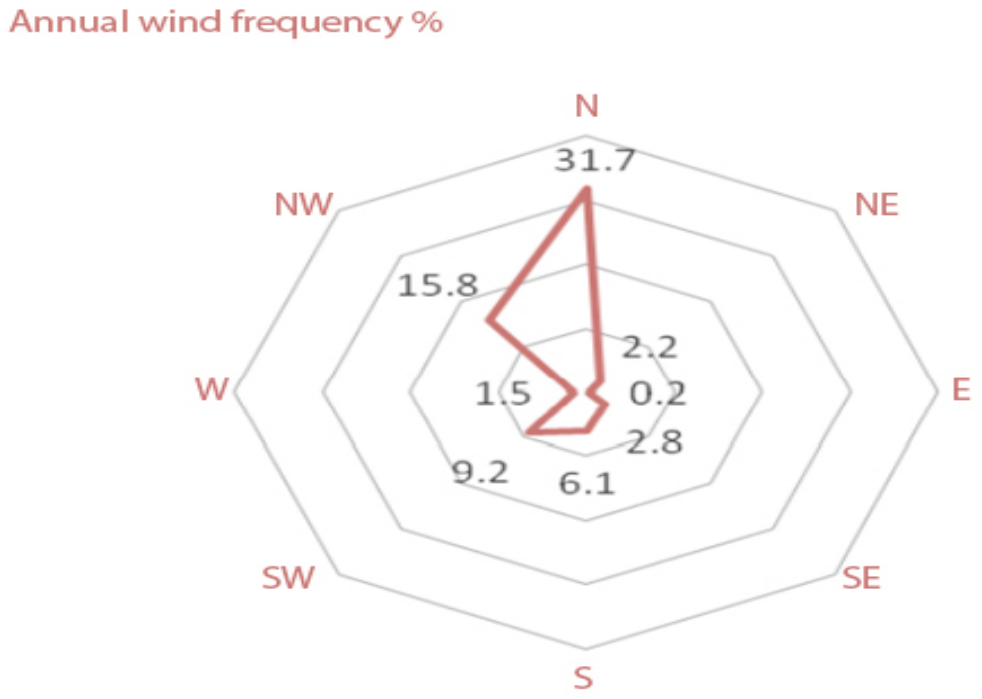
Heraklion (1955-1997)	min	9,0	8,9	9,7	11,8	15,0	19,1	21,6	21,8	19,3	16,5	13,4	10,8
	max	15,3	15,5	16,7	20,0	23,5	27,3	28,7	28,5	26,4	23,4	20,0	17,0
	mean	12,1	12,2	13,5	16,5	20,3	24,4	26,1	26,0	23,5	20,0	16,6	13,7
Heraklion (2006-2017)	min	4,4	5,0	6,5	9,4	12,3	15,8	19,4	20,5	17,0	10,4	10,0	6,0
	max	21,1	22,1	24,4	29,6	32,3	35,9	35,1	33,9	34,0	30,5	26,1	23,0
	mean	12,3	12,7	14,2	17,1	20,4	24,4	26,4	26,5	23,9	20,2	17,0	13,7
Tzermiado EMY (1975-1992)	min	1,9	2,0	2,6	4,7	7,1	9,4	11,1	10,8	9,1	7,5	5,6	3,2
	max	9,9	10,0	12,7	17,0	20,7	24,6	25,3	25,1	23,0	19,8	15,2	11,3
	mean	5,7	5,9	8,0	11,8	15,5	19,1	20,2	19,7	17,2	13,9	10,4	7,1

Source: Enveco S.A 2018

Plateau, with emphasis on the summer period (comparison of data from meteorological station (M.S., N.M.S.). The statistical analysis of rainfall collected data present an average annual value of rainfall height of 483.2mm & 467.7mm in M.S. Heraklion and 800.3mm Avdou. In the M.S. Tzermiado, the average annual value of rainfall amounts to 1183.2mm, a percentage of about 55% of which is observed during December, January and February. Except severe rainfall, in mountain range of Dikti that enclose Plateau it is important to be noted that snowfall occurred from November to April. As for the flat part of it, snowfalls are observed from time to time, mainly during the months of January and February. From the observation of the statistical data of rainfall and temperatures, it appears that the particularly dry period of the hydrological year in the region lasts from May to September (Vogiatzi, 2020). Based on hydrometric statistics of surface runoff it is estimated that the wet period of the hydrological year lasts only from December to April (Koutsogiannis, 2003).

Wind

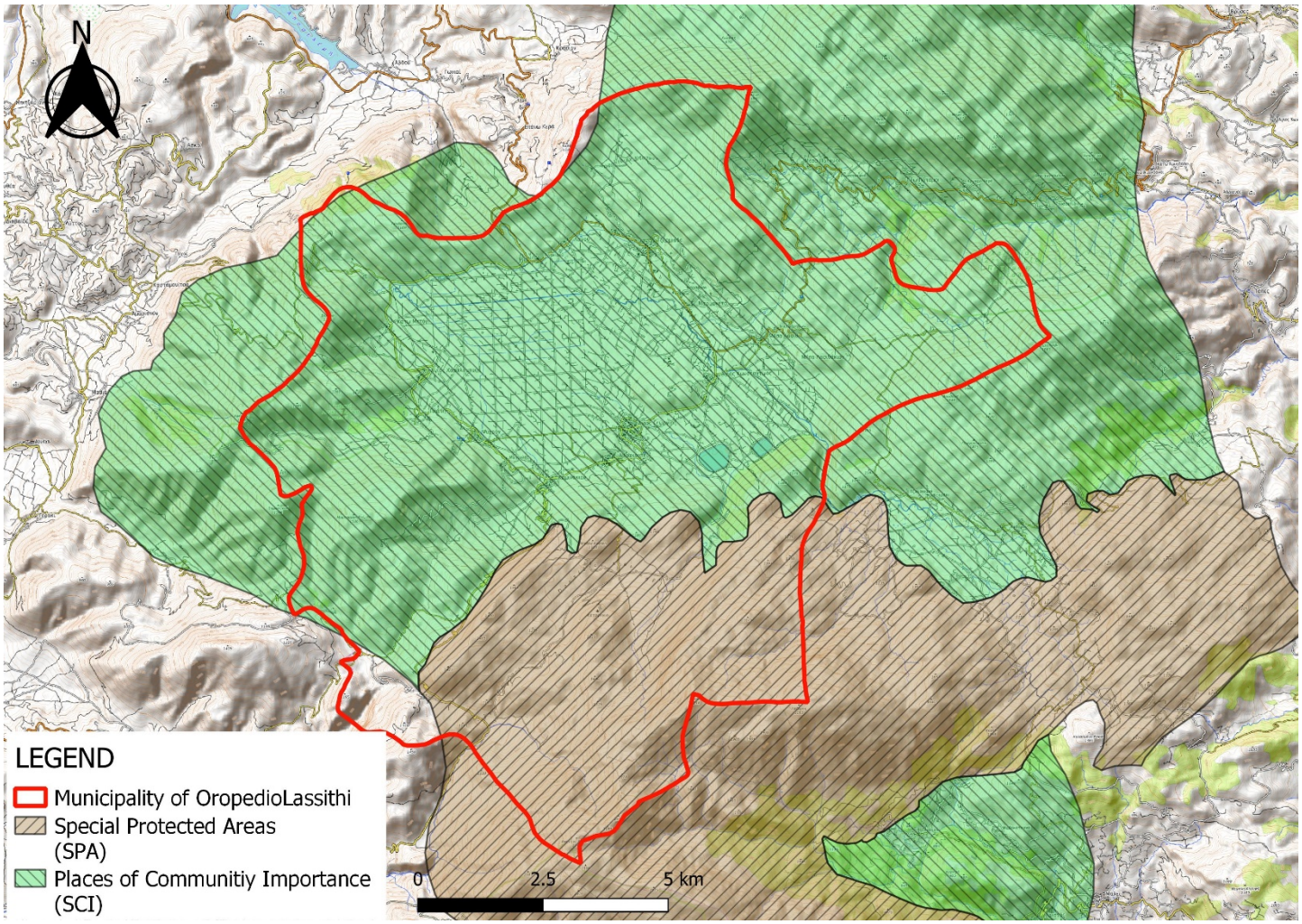
Ancient Greek mythology mention that the birthplace of Zeus was Lassithi and most particular Diktaion Antro cave. Locals combined the above myth with one of the most characteristic climate indicators, wind and name it ''blow of Zeus''. Therefore, it is important to present its main peculiarities. The majority of the wind is low intensity and only a small percentage per year, about 3-4 days, exceeds the intensity of 6 Beaufort. As a result, wind it is not a destructive force for agriculture and local economy.



The collected data from the M.S Tzermiado (N.M.S) depicts that wind mostly originates from N. The average wind speed is 3-5 Beaufort and exceeds 6 Beaufort for 39.4 days per year, while for 1.8 days in total the wind speed exceeds 8 Beaufort. While, during irrigation period wind speed exceeds 6 Beaufort for 8 days.

The percentage of without the presence of wind is 30.4%. The following figure shows the annual wind directions in the study area that occurred during the years 1975-1992, source National Meteorological Service.

Protected areas, flora and fauna Lassithi plateau



Map.3 Protected Area

The Lassithi plateau is an area of special ecological value. In the area there is a variety of habitats, relatively dense forest vegetation and characteristic endemic species of flora and fauna, many of which are typical endemic to Greece and others are found exclusively in Crete. (Wider area of the Plateau), much of it is covered by large mountains and gorges, has been included in the Network of Protected Areas of the European Union (Natura 2000) with code GR4320002 (SCI), which follows specific

European Guidelines for the conservation of natural habitats, wildlife and wild birds. Besides that, the area characterized as Special Protection Areas (SPAs) for birdlife as well as Places of Community Importance (SCIs) that concern habitats and species for protection. For this reason, is important to describe more analytically the local flora and fauna.

Flora

The flora of the area is part of the "Mediterranean vegetation zone" (Quercetalia ilicis), which is divided into two sub-zones of different ecological, chlorotic and physiognomic characteristics and belongs to the sub-zone "Mediterranean formation of Aria Balkan type & Eastern Mediterranean" (Quercion ilicis) (ENVECO S.A, 2018).

The flora of the area includes mainly grasses, phrygana and forest shrubs (Erica manipuliflora, *Spartium* junceum, Sarcopoterium spinosum, *Calicotome villosa*) and aromatic plants (Melissa officinalis , Origanum vulgare, Salvia fruticosa, Matricaria chamomilla, Laurus nobilis, Origanum dictamnus , Lavandula stoechas, Mentha spicata etc.) and at the wetter parts of Plateau, rare and unique species of Acer Creticum is cultivated. (Zaimakis G., 2021)

The special features of the area are the riparian vegetation with common perennials and annuals, pine forest, forests Quercus coccifera but also a large forest with Quercus ilex of about 7 m^2 (700 ha), which is one of the few large arias forests who remained in Crete (Ministry of Environment and Energy, 2016)

Fauna

At national western and the southern steep rocky mountain ranges of Mount Dikti are, the most important area for protected predators. In the area we also find endemic and rare species, such as the very rare snail Helicodonta wilheminae, (Hyla arborea kretensis), Felis silvestris cretensis and Oxychilus amaltheae that is found exclusively in the cave of Diktaio Andro and is facing the risk of extinction. The habitats are considered to be of major importance for a number of protected predators, which either nest in the area, such as the vulture Gypaetus barbatus, Gyps fulvus, Aquila, Falco biarmicus and the Pyrrhocorax pyrrhocorax, or have a sporadic appearance.

According to the Red Book of Endangered Vertebrates of Greece, the vulture species Gypaetus barbatus, in the western Dikti, is characterized as endangered. (Vogiatzi, 2020). Based on Diktis Area Management Plan, 175 bird species have been recorded in the area of Dikti and the Lassithi Plateau, of which 44 are permanent residents of the area. In the same plan bird fauna of plateau descripted as greatest importance, rare species are Otus scops, Calandrella brachydactyla, Lullula arborea arborea, Certhia brachydactyla brachydactyla. Also, mammal species concern Apodemus sylvaticus, Rattus rattus, House mouse, Crocus, Suncus etruscus, Erinaceus concolor, Lepus europaeus, Martes foina, Meles meles, Mustela nivalis and Rhinolophus ferrumequinum. In addition, regarding the reptiles, species Lacerta trilineata, Chalcides ocellatus, Coluber gemonensis, Telescopus fallax, Natrix tesselata, Ela and the amphibians, Bufo viridis, Hyla arborea and Rana cretensis (ENVECO S.A, 2018)

History, social and economic life

Archaeological interest on Lassithi

The Plain of Lassithi first aroused the interest of archaeologists late in the 19th century. Drawn by finds from the cave above the village of Psychro, the archaeologists J. Hazzidakis, President of the Syllogos at Candia (now the Archaeological Museum at Herakleion), and F. Halbherr, an Italian scholar, conducted a small excavation at the cave in 1886. Evans dug cave of Trapeza where he found various findings of archaeological value, also excavated in the Psychro Cave (Watrous, 1982).

The cave was eventually the site of large-scale excavations in 1899 under D. Hogarth. In the spring of 1914, Richard Dawkins excavated at the site of Kato Kephali the village of Plati. He revealed a part of a large Late Minoan settlement which had also been occupied in future periods. Following a visit to Lassithi in 1935, John Pendlebury decided to carry out a program of excavations at different sites in the area in order "to ascertain the distribution of antiquities in this (northern) part of the district of Lasithi."8 During the years 1936- 1939, Pendlebury directed large-scale excavations at three sites and trials at seven others in the vicinity of the village of Tzermiado. In a

systematic manner, he first dug at cave of Trapeza in 1936, then in the following year at the settlement of Kastellos, and finally at settlement of Karphi in 1938/1939 (Watrous, 1982)

Ancient period

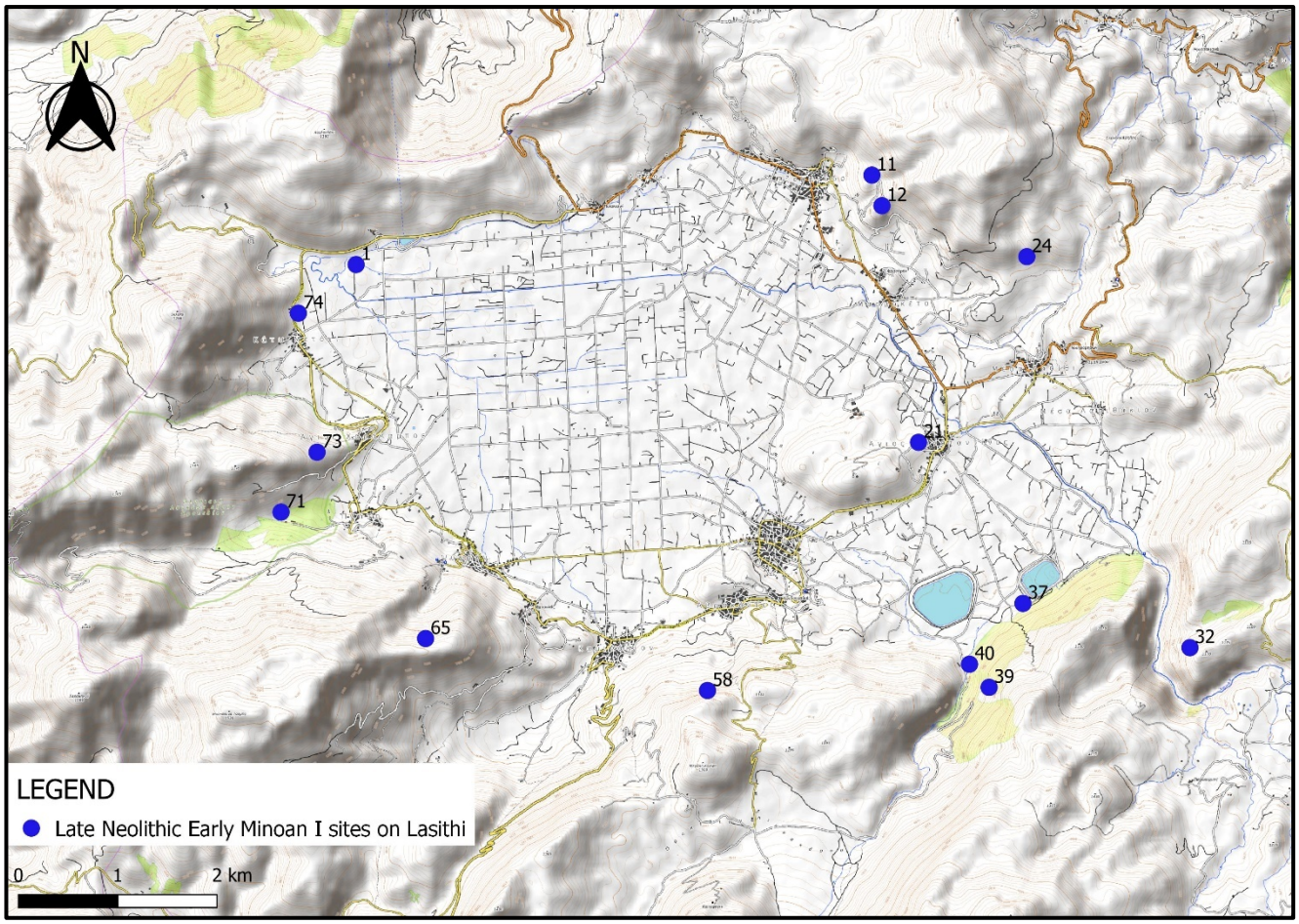
As archaeological research by Arthur Evans (1896) has shown, R.M. Dawkins (1913) and the English School of Archeology in Athens led by John Pendelebury (1937-39) Lassithi has been inhabited since the Neolithic period and has significant human activity in the Minoan period (Pendlebury, 1963). This is shown by remarkable finds, such as bronze figurines, built altars, spearheads, knives, axes, bronze tools, shrines, sanctuaries, ceramic and Neolithic tombs, vases, temples and temples, which have been identified in various archeological sites, such as Trapezas cave, east of Tzermiado, the Kastelo hill, and the Dikteon Andron Cave in Psichro.

In addition, settlements and building complexes have been identified at the top of the Papoura hill, where times, on the Karfi hill on a one-piece rock in the western accesses of Selena and in the village of Plati. (Zaimakis G., 2021, p. 13).

LATE NEOLITHIC-EARLY MINOAN

It important to seek, for each historical period, the social and economic dimension of community life. The earliest evidence of habitation in Lasithi consists of 15 archaeological sites dated to the Late Neolithic or Early Minoan I period **(Map.4)**. Two of the sites are caves, and 13 are open settlements (Watrous, 1982). The findings from the caves indicate the presence of domestic animals' sheeps, goats, oxen, caprices, hogs, piglets and dogs. Also, the existence of marine shells brings to the light the relation between mountainous and coastal areas shows the geographical dispersion of settlements, a choice based on the geomorphology of the plain at the time. Thus, the settlements would have been at bare parts or covered with garigues of the area because foothills would have been wooded (Chapouthier F., 1936). In Lassithi, at four sites stone axes have been found, Richard Dawkins noted from his excavation in East Crete (Palaikastro) that these axes probably used for wood clearance of foothills. From

the above mentioned and based on the archaeological evidence could be described the way of life. Lassithians organized in small groups as seasonal pastorals and exploited the good grazing land (Watrous, 1982).



