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Heritage Evaluation of the Carob Tree MTAS in the Territory of Valencia: Analysis and Social Perception of the Ecosystem Services and Values from Cultivating It

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Abstract: The concept of Multifunctional Territorialized Agrifood Systems (MTASs) arose as an alternative to global hegemonic models in the 21st century. This study intends to identify the main ecosystem values and services generated by the MTAS of the carob tree in the territory of Valencia, which is one of the most characteristic dryland fruit tree species farmed in the Mediterranean. To do so, a multi-criteria quantitative evaluation system has been used that enables values to be assigned to the kinds of significance placed on MTASs. For this purpose, a questionnaire was carried out with 268 local inhabitants. The global score obtained is 7.6 points, indicating a high heritage value. Some of the criteria with the best scores are related to the authenticity of the carob tree and its social and historical values since this crop is a testament to ancestral techniques and traditions. Furthermore, this Mediterranean crop provides numerous ecosystem services and has multiple properties and applications, mainly in the food and pharmaceutical industries. The local population has scored the vulnerability value with only 4.1 points as a consequence of the progressive abandonment of the cultivated area in recent decades. Therefore, greater involvement from social stakeholders is essential in order to preserve this crop.

Keywords: ecosystem services; carob tree; evaluation method; MTAS; agrifood systems; public participation

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1. Introduction

1.1. Theoretical Framework and Research Aim

Food systems were based on the production and consumption of natural foods with little processing until practically the first half of the 20th century. Specifically, they were based on agricultural activity, whose production was mainly for self-consumption and supplying nearby markets [1]. However, during the Green Revolution in the 1960s, the foundations for the paradigm of agrarian productivism were laid down, in which agrifood systems, food and agriculture became industrialized [2].

As a result, in the following decades, this new model of production replaced most agrifood models based on territory and culture [3]. Hence, an agroindustrial system of specialized production and mass consumption became established, generating significant negative externalities [4], such as the production of food surpluses, environmental degradation and the consolidation of saturated consumption [5].

Productivism reached its maximum expression in the late 80s of the 20th century, backed by a techno-economic conception of agrosystems [6]. Since 1990, the food trade has been characterized as being mainly global, less economically sustainable, and with fewer territorial bonds [7].

Nevertheless, in the 21st century, a change in approach has been detected, which requires responses to revitalize the economy and agrarian systems, considering a re-evaluation of territorial heritage.

Hence, as opposed to the predominance of a kind of global agriculture and food supply that tends to shed its territorial peculiarities, other types of local or alternative agrifood systems show intense interconnections with the territory and a spatial uniqueness [8]. The concept of Multifunctional Territorialized Agrifood Systems (MTASs) has emerged as an alternative to the hegemonic models