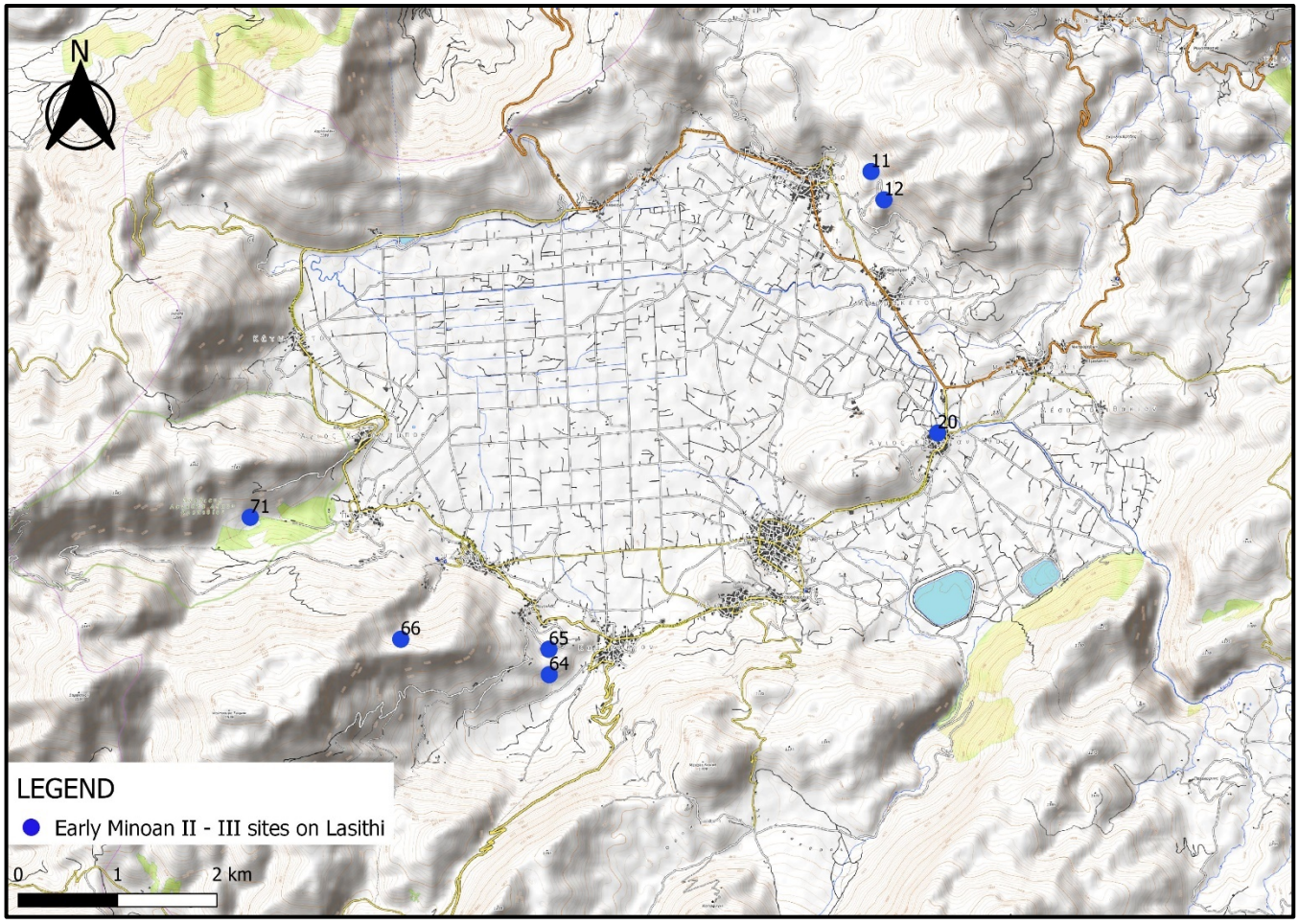
Map.4 Position of sites on Lassithi

EARLY MINOAN II-III

General prosperity of the Early Minoan period didn't leave intact Lassithi plateau, five large sites (Map.5), the four of them new, were situated peripherical of the plain. Even though, an augmentation of the sites happened, in comparison to Early Minoan's, they were relatively small to coastal sites. The motive of sites location stays the same, near the edge of the plain, but the differences on way of life are obvious, agriculture sector seem to be more important and combined with farming, herding and hunting. A hypothesis derived from a study for Dikti region show that the foothills and perhaps the elevated eastern portion of the plain were probably covered with woods of oak,

the flat part may have been marshy for part of the year and covered with reeds, grass, and low brush (P. Y. Sondaar., 1972), served also for animal grazing. As domestic animals, there are no new species in comparison with the previous era, but at this on is evident the hunting of deers, hares and eagles. Also, findings such as spindle whorls, at Kastellos indicate the invention of weaving technology, two ivory figurines, a monkey, a human head, obsidian blades, marine shells proof relations with Mallia, on north, while bronze daggers, cutters and a gold diadem proof relations with Messara on south. (Money-Coutt, 1936)

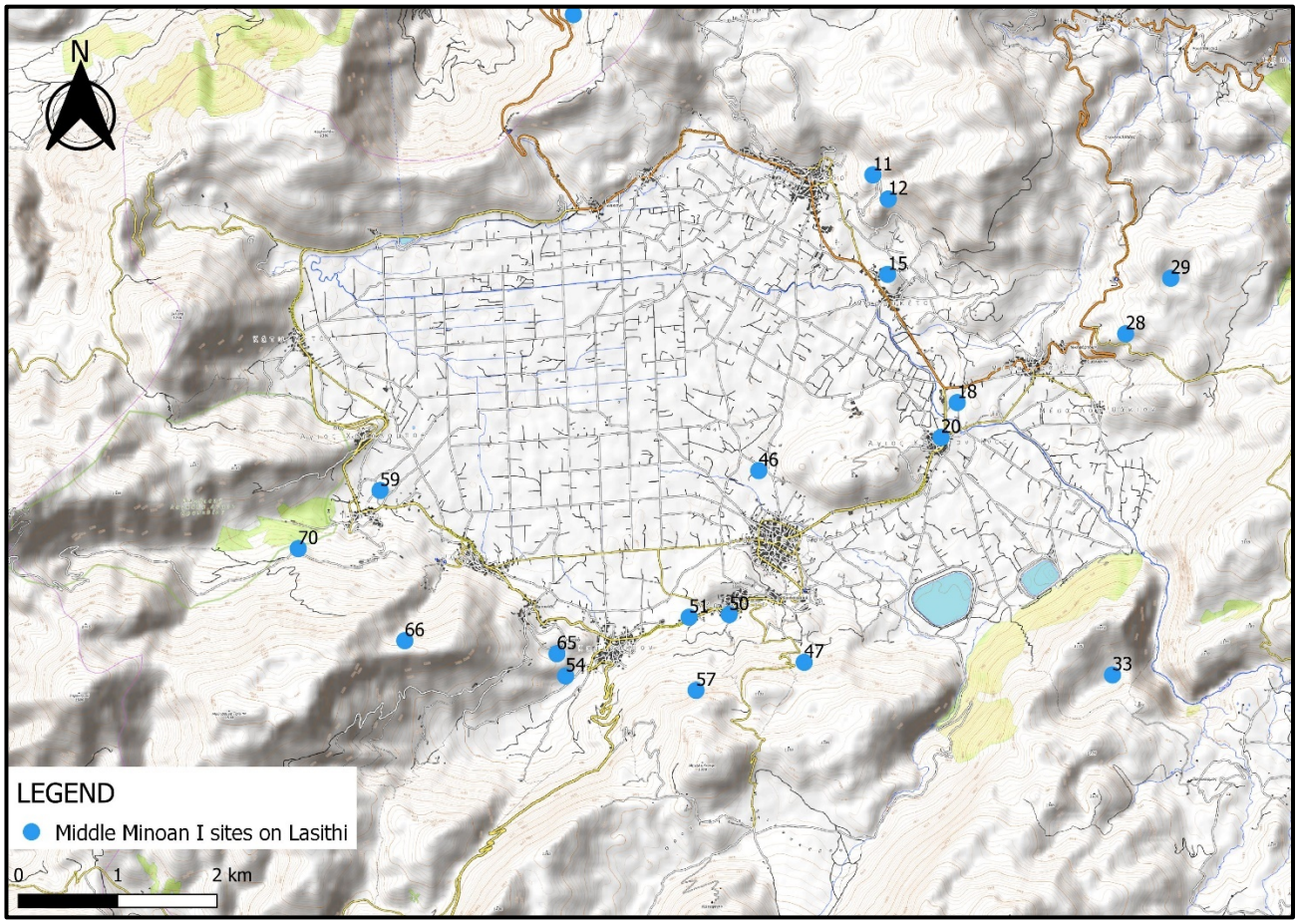
It is important in order to understand better the local social life to mention the custom of burial in Early Minoan period which was burial, usually on the slopes below a settlement or in a nearby cave (Money-Coutt, 1936).



Map.5 Position of sites on Lassithi

MIDDLE MINOAN I

The grow continues as three new large settlements added to four existences raising the number to a total of seven. (Map 6). At this historical period habitants preferred to live closer to the plain (100m above it), for reasons such as bigger space and proximity to arable land (Map.6) (Money-Coutt, 1936). Likewise, the distance between the sites within 20 min walk indicate that the settlers were familiar with the area and probably were from the older sites. Offerings indicate the importance of Psychro cave which considered as the most popular in Lassithi. Also, the custom of burying evolved, as at that time dead buried in pithoi (Money-Coutt, 1936, p. 15 & 40).

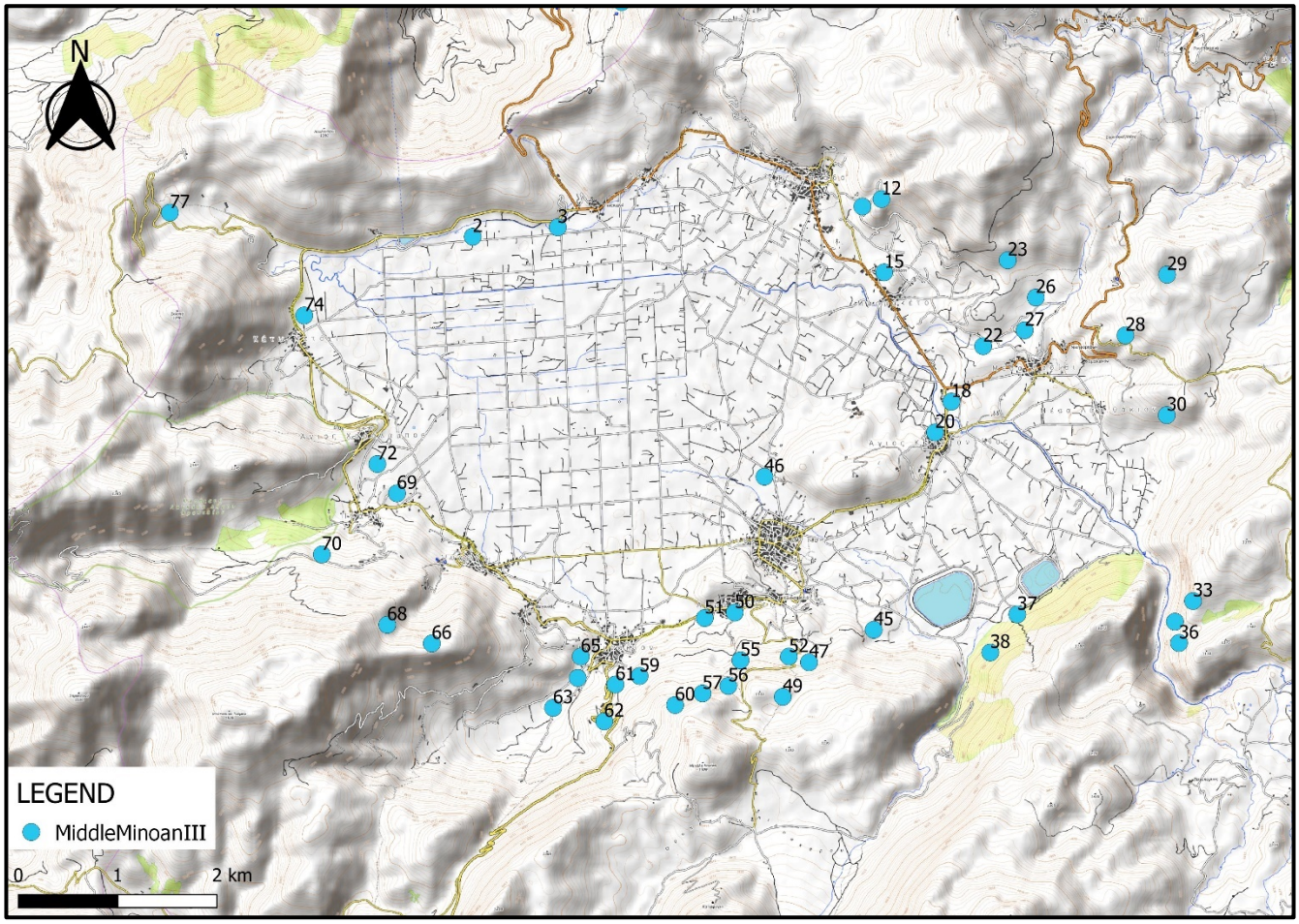


Map.6 Position of sites on Lassithi

MIDDLE MINOAN III

Population in Lassithi reached its maximum, the number of major settlements is ten and new one's founded on the edge of plain (Map.7). Small sites are so numerous in Lasithi during this period that we may discuss them as a separate site, separate group (Hood, 1964). The research discriminates two different types of plots: the first one consisted from sherds and remains of walls, which constructed from natural blocks or shaped stones and the second one which were constructed by simple concertation of sherds. The location of an Agia Pelagia because of its location assumed that during Bronze Age suffered from heavy winters along with a big portion of mud derived from runoff from Mt. Dikti.

Also, sites at high altitude above the plain even at 1.100m, indicate the use of them as agriculture houses – farms. Based on the altitude it is concluded that during the winter were uninhabited and pointed out the seasonal habitation - seasonal agriculture way of life. Finally, there is some evidence for literacy on the plain, in the form of MM III-LM I Linear A tablets, said to be from Papoura (Watrous, 1982).

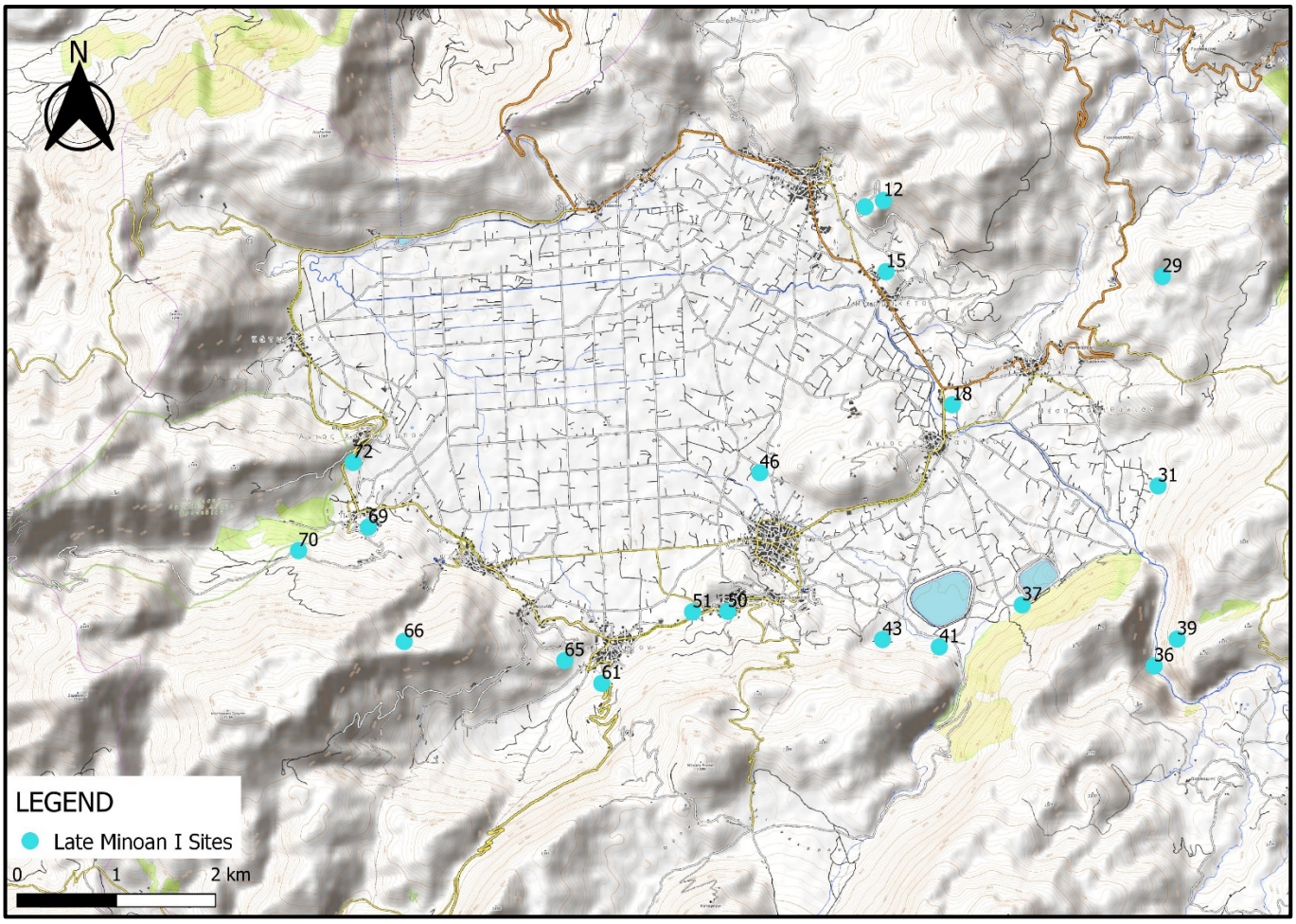


Map.7 Position of sites on Lassithi

LATE MINOAN I

In contrast with the generally prosperity on Crete, here there as signs of abandoned sites on hilltop while others like Plati showed an expansion (Dawkins, 1914). It is the first noticed internal immigration from smaller sites (deserted) to bigger ones, in terms of altitude elevation from high to down onto the plain. Perhaps the most important point is that in each of the above cases the move of the village was in response to external forces of economic centralization (Watrous, 1982) The excavators of the palace at Mallia on the north coast of Crete (Map 2) have suggested that during the LM I period the plain of Lassithi served as a regular source of large amounts of grain for Mallia (Hazzidakis, 1963). Certainly, as mention in previous paragraphs there plenty of evidence that indicate trade with Malia, which is the closest Minoan center, and with other Minoan centers. Secondly, inform us about trade roots, commerce of

local production (probably cheese, grains, and other crops) and raw materials (such as meat, wool, and wood) to palaces. Some form of taxation is possible that indicate that the economy was wider that the geographical limits of the plateau (Map.8).



Map.8 Position of sites on Lassithi

LATE MINOAN II

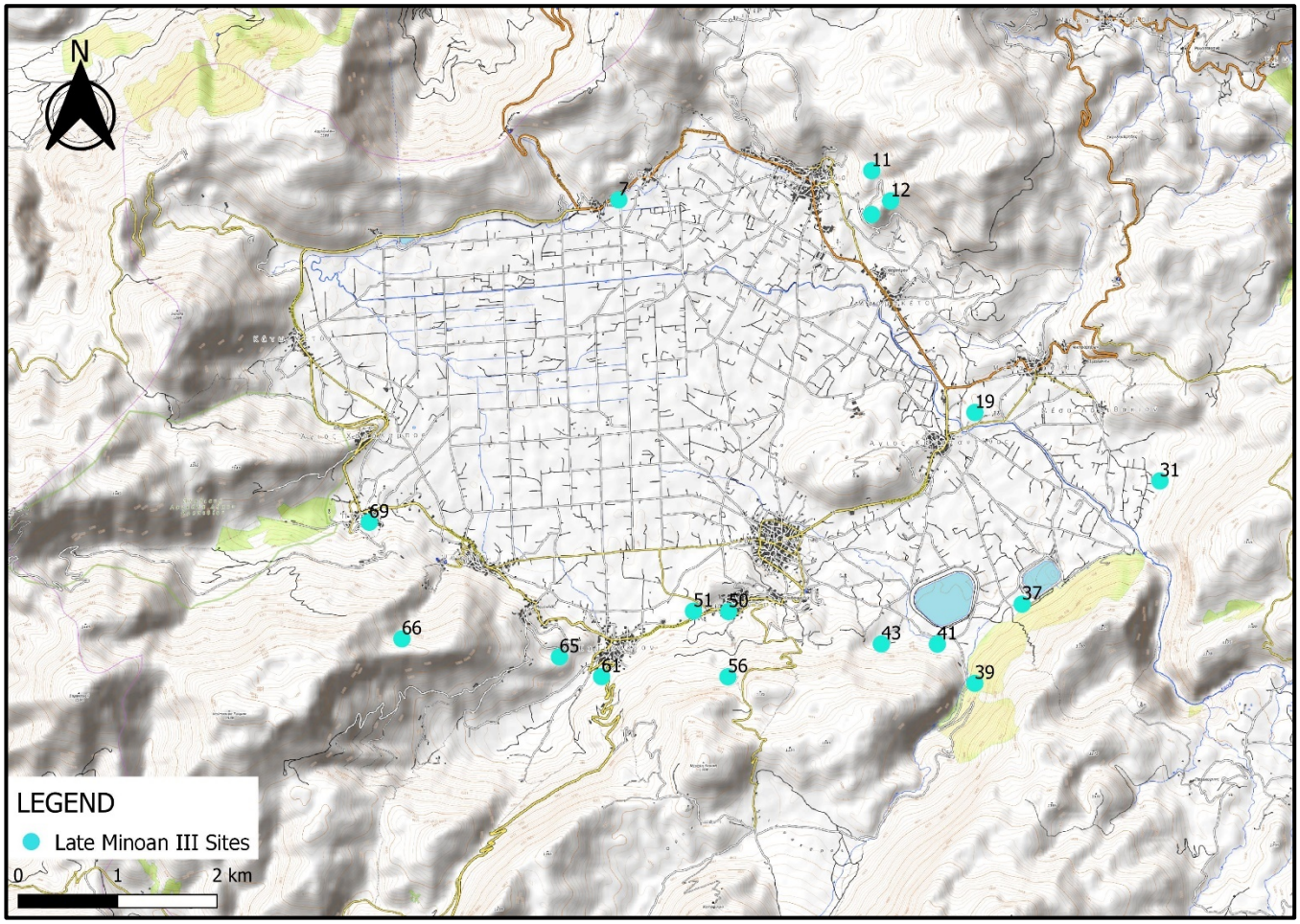
Pottery in Lasithi which could be definitely called Late Minoan II was not recognized by Pendlebury or by us.

LATE MINOAN III A-B

In the succeeding period, Lassithi population dropped sharply, as major sites full deserted and the others mark a significant deterioration of habitation except the site of Plati (Map 9). A chronological approach shows that the decrease of population

followed by the desolation of settlements. It should be noted that this series of events had a catholic application to island of Crete during this period, destruction followed by later reoccupation (Watrous, 1982, pp. 17-18). This dissertation correlates to an historical event which is the eruption of Santorini volcano In Lassithi (Desboroug, 1964).

Dawkins compared the architectural arrangement between a House at Gournia and another of Plati,the first one regarded as a Mycenaean construction. At this time in Lasithi the new architecture at Plati must have been an imposing site, in contrast to other settlements on the plain. It is difficult to avoid the conclusion that Mycenaeans lived at Plati among the remnants of the Minoan population in Lasithi (Watrous, 1982, p. 18). Also, four Linear B tablets enforce the observation of Dawkins. The Mycenaeans at Plati probably controlled the Diktaian sanctuary at Psychro. Mycenaean officials stationed at various locations on Crete appear to have been members of garrisons which were probably responsible for enforcing the flow of tribute from those areas to Knossos. We can be fairly certain that the local population on the plain at that time was supplying tribute, probably grain, wool, and sheep, to Knossos (Watrous, 1982, p. 18). Finally, a new burial method came up, burial on larnakes.

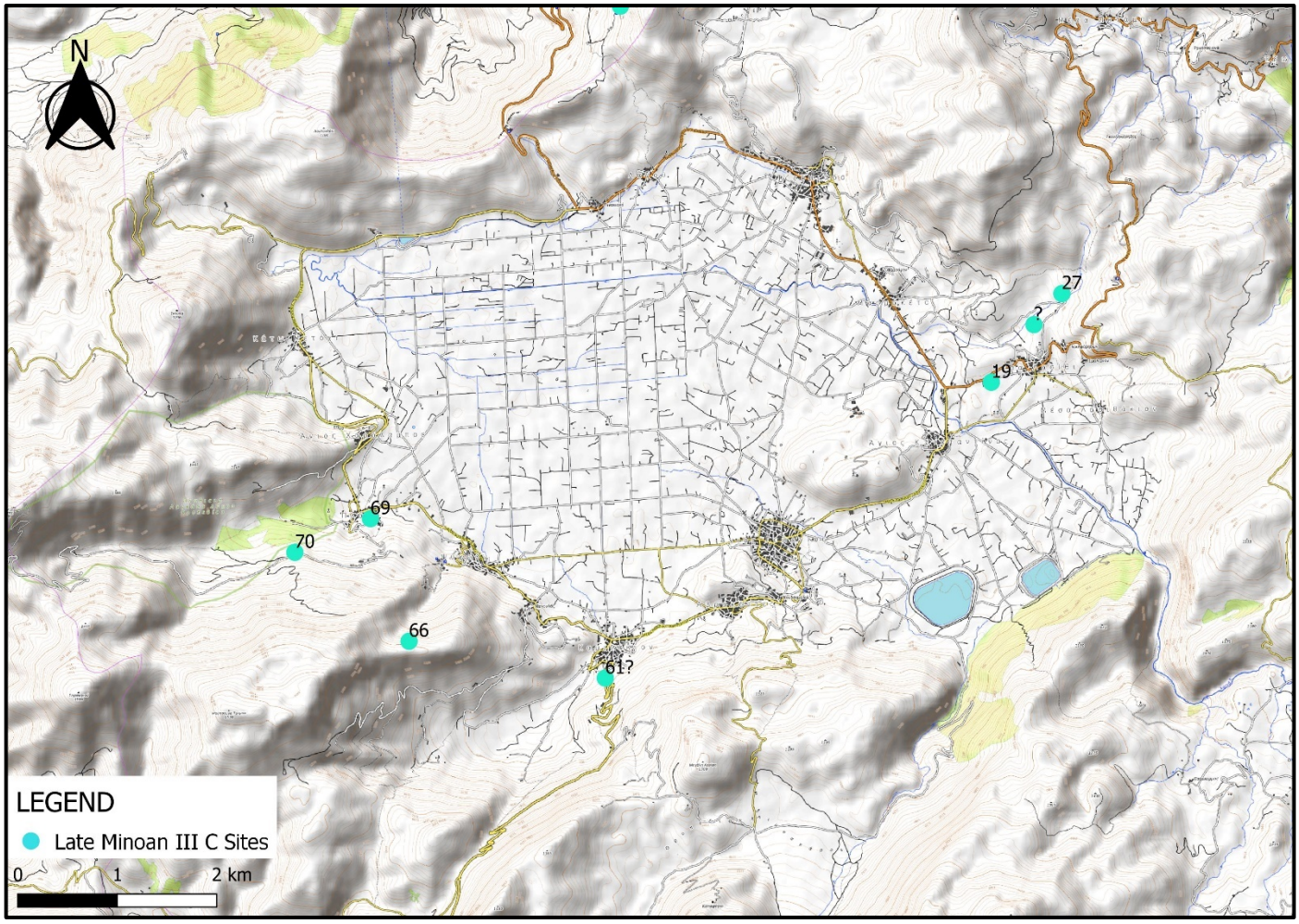


Map.9 Position of sites on Lassithi

LATE MINOAN III C

The phenomenon of diminution of population continues in the island of Crete and to Lassithi too, perhaps four sites in Lasithi continued to be occupied and Plati (Watrous, 1982, p. 19). Around 12th century B.C. the only large site was on top of a mountain peak at Karphi, outside of the plain, a choice which demonstrate the need to be protected. Mixture of cultural materials provide information about the population composition of Mainland Greeks and Minoans (Money-Coutt, 1936, p. 111) (Desboroug, 1964, pp. 172-176). Furthermore, in contrast with Karphi's geographical position characterized as isolated, was revealed the communication with other civilization outside of Crete, such as Cyprus, Italy and central Europe (Boardman, 1961,

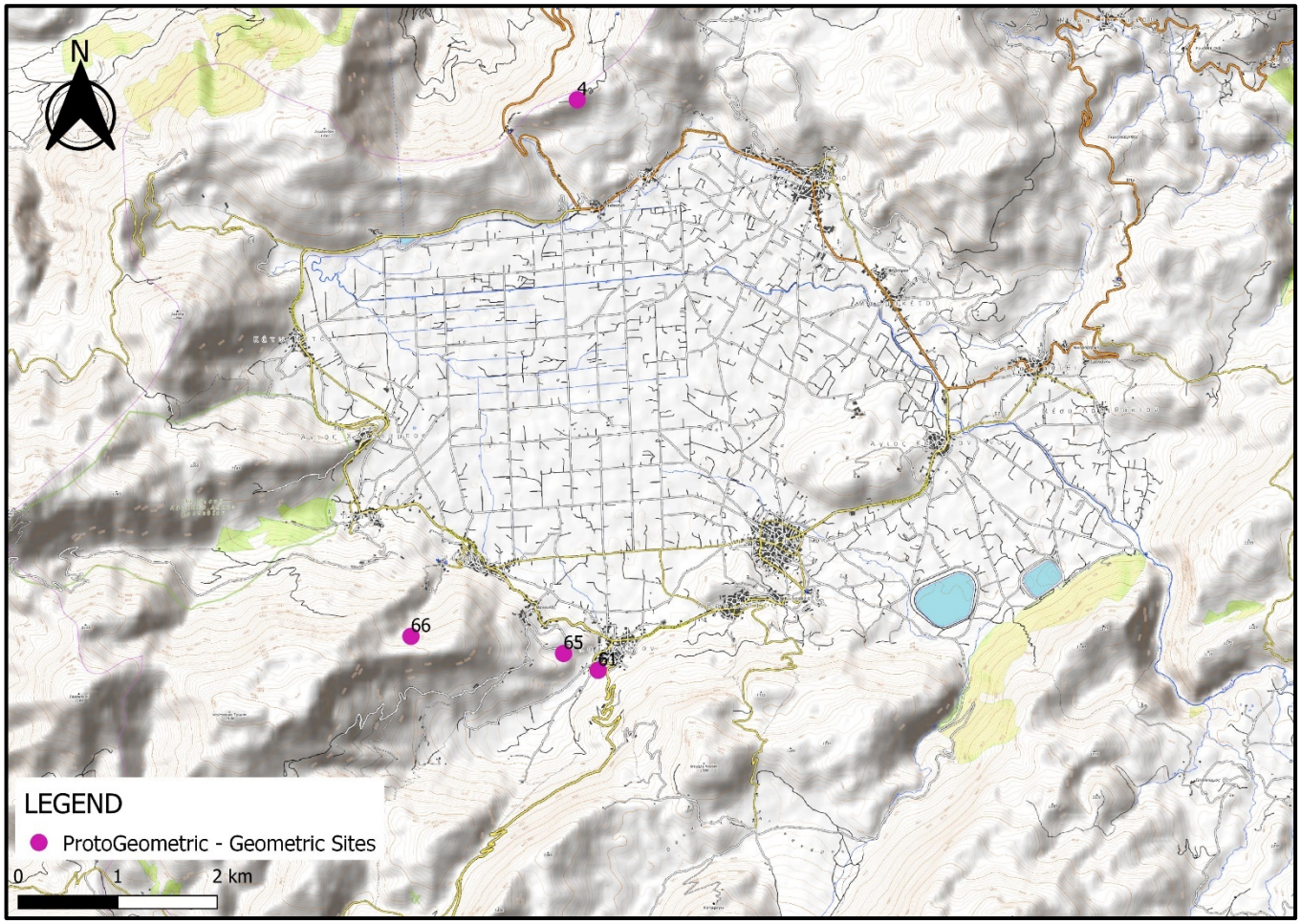
pp. 74-75 & 130) One suspects that not all the citizens of Karphi made an honest living from the soil; some may have tried their hand at piracy (Money-Coutt, 1936, p. 133 & 140). As it concerns the economy life, a variety tools founded such as spindle whorls, spools, loom weights, bobbins, Stone querns, pounders, spinning, weaving implements olive pits and sickles, based on extensive sheepherding, cultivation of grain, olives and hunting (a limited number of deer) (Map10). Geographical, high (ca. 1,250 m.) peak and climatological, cold during the winter months reasons suggested that the pasture took place seasonally and the cultivation of olives in a lower altitude outside Karphi because olive trees doesn't grow above 800m. The pasture seasonality expressed through the foundation of contemporary sites and a ''grazing immigration'' to lower areas with the flock.



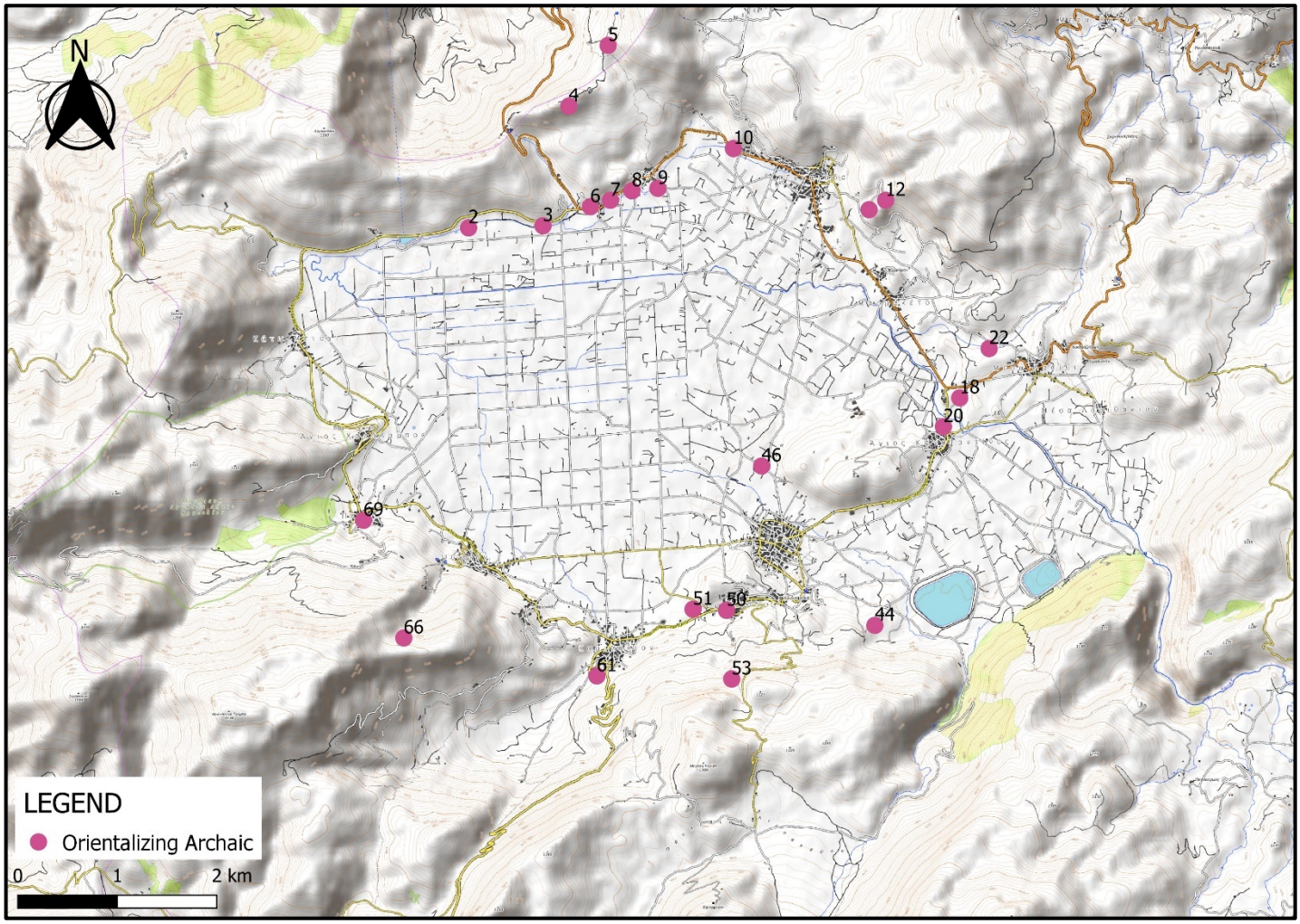
Map.10 Position of sites on Lassithi

PROTOGEOMETRIC, GEOMETRIC AND ARCHAIC

By the end of the 2nd millennium B.C. happened the relocation of Karphi to a place nearer to the plain, about one km at the site of Papoura (Map.11), which was closer to the natural entrance. In addition, had a better position. During the Protogeometric and Geometric periods, the population of Lasithi was concentrated on this large site. During the Geometric period, Papoura was at least twice the size of Karphi, suggesting that the population in Lasithi had increased during the Early Iron Age (Watrous, 1982, p. 21). The habitants were aware of its spiritual and historic link with the previous location as it shown from the offerings of Karphi tombs (Watrous, 1982, p. 21). During Geometric and the Archaic periods, Psychro cave gain reputation to Greek world and during Early Iron Age surpassed the geographic limits of Crete and expanded allover Greece. Poet Hesiod sang (Theogony, 481-484) of Zeus, the father of the gods, referred to the shrine of Psychro which received offerings from all over Greece (Boardman, 1961, p. 36 & 56). In addition, during Archaic period local population with the help of a scholar wrote down their laws.



Map.11 Position of sites on Lassithi



Map.12 Position of sites on Lassithi

Classical and Hellenistic

Archaeological survey showed acutely digressed of population and abandonment of the sites. Surprisingly, there is less evidence for settlement in Lasithi during Classical and Hellenistic periods than at any other time in antiquity (Watrous, 1982, p. 22). As far as economical activities were found traces of dyeing and weaving of wool in the 3rd century B.C (Pendlebury J. , 1963, p. 199). Also, Theophrastos, ancient philosopher depicted the dissertation and gave us information about agriculture sector in previous times through his text: ''if, then, it is true (as proof of which they allege that formerly the hills were inhabited and produced both corn and fruit, the land having been planted and cultivated for that purpose; that there are in fact on the hills of the Ida

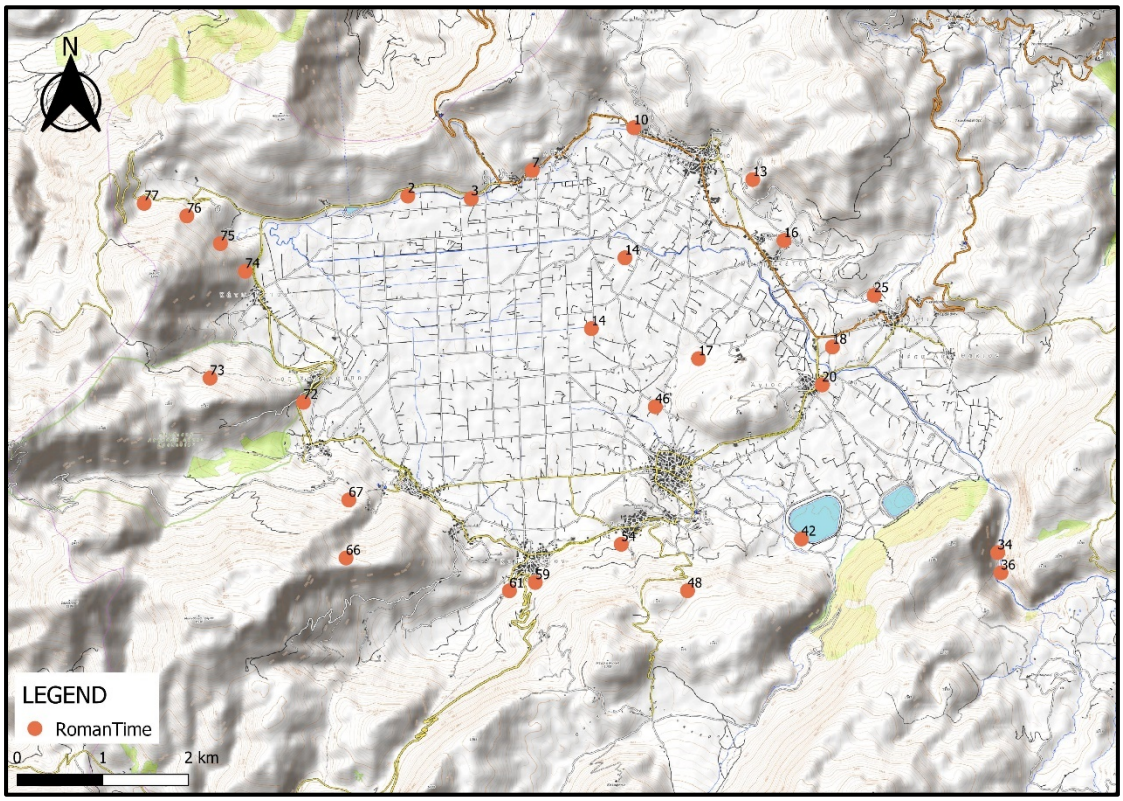
range and on others, plateaus of considerable extent of which nowadays they cultivate not one, because they are unproductive; while formerly as had been said they not only cultivated them, but dwelt upon them so that the island had a large population; and that at the time showers occurred, but much snow and storm did not'' (J. Wood, 1894, pp. 27-29). What philosopher expressed in his text, highlight a climate event or a climate change that affected mostly areas with high altitude and intrigued the abandonment. On the contrary, may there is a political reason, as cited in a treaty between the cities of Lyttos - Lato and Olous, where the demarcation of the border took place. At that time, Lassithi was part of the territory of Lyttos, was enslaved and its inhabitants were serfs as mentioned by Aristotle (Politics, 1271b), obliged to pay rent for their land. Also, the production from herds and agriculture products went to the state. Another, community which was under the rule of Lyttos – Arkadians also deserted during 6th century (Boardman, 1961, p. 148). From the treaties derived that Lyttos defended their dominion by arms, which may also constitute one more reason for Lassithians to desert the area (Guarducci, 1935-50).

ROMAN 69 B.C

The polemic and uncertainty period came to an end with the occupation of Crete by Romans in 69 B.C. when entered a new era of stability and prosperity. New settlers repopulated it (Pendlebury J. D., 1939), Lassithi regained its former status of habitation. During the 4th through 7th centuries after Christ had its maximum number of habitants in comparison with any previous time, but a different motif of sites and their dispersion came up. Under the rule of Roman empire, because of the provided security, the population tented to concentrate in a single settlement rather than a numerous site around the plain. Secondly, from studies on others places on Crete like Messara, during this period sites have been found on the alluvium plain, rather than on slopes (Saunders, 1976). Based on Roman tradition on engineering works especially artificial drainage is it possible the habitation of alluvium be a result of a drainage to

Lassithi plain (Map 13). A hydraulic work that justified this hypothesis is the aqueduct of Lyttos which supplied it with water from Lassithi plain from its sinkhole.

In the following periods of Cretan History until the Venetian occupation no remarkable information about Lassithi is reported. At this point it is important with the few available resources to depict aspects of social and economic life.



Map.13 Position of sites on Lassithi

Byzantine occupation I

The fifth century marks the beginning of an era of silence and obscurity which lasted until the beginning of the 13th century, an era absent from literature. The first half of the 5th century characterized as catastrophic because a series of natural disasters, earthquakes, plague and famine took place. Despite the results of the natural forces, as Christianity adopted as a new religion, brought up a massive building activity, basilica churches allover Crete, but it is not proof of a prosperous economy. In contrary it could be said that island enjoyed a long period of peace. Archaeological evidence showed that 6th and first half of 7th century were the ''golden era'' of Byzantine Crete.

It came to an end because of the rapid expansion of the Arabs and was frapped by two more destructive earthquakes *(618 A.D & 670 A.D)* (Tsougarakis, 1988, p. 22).

As often happen to human history nothing lasts forever, so 8th century, as derived from archaeological findings, a retreat in economy and social condition of Crete occurred. Ruined towns, churches and coins depicts that a new ''Dark Age'' caused mostly by climate change, a severe drought which mentioned on St Andreas life. (Tsougarakis, 1988, p. 26). Previously, plague stroke Byzantine empire and among them Crete, urban areas affected more than rural and a demographic decline happened.

The Arab Conquest 825/826 - 961

Although highly valued for its resources, Roman, and subsequently Byzantine, Crete was gradually neglected and entered a long period of decline, and had been largely overshadowed by Sicily in terms of strategic importance. The earliest recorded Arab's raid against Crete was conducted under the rule of **Abu *I' 'Awar*** and his army (Tsougarakis, 1988, p. 22). More specific the one that conquered it were Andalusī Muslim in *827*. At that time was a minor province of the empire characterized by chaos, disorganization, and disunity. The Andalusīs left the local religious infrastructure of Crete intact, allowing the native population to maintain their religion, but implemented Islamic patterns of taxation, urbanization, and administration (Delgado, 1991, p. 225) (Christides, 1981, p. 98) (Christides, 1984, pp. 104-117) , *Jizya* (poll tax) was imposed upon the conquered non-Muslim populations (known as ***ahl al-dhimma*** or "protected people"), Cretans secured active support from the Ṭulūnids of Egypt (868–905), demonstrating a certain level of political aptitude (Christides, 1984, p. 109) (Christides, 1981, p. 98).

In comparison, with present periods under ***Andalusī*** rule Crete reentered prosperity status, economy life improved the island went from being a remote, subordinated province of the Byzantine Empire to an autonomous, self-sustaining country with extensive trade, intensive agriculture, and the accumulation of vast wealth as a result

of trade, raids, and local enterprise (Christides, 1984, p. 117). So, its transformation proved from the fact that Cretans had the own coin - currency, which not only included copper coins but also silver and gold, demonstrating their wealth and political autonomy from the rest of the Islamic world, trade with Egypt and Vikings in such commodities as honey, olive oil, timber, weaponry wine, cheese, milk, honey, pomegranates, nuts, precious metals, and unique herbs, known as *al-Antimūn* (Antimonium; used in medicines and dyeing) to the rest of the Islamic world (Christides, 1984, p. 114) (Delgado, 1991, pp. 227-228) (Miles, 1964, p. 1–32). From the above derived the cosmopolitan character of Crete cosmopolitan caused a social interaction between Greek population Andalusī conquerors, and Arab Muslim settlers (Christides, 1984, pp. 105-107) (Tsougarakis, 1988, p. 75). The fruits of piracy were important source of income and social capital, through trade and wellbeing. The island was not reconquered until 961 by a revitalized, resurgent, and militarily powerful Byzantine empire.

Byzantine occupation II 961 - 1211

In the following periods of Cretan History until the Venetian occupation no remarkable information about Lassithi is reported. The only important fact beside the liberation of the island from Nikiforos Fokas, are written sources that referred to the economic aspect, it had the advantage of to provide a certain amount of surplus agricultural produce and to pay considerable taxes (Tsougarakis, 1988, pp. 80-81).

Venetian occupation 1211 – 1669

With the document of 1211 (Concessio Cretae - Concession), according to which the doge of Venice Pietro Ziani ceded Crete to the Venetian settlers, the Venetian occupation of the island formally began (Gasparis, 1997, p. 25). A time when the effects of foreign domination on the people and the area can be historically documented (Watrous, 1982, p. 25) (Spanakis, 1957, p. 9). As will be seen, the new rulers viewed Lassithi primarily as an exploitable source of grain. However, For two

centuries it became a famous refuge and settlement for Cretan rebels who were against the Republic of Venice. Its geographical position, high altitude and its remoteness from city centers was ideal for defensive purposes. In addition, it had only a short road entrance, easily guarded by a few warriors and had a fertile plain suitable for the production of cereals, necessary for survival (Spanakis, 1976, p. 19).

In the late 13th century (1283-1299) the Venetians reacted to the resistance by a series of prohibitions lasting until 1514, the first of which was the banning of settlements on the plain (Theotokis, 1936, p. 41) (Watrous, 1982, p. 25). Following this, in 1341 by, the Venetians forbade cultivation and set a fine of 100 gold coins (Spanakis, 1957, pp. 10-14). In a later document, dated 1343, refers to the exact geographical boundaries of prohibition, one of them was the watermill of ''Havga'' a technological achievement of its day, using the power of water for grinding different type of grains (Tzompanaki, 2007, p. 154).

The third one in *1364*, was the harshest (Spanakis, 1957, pp. 15-16) (Watrous, 1982, p. 25), according to which it was ordered the demolition of all the houses in Lassithi, settling was forbidden, along with the planting and grazing flocks or horses in the plain. For those who violated it, the punishment was amputation of a foot. As a result, the Lassithi plain was deserted. . In *1421* the traveler Buondelmonti related that the plain was not cultivated but was grazed by 'a multitude of herds and flocks' (Rackham, 2010, p. 272). Venetian Senate lifted the ban (*1463*) for political reasons, more specifically because of the hostilities and war campaigns against the Ottomans. They needed all the available space such as mountainous areas and plains to be able to cultivate grains for the needs of their army (Spanakis, 1957, pp. 17-18). For this purpose, Senate ordered in *1465*, the government of Crete to ensure that Lassithi be a place without herds and to be planted with wheat (Spanakis, 1957, p. 14). As a result of desertion, the lack of any agricultural activities and local opposition to the plan, the plain, that had become a forest, was cleared as the order took flesh and bones in *1514.* (Spanakis, 1953, p. 58).

As a result, the total area was cleared and divided into ***342 boudees***[2], each of which was subdivided into ***8 ½*** fields that were leased publicly. The land rental was to be paid with a portion of the wheat crop. (Watrous, 1982, p. 25) (Spanakis, 1953, p. 58). ***Boudea*** *or* ***Voudea*** was a field metric system, corresponded to *ox-ploughing and was equivalent to bovina*. Each **voudea** is subdivided irregularly into about 34 fields - a total of c. 5900 fields, with a mean area of 0.155 ha (Rackham, 2010, p. 272). During the year *1545,* Senate ordered Candia local government to ensure that grain productivity was doubled and an official record gives more details about leasing terms, ten settlers were given land averaging *550 mouzouria*[3] *per grant,* with the responsibility to turn over half of their wheat harvest to a grain warehouse in Candia. Each mouzouri paid by local government 8 gazettes[4]. The productivity goal for Lassithi was set at 7000 mouzouria when the preceded year goal was 5000 mouzouria. Besides this, the unproductive marshy western part of the plain had been a problem that needed a tangible solution, for this purpose, the Senate donated 1500 gold *ducati*[5]*.* This amount of money was used by engineers in order to inspect the plain and propose a suitable and permanent solution. Consequently, it was decided that the *468 boudees* of unclaimed land were also to be leased (Sathas, Paris -Athens, p. 376).

To reach the expected grain yield, in *1548,* Senate launched ''the colonization program '' with settles from Nauplion and Monevasia, more *368 boudees* of unclaimed land was granted to colonists under the term to be cultivated and not to be sold or expropriated. In turn, the settlers were exempt from forced labor (on the construction

[2] **boudea (- es)**: During Venetian rule, the amount of land which could be sown by 30-35 mouzouria of grain.

[3] ***Mouzouria*** *(mensura):* Capacity unit for cereals. It was equal to about 17 kg. Also, a unit of surface for the land cultivated with cereals. It theoretically represented the area of land that required sowing a grain of cereal. Its area has not been precisely determined; however, it is estimated at about 400 m^2. (Gasparis, 1997, p. 43)

Mouzouria: Venetian measure of wheat, equal to 16 okades taken in a standard copper container. The area of land which could be sown by this amount of grain.

Oka (okades): 1.25 kilos (Watrous, 1982, p. Glossary)

[4] ***Gazette***: coin worth two *soldi*.

[5] ***Ducati***: coin of Republic of Venice

of the walls of Candia and in the fleet) and the ten-percent government tax (Sathas, Paris -Athens, p. 376).

During *colonization period*, official documents give a detail description about every day and agricultural life. The roads were so narrow that was impossible for two people to walk side by side (Spanakis, 1953, p. 82) and the most common entrance from Seli was the only one accessible by horse (Codex 918 [8392] (Spanakis, 1957, p. 82). The agricultural area is represented as very fertile, wheat monoculture and its western part as marshland ["Terreni paludosi," (Spanakis, 1957, p. 30), (Sathas, Paris -Athens, p. 376). The Surrounding mountains were covered with wild holm oak and forbitten fruits as grapes appeared at the foothills (Spanakis, 1957, pp. 74,79-90).

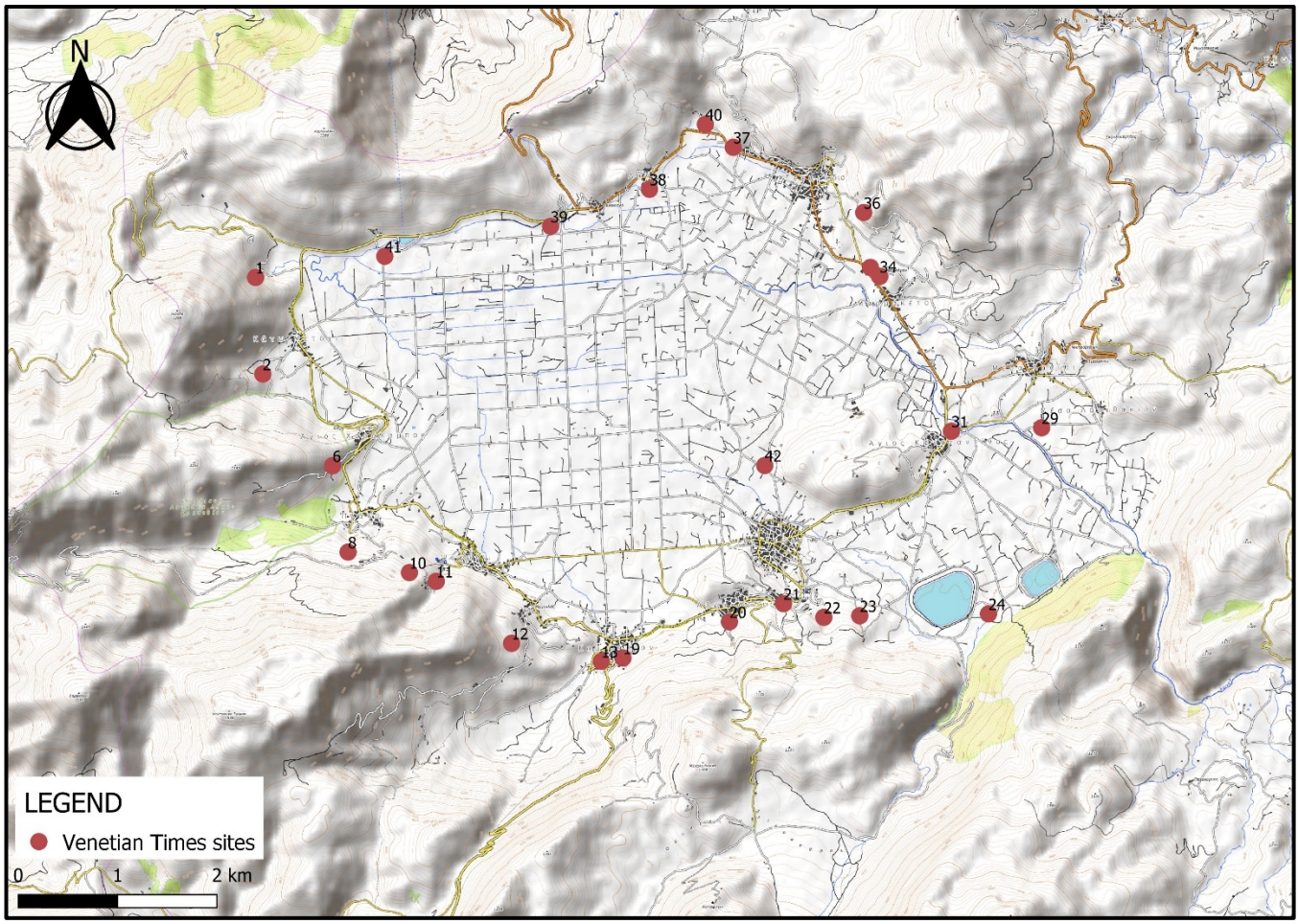
In *1572*, Proveditor General Marin Cavalli after a visit from Candia discovered the disobedience of settlers to official decisions [Codex 918 (8392), (Spanakis, 1957, pp. 32-33)]. Farming occurred wherever they wished while colonists had leased their land to others without any documentation of the renters. But the inconsistency weren't restricted only to cultivation but extended to non-payment of taxes for timber exploitation and the ruining of mountainsides by the burning of trees. A list with settler's names and a report to Senate have been made with a recommendation, of General, for a surveyor and accountant. The recommendation described the need to divide the land into fields of 10 *boudees* and to be numbered and recorded in a catalogue [Codex 918 (8392), (Spanakis, 1957, pp. 32-33)].

Despite the interference of local authorities to impose the decisions and to maximize grain yield, Candia headquarters (report *1574),* narrated a bleak economic situation for the local community. In compliance with it, 10 years earlier, 400 farmers families were rich and blooming, paying 30000 mouzouria of wheat when at the time of the report the number of families had diminished to less than 200, depicted as poor, unable to pay annually taxes equal to 25 stara[6] of wheat, because of bad harvests. As a result of the above situation, families kept the harvest hidden to provide food for their children. The other 200 families were forced to migrate to other parts of the

[6] ***Stara*** :A Venetian measure capacity, weighing 83.3 kilos, used for wheat

island to avoid hunger and poverty. The report ended by suggesting the appointment of an official with authority to control the seasonal collection of wheat harvest.

General Cavalli's proposal , a cadaster of *1582,* recorded local population (Map14) to be 1054 persons, inhabiting 40 temporal residences, because the construction of permanent houses was banned to avoid incidents of the past such as the cultivation other than wheat, vines and certain (probably fruit) trees (Watrous, 1982, p. 27)**.** [7]



Map.14 Position of sites on Lassithi

[7] *" ... alcune casupole, habitatione solamente per reduto delli huomeni, et animali, et questo no(n) si poter fabricar casa grande, et cio per essur stato prohibito, dall' Eccmo Conso de X per la qual cosa gli viene obstrato di no(n) poter fabricar case, piantar vigne ne nussuna fossa d'albori ...." Codex 918 (8392), folio 38R, Mss. Ital. I. VII, San Marco Library* (Spanakis, 1957, p. 82).

The first official recording of agricultural production (aprox. 1592) referred to 10000 – 12000 mouzouria grain (Spanakis, 1953, p. 58). The appearance of a tax official in the region happened (Spanakis, 1953, p. 89), approximately 20 years (Candia report *1595*) after tas evasion due to the economic crisis. His residence was located at Moros on the southern side of the Kephala fig.9), fig 10., while the surrounding buildings served as grain storages (Watrous, 1982, p. 28).

It is important to identify the reasons for the economic crisis and crop failures between the years *1574 – 1592.* The first one was *''sirica'',* a disease which afflicted wheat crop and could be disastrous for an entire harvest. Regardless of ''sirica'', another serious problem was too much water, causing floods, a climatic event — part of the Little Ice Age — which either the rivers or the ''C*honos''* failed to drain in spring (Rackham, 2010, p. 275). *''Chonos''* /is a sinkhole where all the amount of water gathered and is located on the western part of the plain. Average flooding lasted 12-15 days while during extreme climate events might last up to 50 days. Its fluctuation was key factor for grain growth, if flooding happened before the sprouting of the sown wheat, the crop was lost, if not the crop could last underwater for up to 15 days, for temperatures above zero (Spanakis, 1957, p. 134) (Watrous, 1982, p. 28).

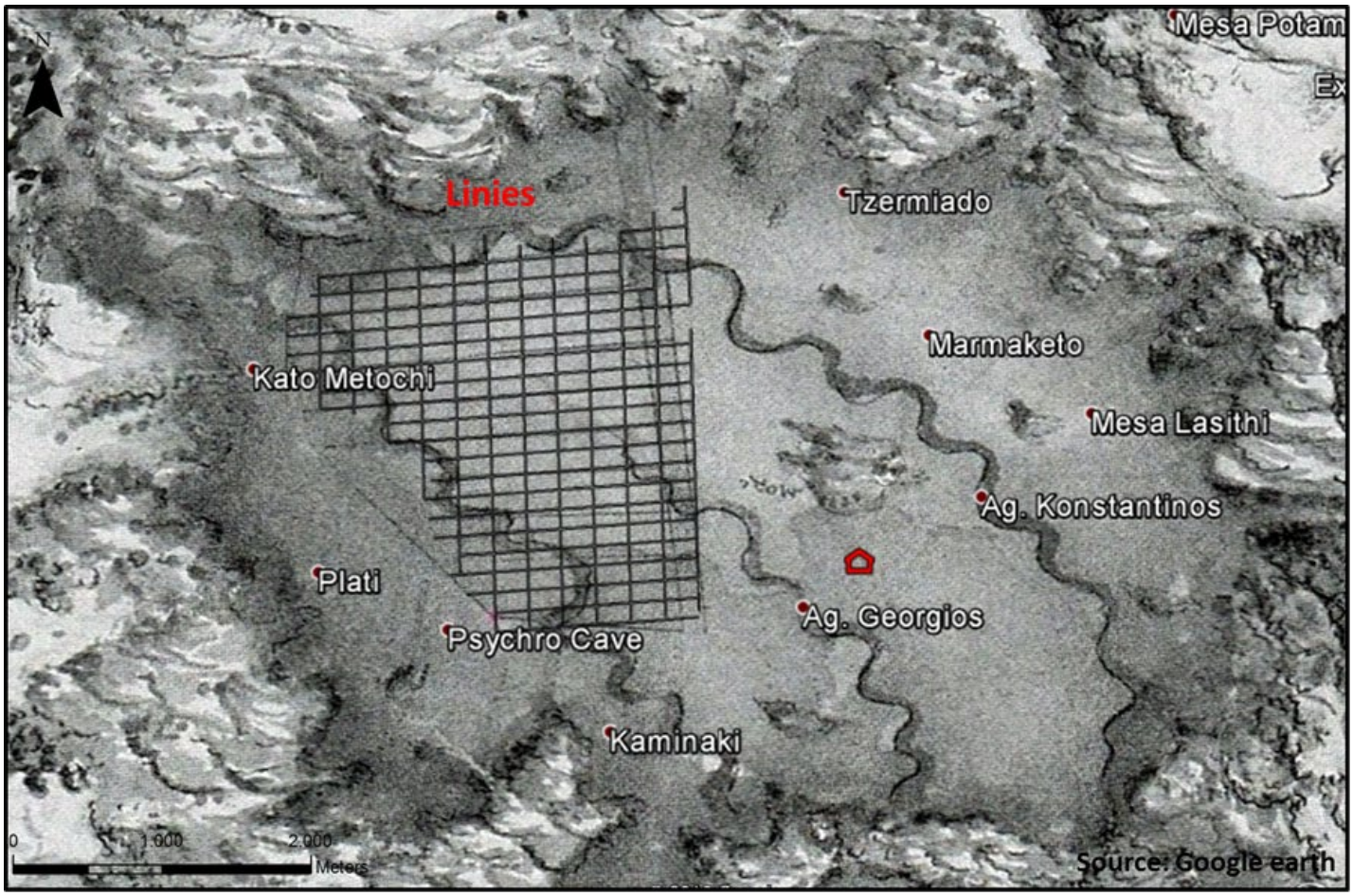
Distressed by these problems and determined to solve them, The Central government of Venice and Senate sent engineers to Lassithi. In *1630 Francesco Basilicata* inspected the plain and submitted a note with a series of actions whereby the plain would be divided into many parts, giving the flood waters time to drain easily into the sinkhole. Essentially, the notes referred to a deepening of the ditches between *voudees.* It Is logical to have categorized voudees as an earlier effort for drainage, as part of the colonization program (Rackham, 2010, p. 275). The flooding and sirica would thus be eliminated and the plain would be fruitful as in past years when it was called "a granary of the city of Candia" [Codex 1683 (8976), (Watrous, 1982, p. 28)]. Basilicata sketched a map where the geographical dispersion of settlements is shown (**fig.1).** As a geographer, he provides information about ''*the names of settlement Marmaketo (Marmachioti), Agios Konstantinos (Costatin), and*

Agios Georgios (Zorsi), and the warehouse (Magazeno) of the Venetian tax'' (Watrous, 1982, p. 27), geomorphological characteristics as nearby Limnakaro (Limniacaro) and Nissimo (Gnissimo) plateaus, chavgas stream, chonos sinkhole, mountain, their peaks and finally he depicts the results of the plateau's deforestation, leaving only small wooded patches in the plain. Furthermore, he is the designer of a big watermill, positioned west of the plain near ''Ampelos'' location.

https://upload.wikimedia.org/wikipedia/commons/4/44/Campagna_di_Lassiti_-_Francesco_Basilicata_-_1618.jpg/

Another engineer Nicolo Zen in *1633,* pointed out the existence of an orthogonal grid of ditches, crisscrossing the surface of the plain. It is evidence that the proposition of Basilicata was realized between his arrival and Zen's. The works were the subdivision of land into 193 $^{1/2}$ rectangular plots each of which was about 35 mouzouria area (= 35x400m^2 =14000 m^2). Each plot corresponded to a *boudea* and returned between 26 - 60 mouzouria of wheat annually (1mouzouri = 17kg, 442kg – 1.020 kg). At that time, there occurred the first systematic record of plots, using unique numbered stone

pilars as an identity for each plot. Ditches primary role was to drain the fields, but their efficiency was still depended upon by the amount of precipitation, capacity and the state of the sinkhole. This network of ditches, named *''Linies''* even today is visible (Fig.2). *''Linies''* constituted a hopeful engineering tool as an answer to the problem of poor grain yield.



Although, a Codex 918 (8392) mentioned the northwest portion of the plain as a lake, where around 85% of the fields were useless. The Proveditor General Isepo Civran, *in 1639,* provided some information about the income of wheat which was about 13,000 mouzouria yearly, without knowing its return because of climatic events such as torrential flooding, mists, and hoarfrost which destroyed the seed. According to the same document Lasithi had produced only 6,000 mouzouria by that year, and 3,000 in

the preceding year but the situation deteriorated significantly by the poor quality of the wheat, used for hardtack for Venetian fleets (Watrous, 1982, p. 28).

Ottoman period 1669 – 1889

During the Turkish occupation, the Plateau played an important role in the liberation struggle as a refuge for revolutionaries in Eastern Crete. During this period, with a few exceptions of Turkish officials, the population of the area was purely Christian. The area was destroyed twice. After a series of law changes concerning property, large-scale field transactions were made and systematic cultivation continued (Tzompanaki, 2007, p. 155). Additionally, a series of important pre – industrial construction works took place, the massive construction of grinding windmills, on the N - NE slopes of the mountains surrounding the Lassithi plateau and watermills, on S – SW part of the plain, where the water was in abundance (Tzompanaki, 2007, p. 156).

The oldest written source mentions a complex of 15 such windmills that were in operation in 1845 in Zaroma location. The Greek - Lassithian rebellion in 1867 led to the burning of the complex and the insurgents. As a result, the area was thought to be contaminated by the locals and two complexes were built successively, one in location of Asfentami and the other in Seli Ampelou which was consisting of 27 windmills (fig3).

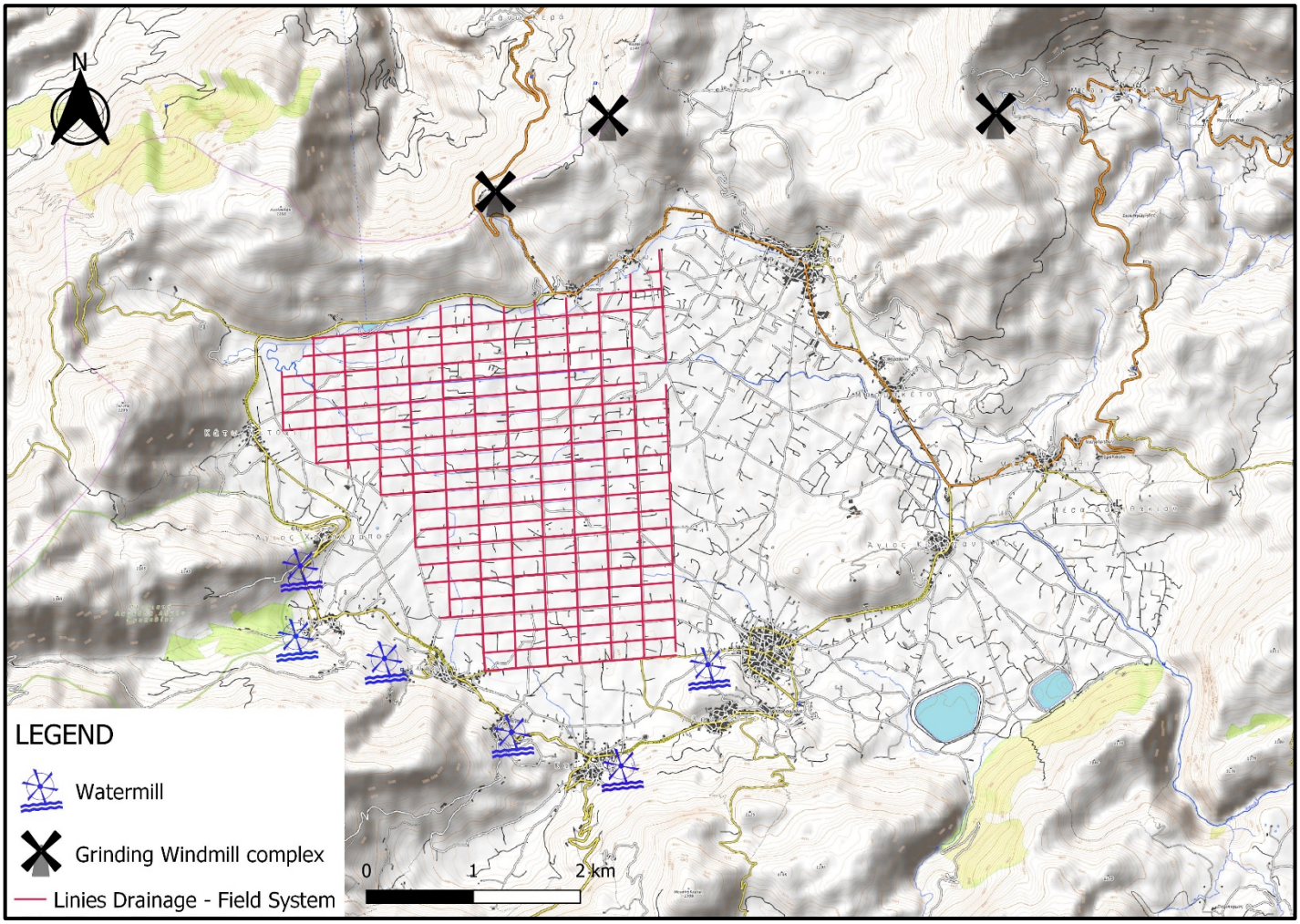


Fig. 3: Map of the plateau on the location of the bands of Grind, water windmills and linies.

Description of Griding windmills

There are different types of grinding windmills based on their characteristics, the ones that appeared in Crete and more specifically at Lassithi plateau and Merabello belong to the category ''*Cretan grinding windmill*'' (fig.4).

External form and shaping

The type of horseshoe-shaped windmill, with a horseshoe-shaped plan as mentioned, consists of a semicircular section, always oriented in the direction of the wind (in the case of Crete to the north-northwest), a small straight side (opposite the semicircular section) and two straight sides either parallel or slightly diverging, with a length ranging from 6.5 to 8 meters and an average width of about 3.5 meters. The wall thickness varies depending on the size of the mill from 0.60m up to 1.00m.

The building was made of local stone and was covered by a wooden roof, slightly sloping to the narrow side, in which there was the entrance door, on a longitudinal imaginary axis with the impeller and the grinding mechanism (Tzompanaki, 2007, p. 108), which was placed in the semicircular section, in a slightly elevated position. Rarely is the elevation so large that a space appears below it, where the grinding mechanism is placed and, in some cases, a small storage space. The space inside was very dark, as there were only a few openings that allowed the sun to enter, usually on the two larger sides. The characteristic of the Cretan mill windmill is its permanent orientation to the northwest from where the wind usually blows over the island.

Its construction materials were local limestone, usually raw in a variety of shapes and sizes. As a cohesive material, mud was used from pure soil, sometimes mixed with straw and the gaps were filled with small stones and internally, they used a coating of earth mud often mixed with straw or goat hair. The roof rests on raw trunks of cypress or maple, on which thinner wood was placed (branches or "splits") and then a layer of shrubs (usually shingles) was covered with clay soil about 20 cm thick that made the whole waterproof. This sloping structure was the most suitable for the rapid drainage of rainwater. Generally, there was a minimum distance of about 8 meters from mill to mill which secured a space for the right operation of the impeller.

The whole mechanism of the mills was wooden and handmade (later some accepted small additions from iron parts) and consists of two groups of mechanisms, the kinetic and the grinder. The kinetic mechanism was located outside its stone tower windmill and was essentially the converter of wind power into kinetic. The construction of all parts of the mechanism required a lot of know-how but also extensive manual labor and required lengthy construction time, making them undoubtedly a monument of folk technology. The building composition and consequently the shape of the windmills was the absolutely successful result that was determined by the observance of one of its most basic principles.

It can be said that for architecture of the last century, when designing a structure, the form is determined by the function. In this case, the aim was to ensure such a shape

in the building of the windmill, so that it is not hindering but assisting the force of the wind in causing the movement of the milling mechanism (Tzompanaki, 2007, p. 101), which was achieved. Their shape, then, has emerged from their purpose and function, without any reason for aesthetics. The ''Cretan grinding windmill'' consisted of two main mechanisms: kinetic and griding

Kinetic Mechanism

The kinetic mechanism was outside of the building and constituted of the converter of wind power to kinetic. The impeller had an auxiliary system for transporting or transmitting the movement to the grinder stones and another system for stopping the movement when needed.

Grinding Mechanism

The griding mechanism was constructed to grind cereals. It consisted of grinder stones and their components, a supply system, a system to regulate grinder stones and another one for the concentration of produce, such as flour (fig.6) (Papantonis, 1995, p. 10).

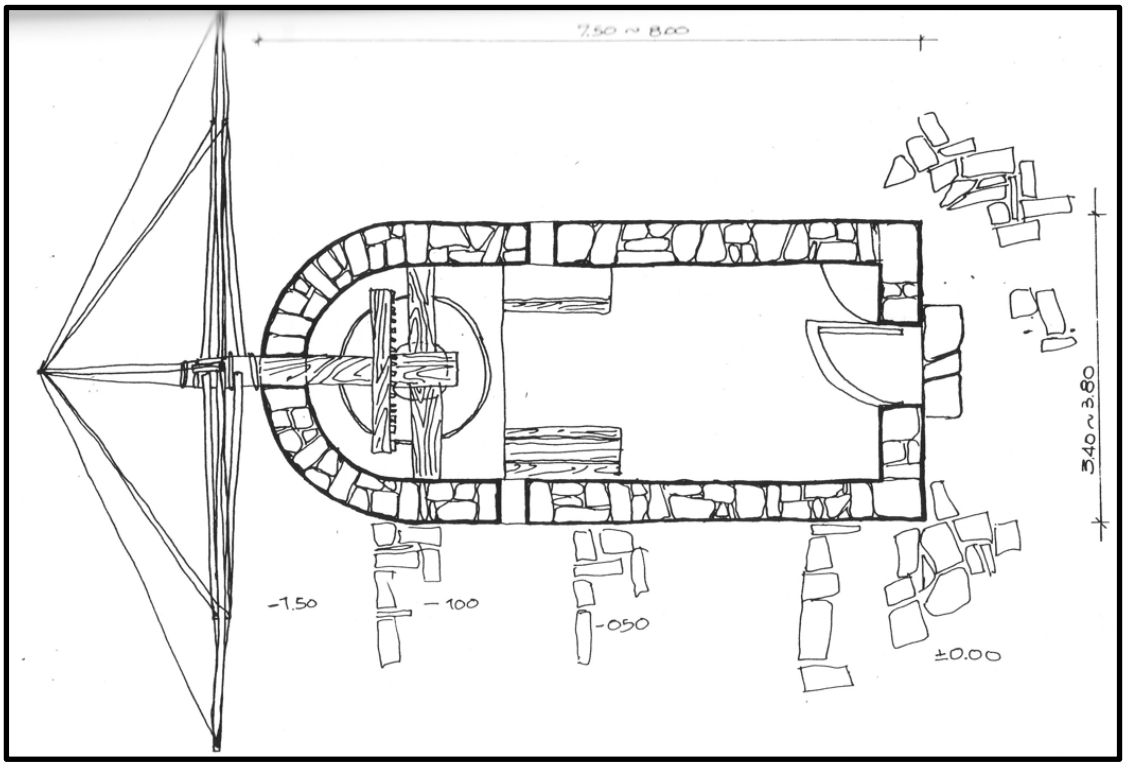


Fig4 ***Grinding windmill, horseshoe-shaped floor plan Papantonis Dimitrios, scale:1/50.***

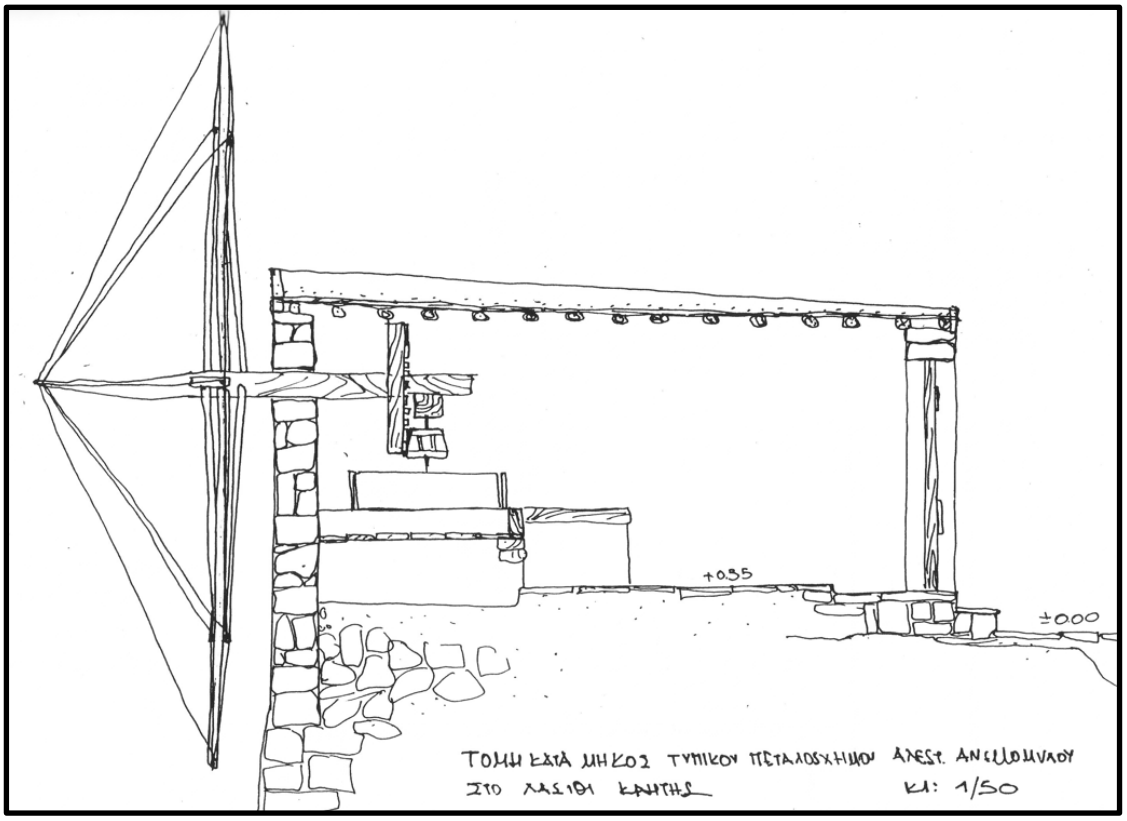


Fig5. ***Grinding windmill, horseshoe-shaped incision lengthwise Papantonis Dimitrios, scale:1/50.***

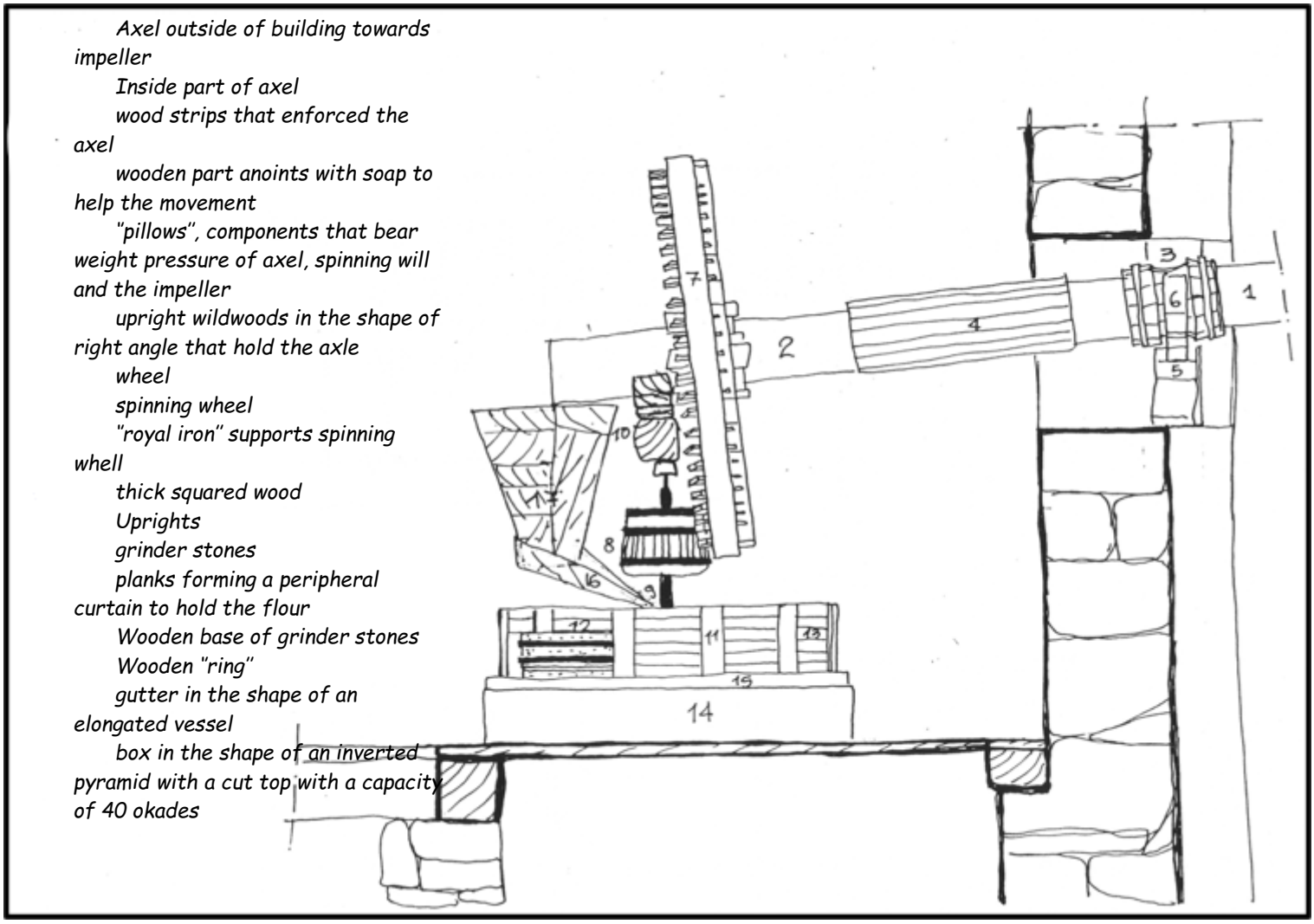


Fig6 *Grinding mechanism and its components Papantonis Dimitrios, scale:1/50.*

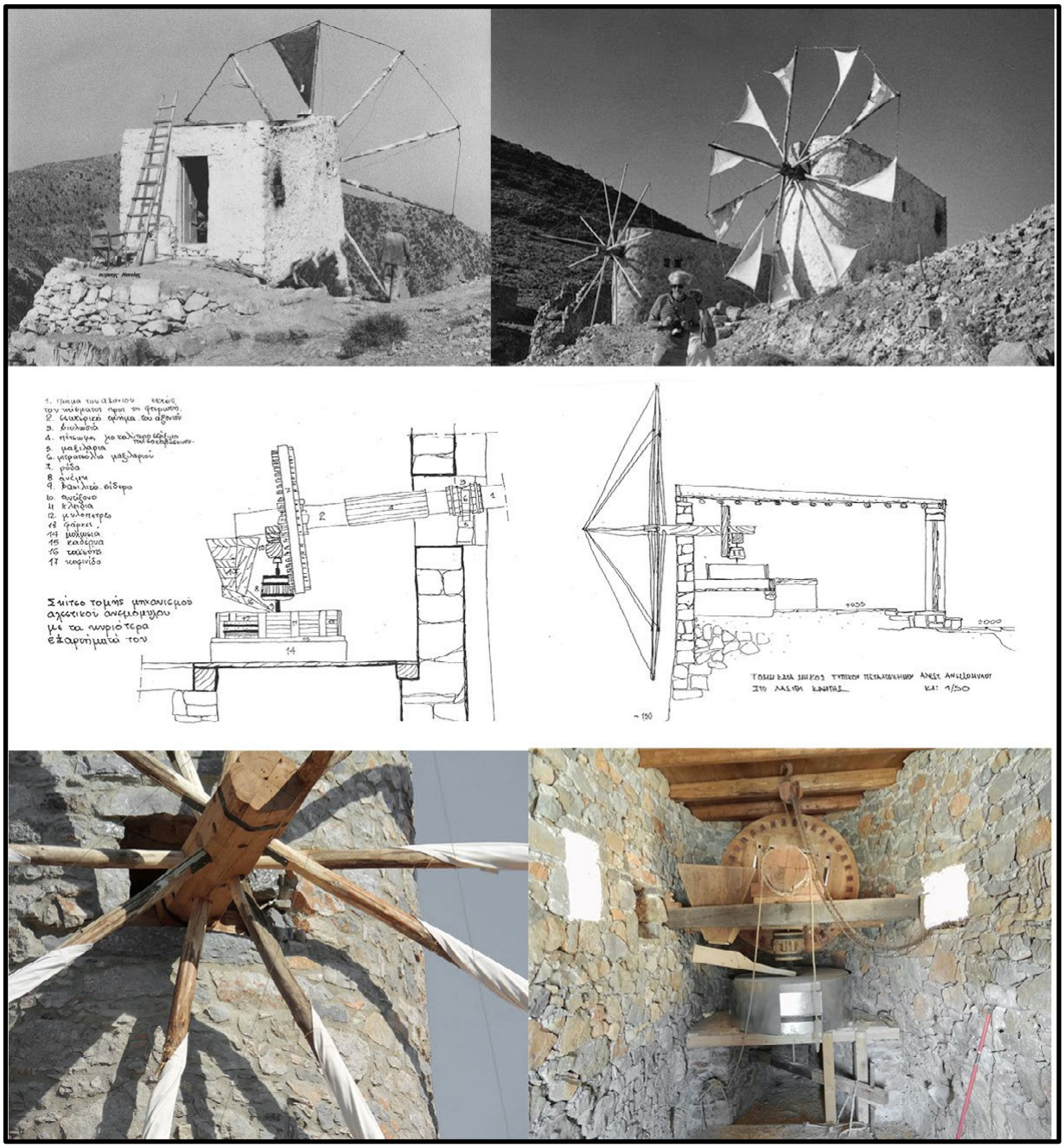


Fig 7. Picture and sketch, MSc Moschou Theodora, "Landscape of Coexistence of yesterday and today, Restoration and promotion of a cultural landscape, Lassithi plateau'' (Moschou, 2020, p. 22)

The numerous windmills were justified due the type of products that were produced in the surrounding area, more specifically the cultivated cereals were wheat, barley, oats and rye. Vegetables pulses and fruits were only produced for family consumption, surprisingly the absence of olive and grape cultivation is noticed due to the altitude which was above 830 asl (Tzompanaki, 2007, p. 156). *Spanakis Stelios*, after his father's testimony describes the chronological order (as mentioned above of windmill complexes, Zaroma complex worked until the last quarter of the 19th century as well as their wings having wicker sails). Then, by the end of 19th century, the windmill complex was relocated to Asfentami at which point the wings' material was updated from wicker to cloth, and finally it is mentioned that the last windmill from Asfentami to Seli Ampelou was relocated in 1910 (Spanakis, 1973). The last one was the largest and more impressive complex, located in the entrance of Lassithi plateau, while the distance between the first and last was 350 m.

Individual windmills, located at many different sites such as Vigla, east from Mesa Lassithi, north from Gonia, inside Marmaketo, Pinakiano and ''Spano's windmill'' inside Tzermiado (Tzompanaki, 2007, p. 158). Also, there is information regarding the geographical dispersion of watermills and the fact that they operated during winter when water supply was adequate for their operation. A big group of them about 20, located outside of the plateau near Kera village served the needs of other regions such as north Pediada and Upper Merabello. Three more were in the southeast of Kaminaki village, worked with spring water of ''Koutsounara'' and '' Skia of Water''. East of Magoula village towards Kaminaki, there were 2 watermills, one on the upper side and the other on the lower one. Also, were 3 of them at the south hillside of Plati village, while another one located between Plati and Agios Charalabos, Plati and Psychro and finally north of Avrakonte village (Tzompanaki, 2007, p. 158) fig.3.

Travelers who passed through Crete in the 19th century, Pashley (1837), Spratt (1865), and Perrot (1867) provide us with substantial contemporary details of the Plain of Lassithi and its environs.

''The villages of the Lassithi basin lie dotted around its margin upon small eminences and spurs that extend from the enclosing height, and the habitations are for the most part surrounded by clusters of fruit trees and some vines, the fruits being chiefly pears and apples, such as are natural to a very temperate region like Northern Europe; for the olive does not grow in it, from its elevation and aspect"

T. A. B. Spratt, Travels and Researches in Crete

Spratt depicted Lasithi as a "perfect oasis embosomed betwixt harsh ''naked hills'' composed of 15 villages, around a cultivated plain with substantial amount of fruit, full of people with small houses and farms. Beside cultivation another local economic activity was pastoralism with large flocks, grazing on the plain. It was a seasonal job, which demanded seasonal migration to lower warmer areas during winter seasons and the contrary during summer seasons., As well as pastors, some other inhabitants descended to avoid cold weather.

Spratt and Perrot understood the flooding problem linked with sinkhole drainage capacity. The latter also described the poor economic condition of society and their agricultural products as excellent.

Pashley, gave an estimation of Lassithi population, 490 families (each family consisting of roughly five individuals), or a total of 2,450 inhabitants for 17 villages. Spratt, 30 years later, estimated the existence of 3000 - 4000 people. Pastoralism characterized as the most important and profitable economic activity at the end of the 19th century. So, Lassithians economy was a mixture of farming and animal husbandry (Spanakis, 1976, p. 29).

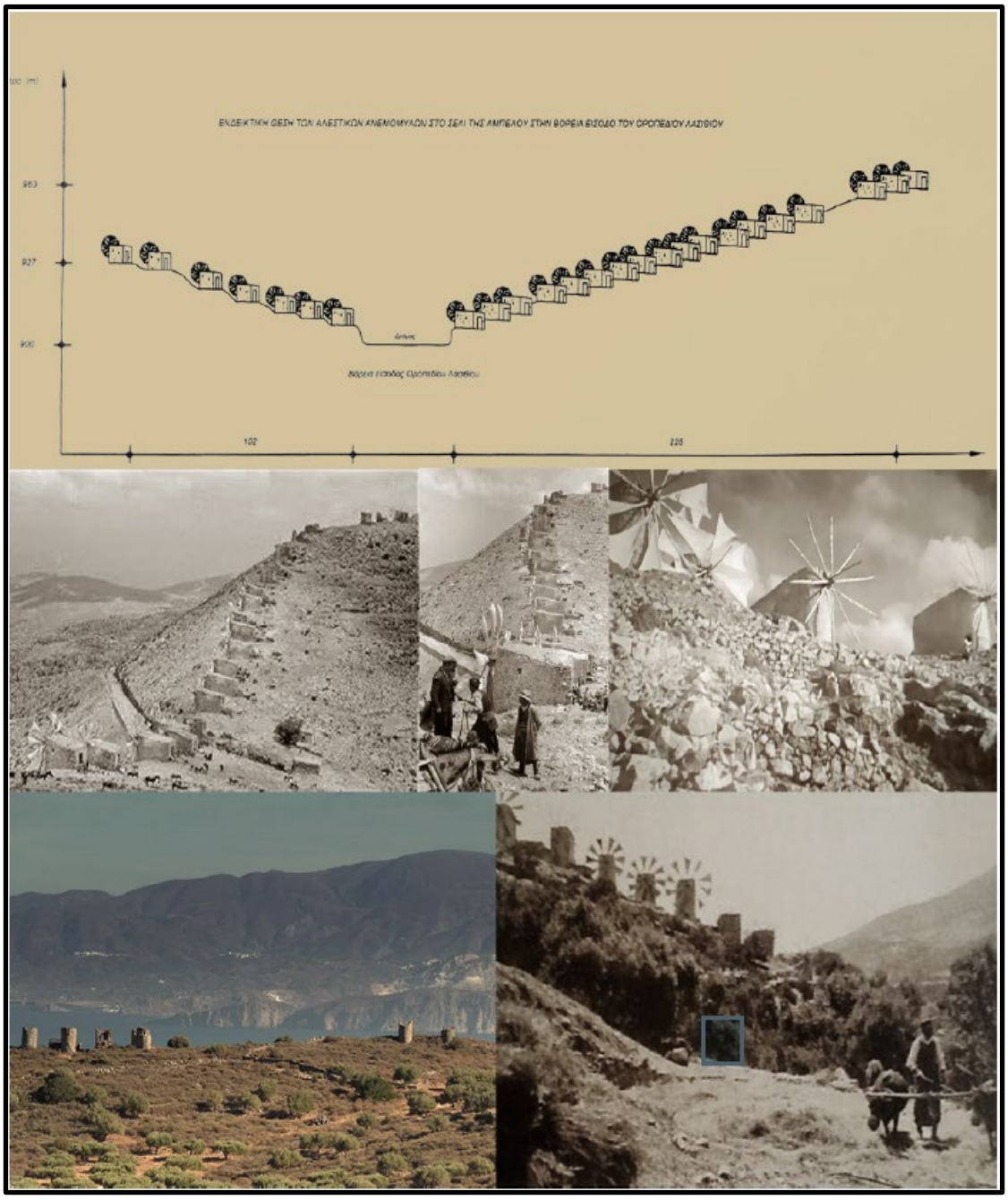


Fig. 8 Seli Ampelou complex collage, MSc Moschou Theodora, "Landscape of Coexistence of yesterday and today, Restoration and promotion of a cultural landscape, Lassithi plateau'' (Moschou, 2020, p. 22)

Travelers notes, confirmed also by Spanakis and elders' testimonies. So, pastoralism seasonality included the descent period, from October to November, and the ascent at the begining of spring until end of autumn, when flock owners came back to a green plain to feed their animals. Also, this migration provoked diminution of local

population and at the villages remained women with children still in school and old people uncappable to work. The remained people were self-sufficient and had accumulated supplies to pass this difficult period.

During the olive harvest they migrated to lowland to help in the collection. From April to October, working transferred uplands to nearby plateaus such as Limnarkaro, Katharo. The colder weather circumstances were ideal for cheese manufacture and its preservation. Moreover, he described the architecture of farmsteads, which was consisted of a stone building with several hearths for the boiling of milk (PI. 9:b) and a special storage area, dug into the hillside, where the cheese was kept cold during this period (Watrous, 1982, pp. 34-35).

The epoch, during the last 2 decades by the end of 19th century and 2 at the beginning of 20th century, is characterized as the ''transitional era'', as a foreign product, introduced to Greek agricultural production, meant to mark and radically change the local economy, the potato. The dawn of Ottoman period coexisted with the rise in potato use.

Independence Period (*1889 – 1980)* |Early 20th century to early 1980's

''Transitional era'' (1890 – 1920)

Power may have passed over, from Ottomans to Cretans bu itt was not combined with a significant change in social and economic life. Cultivation products were the same as previous years (cereals, legumes etc.) and flooding still existed in the western part of the plain called by locals ''Limni=lake'' and used by shepherds for grazing and watering the flocks.

Furthermore, the majority of local families worked as farmers or shepherds, the rest were craftsmen, stone-masons, house builders, carpenters, smiths, stone carvers, tailors, dyers, fullers, shoemakers and bootmakers, saddle makers, ironworkers, bellmakers, and weaving-related work. Beside their main work, each family had a small number of animals(sheep and goat together) to serve their dairy needs and a small piece of land to

produce vegetables, fruits etc. At the begging of 20th century reports give an estimation of 50000 animals and shepherding was more profitable than agriculture (Spanakis, 1976, p. 29). As mentioned, the cultivation of potato gains the favor of the Cretan farmers and replaces the traditional one of the cereals, the majority of the fields are planted gradually with potatoes. By the ''transition era'' irrigation was made by gerani (fig.8), or pole-and-bucket lever, drawing water from wells. Its use was time consuming and very difficult. For a field of 2-3 acres (stremmata) each farmer needed to devote one day to watering it. Based on these circumstances, the major agricultural products were dry crops like wheat and legumes.

Fig.8 Gerani –3d representation based on drawings and photographs (creator: Demelis Nikolaos).

Potato's greater need for water leads to the replacement of the old irrigation ''gerani'' system by pumping windmill. Two villages seemed to play a decisive role in the economic development, Psychro and Tzermiado, operated as economic and social centers serving from on the one hand the development of technique and on the other the dissemination of education and of letters. Thus, Psychro gathered a variety of technicians that played and contributed significantly to the development of the first pumping wooden windmill, while Tzermiado hosted all administration services, the elementary school and notary.

Wooden windmill

The first wooden pump windmill was built by the carpenter *Manolis Papadakis* (with the nickname *Spirtokoutis = matchbox*) shortly after 1890, motivated to relieve the farmers from the hard work to using wind power (Spanakis, 1973, p. 262). Papadakis before his death, in 1912, passed his art to local carpenters and more specific to his assistant *Stefanos Markakis* (nickname Markostefanis). His choice to construct the entire pump windmill from wood pertained with the availability, accessibility of this material, because of nearby Selakano forest on the eastern slope of the Dikti mountain, which served as a supply source, and the isolation of the plateau which made difficult the importation of other material such as metal. Moreover, each piece, each stage was handmade, creating uncertainties on the construction such as, the process wasn't standardised and each carpenter had different agility and skills.

The very first models had only 3 legs and a fixed head-piece permanently pointed to the Northwest, without triangular tailor vane on the front. The construction of the rotor was most likely inspired by the design of the rotor of the grain grinding windmills and was probably not very different from the present design. The pump was the only part made of metal. It was an ordinary suction pump ('*touloumba*') which was said to be imported from Italy by Mr. M. Xetripis (Spanakis, 1973, p. 263) (fig.9). These windmills were all placed on already existing wells, which by around 1910 occurred only in the home gardens close to the villages. Round 1890, *Psychró* was said to have

only 5 wells of 3 - 4 meters depth. After 1900 the first wells were dug on the plain, outside the home garden area.

The most important factors that seem to have determined its limited spread is on the one hand the high cost of construction of both the Italian pump and the manual labor required for its construction, while on the other the poor performance. The tripod tower was rather unstable and the use of wood made it necessary to continually re-adjust the moving parts. The fixed direction of the head-piece prevented the use of the favorable southern winds which occurred less frequent than the NW Meltemmia but generally, at a time when irrigation was mostly needed[8] (Spanakis, 1973).

Most farmers stuck to their 'gerani' or 'savki'[9], which were not only cheaper, but also more reliable (Hoogervorst N., 1983, p. p. 35).

[8] Southern winds come from the Sahara and are usually much warmer than the NW Heltemmia winds.

[9] A 'savki' is a chain pump with buckets, driven by a mule or a donkey.

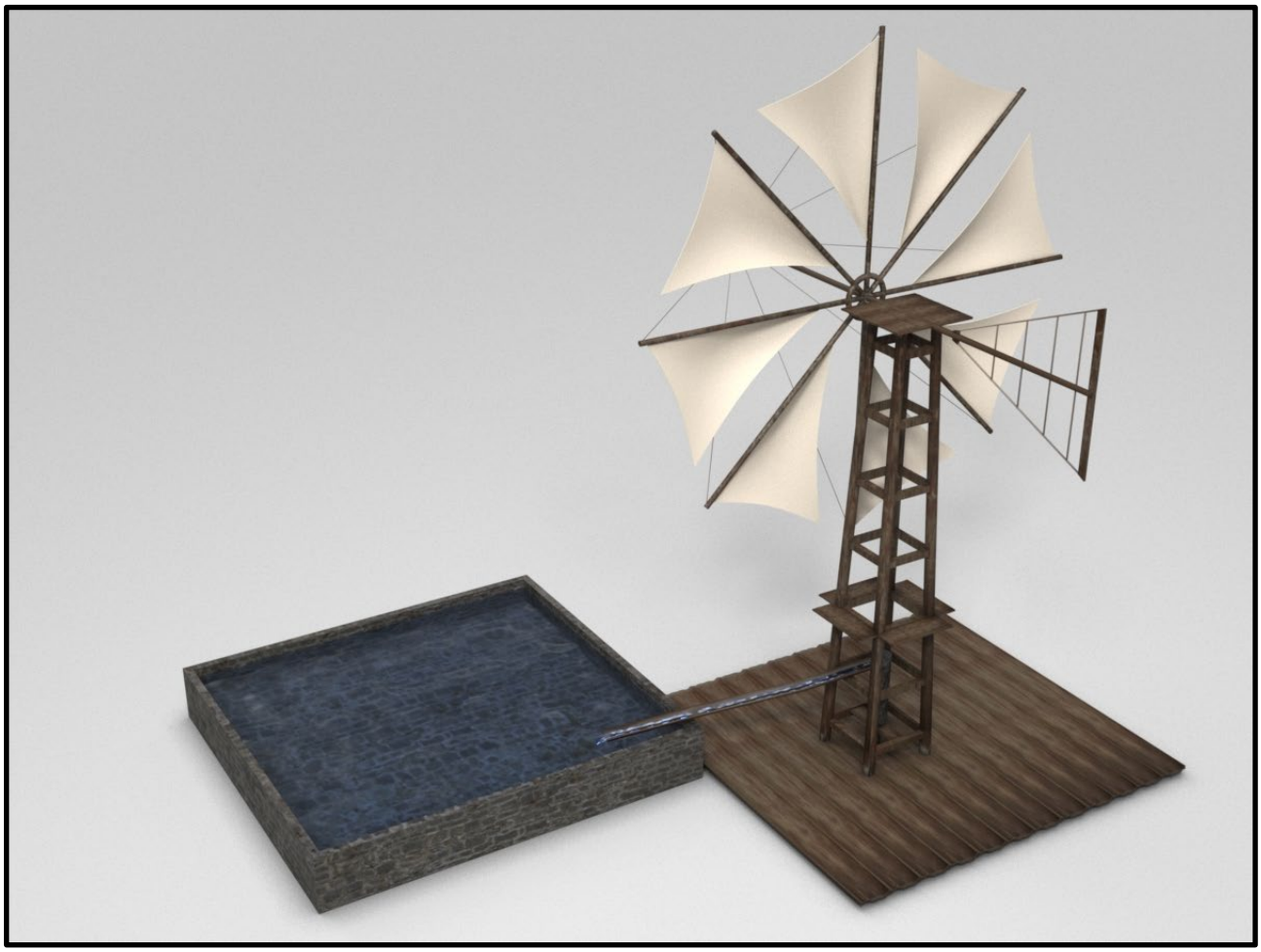


fig.9 wooden mill - 3d representation based on drawings and photographs (creator: Demelis Nikolaos)

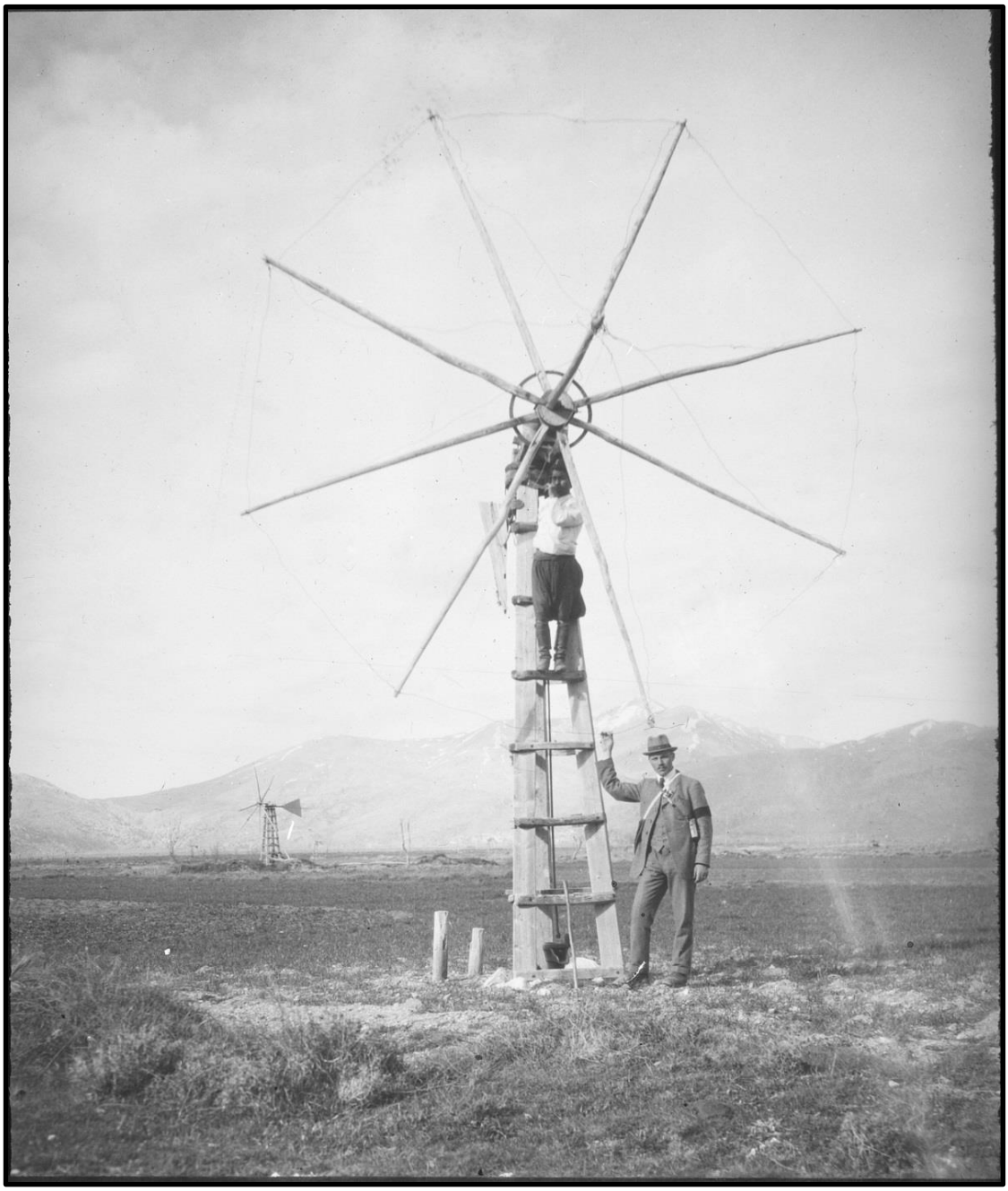


Figure 10 ***wooden mill around 1921, source: ETH Bibliothek Zurich***

Iron windmill

Shortly after the introduction of the first wooden mill and as a consequence of its disadvantages, constructors tried to improve the existing model. The first modification was a change to the tower which became more stable and four-legged instead of three. Next, the construction was improved by introducing an iron spindle. A later

upgrade was the invention of ''kouloura''= wooden construction which made it possible to change the direction of the headpiece according to changing wind directions. However, due to its heavy weight, it proved not functional. As mentioned above, Papadakis was a visionary, inventor and responsible for conceiving the idea of a wooden windmill, but his assistant Markakis, was the one who developed and improved his vision. He started his practice in Tzermiádo and actually built only one wooden windmill, he experimented with other materials, upgrading different parts and imported new mechanisms.

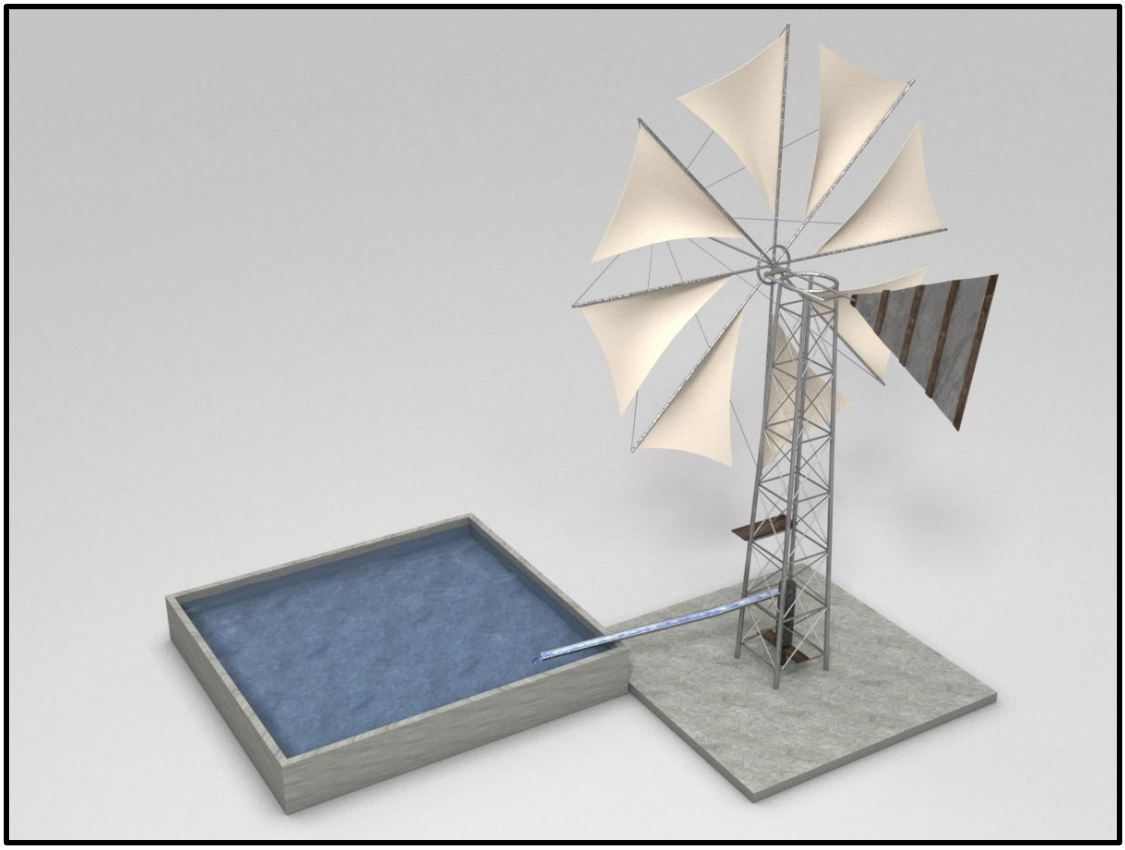


fig11 Iron mill- 3d representation based on drawings and photographs (creator: Demelis Nikolaos)

Spanakis is quoted to have saide about him, ''*with his inventiveness and ingenuity he perfected the windmill design. It became lighter and easier to set in motion which made it comply with the demands on the plateau."(1973)* (Hoogervorst N., 1983, p. 36).

Some of his adaptations were, the perfection of the turntable construction by making the outer ring out of iron and the invention of the triangular vane to keep the rotor pointed to the wind. Moreover, he made an iron tower and used WWI cannon shells, which he imported from Macedonia, as pump cylinders.

All these upgrades made the iron windmill more efficient, at that point it was capable of exploiting wind power from all directions, the tower became more stable and its height independent from the length of threes as the wooden ones were. In addition, iron shafts permitted a better adjustment of moving parts. Furthermore, iron had an impact on the economic aspects as well. In comparison with wood, iron was more cheap, easier to treat and maintain, and not so labor consuming, where as one had to find and collect suitable trees and poles. Selákano forest, a wood resource had a limit in terms of supply and needed time and human resources to find and collect suitable trees and poles. Finally, the new economic situation of the agricultural production created an increased demand for new improved pump windmills to fulfill new irrigation needs. Despite the general advantages of iron over wood not all parts were made of iron right away. The rotor, the inside turntable ring and probably also the carriage remained to be made of wood for a longer period as it was more resistant to wind power. New material combined with increased demand for irrigation, made the iron model spread on a large scale throughout the plateau. It was such a successful technological achievement that after 1920 many windmills appeared on the plain (as opposed to 'round the villages) and consequently many new wells were dug there. Between 1920 and 1930 all wooden windmills disappeared from the plateau and were, most likely, replaced by iron ones (Hoogervorst N., 1983, pp. 36-37).

Design of Iron Pump Windmill

The iron pump windmill consisted of 7 major parts fig12: **a**. *the base*, **b.** *the tower*, **c.** *the head*, **d.** *the rotor (impeller)* and **e.** *the pump* **f.** *the cistern, tank*

a. *The base:* is formed by 2 wooden beams crossing the well. The four legs that form the tower were bolted onto the beams in this manner so the windmill was at the center of the well. Perpendicular and in the middle of these 2 beams, a third was

attached to hold the pump base. The stone made well had a diameter of 2.20 m. and was 8 – 8.5 m. deep.

b. *The tower:* was a four-legged 5-meter-high structure. The distance between two legs is 97 cm. at the bottom and 36 cm. at the top. At about 1.50 meters above the tower base a wooden beam supports the shaft or spindle. The tower is bolted to the wooden base.12

c. *The head*: consisted of a orthogonal rotating support frame (gavelia), a triangular alignment blade (steering tail), two radial bearings (postitsia), an axial bearing (skoufia) and a crankshaft (axoni).

d. *The impeller:* consisted of the hub, the headboard, the radial antennas and the wire ropes, rigging that stabilized it in the correct position.

e. *The pump:* was based on a wooden beam (plakotari), positioned near the base of tower. It was a piston pump made from old missile shells

f. *The cistern|tank*: was built next to the pumping windmill with a length of 4m, width of 3m. and height of 1m. The level of its bottom was formed a little above the ground level (Tzompanaki, 2007, pp. 169-170).

Genesis of Aeolian Park – expanding of Irrigation

Due to the superiority of the new iron model, production escalated rapidly and continuously after 1920, in 1925 the number of windmills reached a high level and until 1935 all the plain was covered by them, creating a unique rural landscape. There are no official records about the exact number of them but before WW II, an estimation from local people calculated 9500 – 10000 windmills. The war had an adverse effect on economy, as well to agriculture. While all men left the area to battle, agriculture activities and windmill operations were carried out by women, older people and children. Thus, the expansion was stalled but right after WW II the number started to rise again, 11000 – 12000 and reached its maximum number of 15000 between 1960 – 1965. If taken into account the area of plots, that were smaller than

2 stremmata [10], it is an indication that all the plain was irrigated by the power of wind (Hoogervorst N., 1983, p. 41).

Introduction of Motor Pump

The introduction of small motor pumps in 1955, signified the dawn of new irrigation era. The relationship between motor pumps and iron windmills was inversely proportional, as the number of the first increased the construction of the latter decreased. In 1960, the replacement had been an on-going process followed by the decrease of windmill use, first to 8000 in 1973 and about 1000 in 1983 (Hoogervorst N., 1983, p. 41).

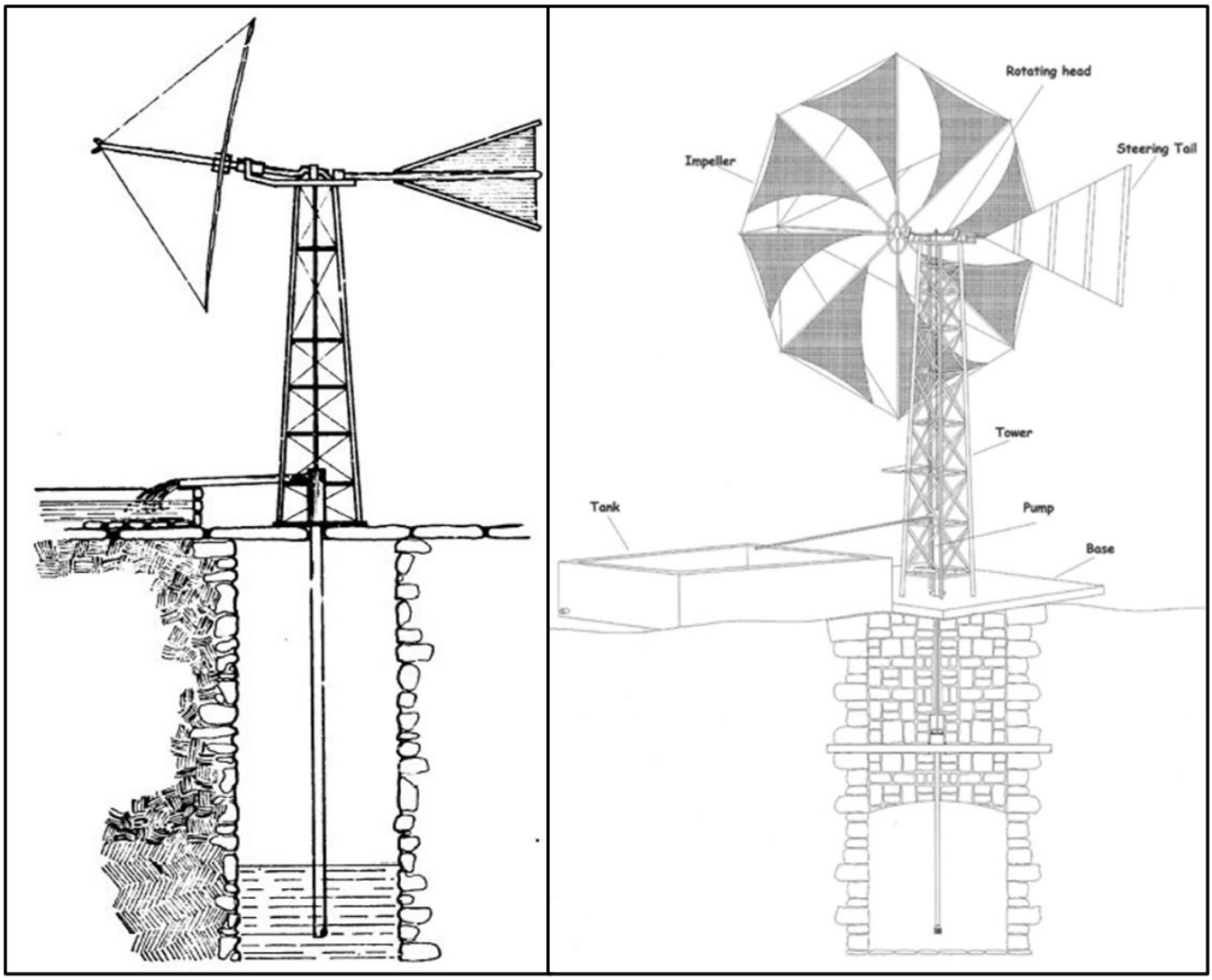


fig.12 Sketches Galvert, Chatzakis

[10] an area of 1½ - 2 stremata per windmill and a total agricultural area of 25.000 stremata. max of 15.000 windmills seems likely accurate (Hoogervorst N., 1983, p. 41).

Abandonment of Aeolian Park – Motor pump domination over windmill

Along with, the above-mentioned small pump motor, another type of motor pump appeared in the plain at almost the same time during the mid-1950's: the high- power pumps, the big centrifugal and the ''*pomona*'', of American origin. 1960 was the starting point of the gradual replacement of windmills by the motor – pumps. After 1965, the number of high-power pumps on the plateau increased rapidly (see chart2), Tab.3, that happened because of a series of reasons. Firstly, there was less engine trouble in comparison with small motors leading to a greater capacity to supply more amount of water. Secondly, the supplied water per time-unit was independent of groundwater level. A quantity of water to irrigate one stremma was 25m^3, a small pump needed one to two hours more than ''pomona'' when groundwater level dropped from two to eight meters. Furthermore, it could bring water from depths bigger than eight meters without having to relocate the motor, when for the other types it was necessary to descend into the well to pump the water (Hoogervorst N., 1983, p. 55). It is evident that as all the changes did not happen in the blink of an eye, so it was that the replacement of small motor by lager motor pumps and finally the abandonment of the use of pump windmill, happened gradually. The conveniences that the motors offered were numerous, from the reduced and easier labor hours to the enlargement of agriculturally exploited land.

Years	Inhabitants	Windmills
1881	5035	0
1900	5058	20 (wooden)
1920	4406	100
1928	6462	4000
1940	7669	9000
1951	7351	10000
1961	6657	8000
1971	5368	7000
1981	5142	5000
1991	4348	1000
2001	3185	500
2011	2460	300

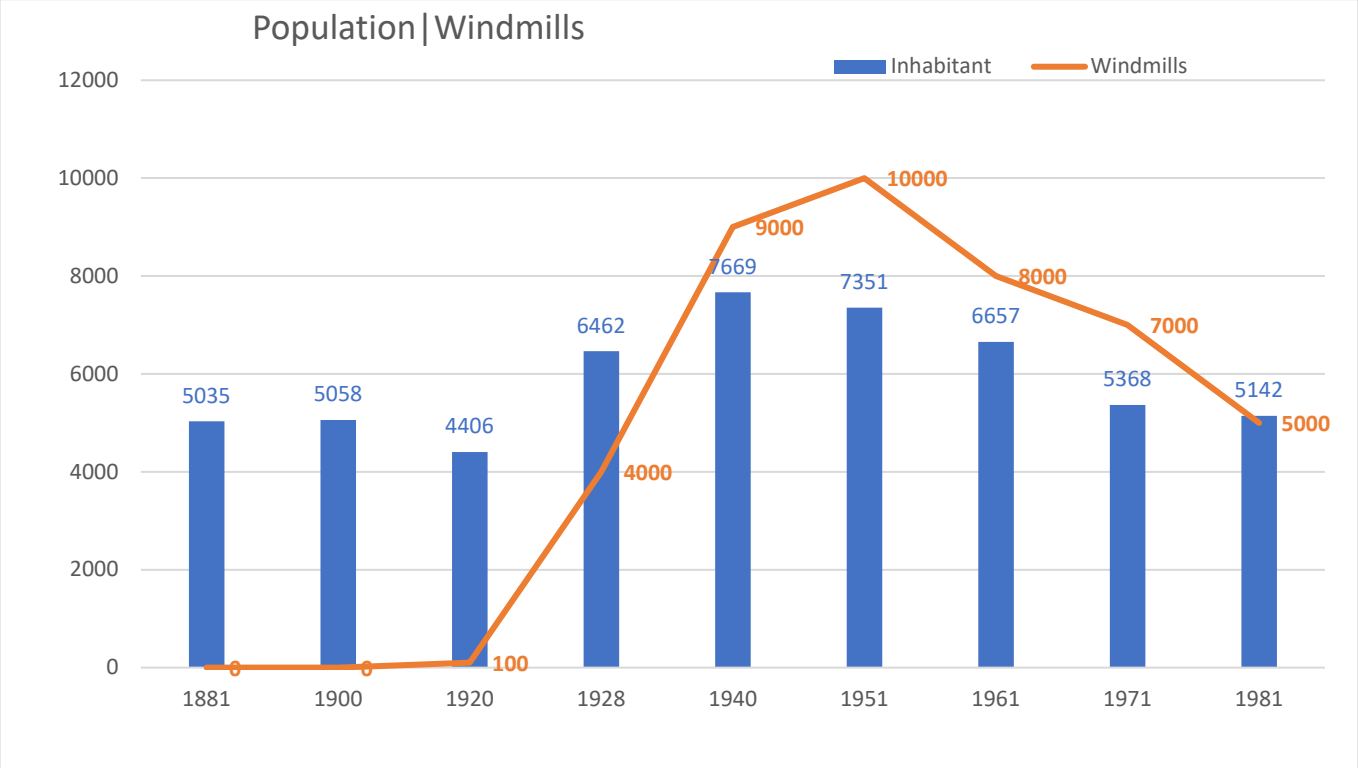


Chart2. Relation between population and pump windmills.

Research Framework – Methodology

The historical evolution of Lassithi as presented above, from Minoan times until 1980's, is an evolution of a rural area. Considering the word rural is widely used by the majority of people, it has adopted a different meaning as a result of different cultural, natural and economic conditions. It is also important to note that the scientific community itself has not been able to define a commonly accepted definition. It is understood from the above that the examination, definition and understanding of this concept concerns many scientific disciplines, with different approaches, goals, methods and tools. Rural is a space of interactions where rural man-made activities take place and are affected by natural conditions. Thus, rural space is in constant transformation, characterized by the fluidity of the interactions of socio-economic and ecological processes.

Globally, it is observed that ecosystems show periodic changes due to human uses (Scheffer, 2001). These changes are caused by the need of man to adapt nature for his

own benefit without having a full understanding of the possible consequences, and without having foreseen possibilities of different treatment. On the contrary, these adaptations in many cases reduce the resilience of the ecosystem by turning it to unsustainable behaviors and often causing irreversible changes. Climate change is the most obvious example of this behavior. According to the report of the Intergovernmental Panel on Climate Change in 2014 (IPCC, 2014) the continuous increase of CO_2 concentration levels in the atmosphere, which is associated with the burning of mineral resources, deforestation has altered the patterns of rainfall and temperature, resulting in the augmentation of floods and droughts. At the same time, rural societies, which rely directly on ecosystems, face major social and environmental challenges in regards to their services and resources.

Throughout time, human and environmental history has been characterized by a variety of challenges and changes. The identification of which has always been the subject of human sciences and of different disciplines, geography, anthropology, cultural and social geography, have explored landscapes from a different point of view and questioned social and individual well – being (Luginbühl 2006).

In our study case, Lassithi plateau and its historical evolution provides information, as rural area, about the interactions between human activities and environment, nature. Thus, in this section an attempt will be made to choose the more suitable method and tools to interpreted the *history of agricultural landscape and to investigate* underlying drivers or causes of landscape changes. This approach can contribute to study the societal, natural changes through a long period of time, to locate the reasons and to understand the causes for them. Moreover, it will offer a knowledge base where future oriented solutions would be planned. In general, landscape research seeks to draw connections among people, between people and places, and between societies in their environment at the landscape scale (ESF2010). In Europe, landscape research has received broad attention since the adoption of the European Landscape Convention (CE 2000) where landscape defined as: “an area, as perceived by people, whose character is the result of action and interaction of natural and/or human

factors" (EC 2000:3). It has also been enhanced by philosophy and postmodernist theories to study the intangible dimensions of landscapes, such as texts, signs, repositories of meanings, ideas, and place attachment (Howard et al. 2012).

The analysis of drivers of landscape change is a core field of research in geography, and builds on a long tradition to understand why landscapes change or remain unchanged, and why they evolve faster or slower, and to identify the causal mechanisms of regime shifts (Verburg et al. 2015). Thus, the system under study includes real-world changes (i.e., land change), human agency (i.e., actors), and influential factors, which have been termed driving forces (Bórgi et al. 2004), keystone processes (Marcucci 2000), or simply drivers (Wood and Handley 2001). The study of these drivers is challenging because they form a complex system of dependencies, interactions, and feedback loops, and they act at several temporal and spatial levels (Kizos. 2018).

The scope of this thesis is to explore Lassithi History based on Landscape change and the identification of drivers that caused them. It is also important to understand its complexity and its relationship with time, both short and long term, and with the actors whose actions affect it in a different scale, local, national global. However, landscape is not only a scale but also includes a management approach that "seeks to provide tools and concepts to achieve joint social, economic, and environmental objectives in landscapes where productive land uses compete with environmental goals" (Plieninger et al. 2015).

Firstly, in the next paragraphs, landscape evolution is explored with the frame of long-term historical landscape research, where nowadays some historical interactions of human with its surrounding environment left traces like drainage systems, field systems, hedgerows, stone walls, technological achievements either in the form of tangible as constructions or intangible as part of local culture and identity (Foster et al. 2003). Some of them are abandoned and stay inactive due to lack of information about their importance, origin and others are transformed or serve the needs of today's agricultural activities. In some cases, policies, planning, and voluntary

incentives have aimed to protect landscape structures and elements that originated through historical interaction (Schleyer and Plieninger 2011); in other cases, large scale land consolidation has been implemented to adapt landscapes to the current needs of their managers. New datasets on land-use history, ranging from decades (Fuchs et al. 2012) to centuries (Kaplan et al. 2009, Kaplan 2012) in span, have recently become available and because of their quantitative nature hold much promise for better characterizing landscapes (kizos_exploring). Landscape biographies and historical ecology are very interesting concepts for our study case, where the first studies long-term transformations in landscapes, preferably from prehistory to the present, viewing landscape at each point in time as a complex interplay between social and economic developments, culturally specific perceptions of the environment, histories of institutions and political formations, and ecological dynamics (Roymans et al. 2009, Palang et al. 2011). It particularly acknowledges that landscapes have their own temporalities and rhythms, in relation to but distinctive from individual and community life cycles (Ingold 1993, Kolen et al. 2015). While Historical ecology is another holistic, ethical, and place-based framework of concepts and methods for studying the past and future of the relationship between people and their environments (Crumley 2015). Particularly rich sources of data are found at the landscape scale, in which human activity and cognition interact with biophysical systems, and in which records from many disciplines are plentiful. Historical ecology provides tools to construct an evidence-validated, open-ended narrative of the evolution and transformation of specific landscapes (kizos_exploring). Historical ecology aims to contribute toward preserving cultural heritage in ecosystems and landscapes, understanding long-term historical trajectories of patterns and processes in ecosystems and landscapes, and informing ecosystem and landscape management (Crumley 2012).

Secondly, a tracing of driving forces, processes, and actors of landscape change will be followed. The interwoven linkages between people and the environment in landscapes and their inherently dynamic nature raise the issue of investigating the

processes that change them, the actors involved, and the rates of change, both short and long term (Schneeberger et al. 2007). Five major types of driving forces that affect cultural landscapes have been distinguished: socioeconomic, political, technological, natural, and cultural (Brandt et al. 1999, Bürgi et al. 2004). Among these drivers, there can be strong linkages, dependencies, and feedback loops over several temporal and spatial levels and with different rates of change. However, most of these driving forces do not have an impact on landscapes directly but rather through actors (Hersperger et al. 2010). Whereas land use and land cover can also be analyzed at large scales, landscapes are closely linked to actors and their land-use practices (Bieling et al. 2013). In particular, land users and landowners are sculptors of landscape development, as can be read, for example, in the composition and structure of forests (Schaich and Plieninger 2013, Rendenieks et al. 2015).

Before applying the above-mentioned method and the tools, it was considered essential to enforce and support the arguments from the disciplinary of climate change that affected mostly the natural environment, its processes and subsequently its interactions with human societies. As a starting point was the Neolithic period. scale for the study to present a chronological time scale that shows the correlation between historical dates and climate events that had an impact on ancient societies.

Lassithi Landscape Biography – Landscape Transformation

The history of Lassithi is subdivided in 8 transformation phases. The first one starts from Late Neolithic when we had the earliest evidence of habitation and ends in the Late Minoan IIIC, named as *Minoan.*

This phase characterized by the gradual augmentation of the population, the start of plain cultivation, pastoralism, some trade activities and ends by a war, invasion and dissertation *phase (Table 1)*.

Period	Variables: Population	Sites Location	Land Use /economic activities	Political/social/ cultural change	Technological	Climate/natural
Late Neolithic -Early Minoan I	**15 sites, Small group of people**	**13 open-2 caves**	**Seasonal Pastoralism/ *Land clearance,***	✖	✖	✖
Early Minoan II-III	↗	**5**	**farming, herding and hunting woods of oak**	✖	**weaving technology**	**Plain marshy**
Middle Minoan I	↗	**7 closer to plain**	**Arable land**	✖	✖	✖
Middle Minoan III	↑ ***max.***		**Seasonal Pastoralism/ habitation agriculture**	✖	**agriculture houses – farms**	✖
Late Minoan I	**signs of abandoned**	**Gathered to bigger**	**large amounts of grain/ trade meat, wool, and wood**	**economic centralization/ taxation**	✖	✖
Late Minoan IIIA-B	↘	**dissertation**	✖	**Invasion/ Mycenean ocup.**	✖	**eruption of Santorini volcano**
Late Minoan IIIC	↘		**spinning, weaving, cultivation grain, grazing**	**Migration to higher elevation/**	✖	

Table 1 Minoan Phase

The second one lasts from Protogeometric and ends in the Hellenistic, this phase *Hellenistic phase (Table 2).* Lassithi becomes famous as a sacred place and the relocation of its plain. It ends with a climatic event, chute of temperature and cold weather. Political reason marked the depopulation of the area.

Period	Variables: Population	Sites Location	Land Use /economic activities	Political/social/ cultural change	Technological	Climate/natural
Protogeometric-Geometric	**Large sites**	**Relocation near plain map**	✖	**Religious center**	✖	✖
Archaic			✖		✖	✖
Classical-Hellenistic	↓	**map**	**dyeing weaving - wool**	**Local inhabitant enslaved / rent for land**	✖	climate event, snow, storms

Table 2 Hellenistic phase

The third phase, *''Shadow'' phase (Table 3).* is from Roman times to Byzantine II, an era of silence and obscurity which lasted until the beginning of the 13th century, an era absent from literature. The most remarkable period is Arab times when riches and wealth came to Crete through piracy. Also, island frapped by major natural disasters, earthquakes and a drought event.

Period	Variables: Population	Sites Location	Land Use /economic activities	Political/social/ cultural change	Technological	Climate/natural
Roman Sites	↑	**Repopulation single site**	***agriculture***	**Peace period**	**artificial drainage??**	✖
Byzantine occupation I	↘	✖	**Gradually population decline**	✖	✖	**Earthquakes** (618 A.D & 670 A.D), **severe drought**
Arab Conquest	↗	✖	**trade, intensive agriculture, income from piracy**	**taxation, urbanization, and administration**	✖	✖
Byzantine occupation II	✖	✖	**Surplus agriculture**	**taxation**	✖	✖

Table 2 ''Shadow phase''

Vulnerability

Although climate variances are most often broadcasted in the case of extreme events, the steady change in climate behavior that led to these events is having a marked impact on flora and fauna, which contribute to the biodiversity and healthy resources in an area, having adapted to certain climatic regions over the course of generations, and are currently undergoing increased stress with the threat of irreversible damage (Fischer et al., 2002; Schröter et al., 2005). It is believed that society, which depends upon these resources, is unprepared for the potential accelerated pace of such changes in combination with the occurrence of extreme events. This unpreparedness will compromise societal security resulting in a further loss of resources and livelihood (Malone, 2008).

Arid and semiarid regions are notably exposed to the impacts of climate change and the Mediterranean is one of the regions that will experience an amplified effect (Kundzewicz, 2007). One of the sectors that is most exposed to the elements and is often hit hardest by drought is the agricultural sector, partially due to the water intensive nature of cultivation. Approximately 69% of the county's water resources are distributed to the agricultural sector (Savvides, 2002), during times of water stress, agriculture is the first to be cut off from water supply. However, it is not only the farmland and crops that suffer. The people that are located in rural regions and rely on farming for at least part of their livelihood are dually affected during these events, as they themselves suffer not only from a lack of water but also must compromise at least part of their livelihood. This contributes to a multifaceted vulnerability both of the people and of the rural communities.

The key parameters of vulnerability are expressed as the exposure and sensitivity of a system to the hazard and its capacity to adapt (Goulden, 2010). Similarly, exposure, sensitivity and adaptive capacity are subject to varying definitions. Here exposure is considered to consist of the impacts or potential

impacts of climate variability and change; sensitivity is the degree to which the rural communities are affected by the exposure; and adaptive capacity is the system's ability to adapt, withstand or recover from the effects of the exposure (Ebi et al., 2006; Hahn, 2009).

The existence of numerous indicators, some of the principal indicators that determine vulnerability to climate change of the agricultural sector include crop types and yield, crop growing seasons, irrigation infrastructure, farm size, a presence or lack of crop rotation, the quality of the natural resource base, management practices, as well as human factors including educational level, participation in support organizations, and subsidies received, amongst many others (Gbetibouo, 2009).

Climate change vulnerability research has often been analyzed from a natural science perspective where models (such as global circulation models) provide insights in the potential exposure of a system and the resulting negative impacts. This perspective looks at the probability of occurrence and magnitude of impacts determined by weather and other climate related events (Goulden, 2010; Brooks, 2003:2). Termed 'impact driven' (Burton et al. 2002) or 'outcome' vulnerability (Fussel, 2009; O'Brien et al. 2007) the objective of this top-down approach is to evoke emission mitigation measures (Ford et al., 2010). Approaches to climate change vulnerability have expanded from the natural science perspective to include perspectives from social sciences. The social science perspective is used to understand the interactions and interrelations of human and environmental systems all within the context of social, economic, and political processes.

One of the most heavily relied upon definitions of vulnerability in climate science is from the Third Assessment Report (TAR) by the IPCC, who define vulnerability as "the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity" (McCarthy et al. 2001). The IPCC provides two additional definitions that are not specified as natural or social

vulnerability, but fit into the separate climate research streams. This contradicts a cohesive understanding of vulnerability, but contributes to the current research perspectives. From the natural standpoint, the IPCC defines vulnerability as "a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2001: 995). From a social standpoint vulnerability is described as the "degree to which a system is susceptible to injury, damage or harm" (IPCC, 2001: 894).

Social vulnerability is frequently broken down into three parameters based on the pervasive typology that has been elaborated by the IPCC TAR, including: exposure, sensitivity, and adaptive capacity- also referred to as resilience and coping capacity (McCarthy et al., 2001; Luers et al., 2003). Exposure, sensitivity and adaptive capacity are inherently linked, and therefore can be hard to decipher (Gallopin, 2006). The parameter of sensitivity is linked to location and is evaluated by the inherent characteristics of the location with consideration to the human-environmental relationship, where both social and biophysical characteristics influence this relationship (Turner II, 2003). As stated by Gallopín (2003: 18), sensitivity is the degree to which a system is modified or affected by an internal or external disturbance or set of disturbances. In so, a system's sensitivity is subject to change over time depending upon the extent of exposure or human influence on the system as well as the extent to which the society is dependent upon the natural resources of the location and their quality. Pielke (1998: 159) defines adaptation as the adjustments in individual groups and institutional behaviour that reduce society's vulnerability to climate. In addition, adaptive capacity is dependent on socioeconomic conditions and human decisions, and has the capability to provide immediate benefits through a reduction in sensitivity to potential climatic risks on varying temporal scales (Ford et al., 2010). According to Smit and Wandel (2006: 282) based on timing adaptations can be anticipatory or reactive, and depending on their degree of spontaneity they can be autonomous or planned all under the context of reducing vulnerability. The other main scale applied in climate change vulnerability studies is the local scale, which identifies vulnerability

of systems such as a coastline, community, ecosystem niche or agricultural region (examples include: Adger et al.,1999; Cutter et al., 1996; Ford et al., 2006; Klein, 1999). Vulnerability assessments that are conducted on a national or sub-national scale with community-level indicators are not common, but can be very beneficial. The important aspects of vulnerability can be more easily identified on a community level both because the regions under study will possess a common political, social and economic structure and because regional experts and local stakeholders are geographically accessible (deem). It is expected that rural communities in the Mediterranean region will be severely exposed to the negative impacts of climate change. A global scale study conducted by Giorgi (2006) evaluated 26 land regions with 20 global climate models and identified the Mediterranean region, along with regions in North Eastern Europe, as the primary hotspot for climate change. Results were based on regional mean precipitation change, mean surface air temperature change, and changes in the inter-annual variability of precipitation and temperature. The Mediterranean region includes some 20 countries where, despite similar weather patterns, vulnerability is felt differently from country to country due to very different political, social and economic characteristics that affect, amongst other things, access and use of land and water resources.

The agricultural sector is the most water intensive sector in Mediterranean countries where over 70% of their water resources are used for irrigation. Countries with the highest irrigation rate and the most cultivated land will be first affected by increasing water scarcity and from the growing demand of other sectors.

For the purpose of this study, vulnerability will be understood from a social perspective and will be interpreted to specifically take the exposure of climate change and water scarcity into account.

Vulnerability is defined as:

- *The degree of defencelessness or propensity of a system to damage or harm due to the effects of climate change and water scarcity. It is a function of exposure, sensitivity and adaptive capacity (Goulden, 2010).*

Rural communities may experience many different stresses simultaneously and the indicators that determine adaptive capacity aim to cope, adapt or recover from undesirable stressors caused by the exposure and/or sensitivity (Yohe et al., 2002). Established or elaborated by Maxwell and Smith (1992), Chambers and Conway (1992), Blaikie et al. (1994), Chambers (1995), Moser (1998), Carney (1999), de Haan (2000), Hahn (2009), and Moser (2005), adaptive capacity is constructed out of five vital livelihood resources including human, social, financial, physical, and natural capital. The concept of the five livelihood characteristics, as defined by Moser (2005), alters the focus of livelihood from income and consumption to directly address the critical role that assets and capabilities play in improving individual, household, social and economic wellbeing. It should be noted that for the purpose of this study natural capital is considered a characteristic of sensitivity. In order to avoid double counting, it will not be considered as an indicator of adaptive capacity.

Thus, the three vulnerability parameters can be defined as follows:

- *Exposure is considered to consist of the impacts or potential impacts of rainfall distribution and climatic events*
- *Sensitivity is the degree to which each community is affected by exposure given the current resource availability, characteristics, and use.*
- *Adaptive capacity is the system's ability to cope, adapt or recover from the effects of exposure* (Goulden, 2010).

Indicator	Sub-indicator	Sub-indicator	Sub-indicator Value	Vulnerability score	Data source
Exposure					
	Climate	*Floods*	Magnitude of Floods based on Standardized Precipitation Index	The higher the flood magnitude, the higher the vulnerability (eq.1)	Decentralized administration / Aquaman project / GENERAL DIRECTORATE OF SPATIAL PLANNING & ENVIRONMENTAL POLICY DIRECTORATE OF WATER
Sensitivity					
	Water resources	*Precipitation*	Average annual precipitation ***(mm)***	The lower the rainfall the higher the vulnerability (eq.2)	Meteorological Service, / Decentralized administration / Aquaman project /
		Ground Water	Sustainable extraction rate (mm/yr)	The lower the sustainable extraction rate the higher the vulnerability (eq.2)	GENERAL DIRECTORATE OF SPATIAL PLANNING & ENVIRONMENTAL POLICY DIRECTORATE OF WATER
	Land resources	*Slope*		The steeper the slope, the higher	Geospatial Information Portal/ Ministry of
			Average slope (%)	the vulnerability (eq.1)	Environment and Energy
		Soil	Water holding capacity (mm)	The lower the water holding capacity the higher the vulnerability (eq.2)	Geospatial Information Portal/ Ministry of Environment and Energy -DEM Model
Adaptive Capacity					
	Human capital	*Educational distribution*	Average absolute deviation of uniform distribution	The higher the deviation the higher the vulnerability (eq.1)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete
		Age distribution			
	Social capital	*Population size*	Total population	The smaller the population the higher the vulnerability (eq.2*)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete
		Service institutions	Number of service institutions / population of community	The smaller the ratio of institutions to people, the higher the vulnerability (eq.2)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete
		Agricultural		The further from the median full	

	Financial capital	*employment*	Percent of farm holders that farm full time	time farmers %, the higher the vulnerability (eq.3)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete/ Observatory of Labor
		Community workforce	Percent of workforce that works within community	The further from the median community workforce %, the higher the vulnerability (eq.3)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete/ Observatory of Labor
		Unemployment	Percent of work force unemployed	The higher the unemployment, the higher the vulnerability. (eq.1)	Hellenic Statistical Authority / Dimelli /Prefecture of Crete/ Observatory of Labor
	Physical capital				
		Agricultural area	Total agricultural area (ha)/stremmata	The smaller the agricultural area, the higher the vulnerability (eq.2*) ευπάθεια / ευαλωτότητα (εξ. 2*)	Hellenic Statistical Authority / Dimelli
		Holding size	Agricultural area (ha) / number of holdings	The smaller the holding size, the higher the vulnerability (eq.2*)	Hellenic Statistical Authority / Dimelli
		Irrigated area	Irrigated area / agricultural area	The further from the median	Hellenic Statistical Authority / Dimelli
				irrigated area fraction the higher vulnerability (eq.3)	
		Government irrigation scheme	Presence of government irrigation scheme	The lack of irrigation scheme increases the vulnerability	Decentralized administration Region of Crete / Prefecture of Crete
		Livestock	Number of animal units /number of holdings	The lower the number of animal units, the higher the vulnerability (eq.2*)	Hellenic Statistical Authority /OPEKEPE (Greek Payment Authority of Common Agricultural Policy (C.A.P.),
		Crop diversification	Number of different crop categories	The lower the number of crop categories, the higher the vulnerability (eq.2)	
		Livestock diversification	Number of different livestock categories	The lower the number of livestock categories, the higher the vulnerability (eq.2)	

* The logarithm of the sub-indicator was used

Calculating vulnerability

Based on the index that Holly Jean Deems 2010, developed.

The vulnerability index was originally calculated by summing all of the indicator scores in the following equation:

$$\boldsymbol{Vuln\ Ind} = \frac{Climate + Water + Land + Human + Social + Financial + Physical\ Capital}{7}$$

Although this was the equation presented at the expert meeting, a second equation was developed to reduce the effect of an unequal number of indicators creating weight for one parameter's significance. For example, only one indicator is used for exposure, while four are used for adaptive capacity. Thus, when using this equation, adaptive capacity contributes four times more than exposure in the final vulnerability score. Thus, the vulnerability index was calculated by summing the parameter scores. As such, the vulnerability due to exposure, sensitivity and adaptive capacity are counted equally, by using the following equation:

$$\boldsymbol{Vuln_{Index}} = \frac{E+S+AS}{3}$$

Where E represents the vulnerability due to exposure, S is the vulnerability due to sensitivity and AC is the vulnerability due to adaptive capacity. To reach the parameter scores, the indicators within each parameter and summed and then divided by the number of indicators that were summed. For instance, the example of adaptive capacity:

$$\mathbf{AC} = \frac{\mathbf{Human + Social + Financial + Physical\ Capital}}{\mathbf{4}}$$

Summing the scores of the sub-indicators and dividing by the number of sub-indicators determine the indicator scores. Using the example of human capital:

$$\frac{\mathbf{Human\ Capital} = \text{Educational distribution score} + \text{Age distribution score}}{\mathbf{2}}$$

All sub-indicators must be equalized for their comparability and calculation in order for this formula to be accurate. Similar to the calculation method used by the United

Nations Development Programme (UNDP)'s Human Development Index (UNDP, 2002), equations were applied based on the sub-indicator's relationship to vulnerability

Equation 1 Score = (actual value – minimum value)
(maximum value – minimum value)

Equation 2 Score = (maximum value - actual value)
(maximum value – minimum value)

Equation 3

a) Score = (median – actual value) if actual value ≤ median
(median – minimum value)

b) Score = (actual value – median) if actual value > median
(maximum value – median)

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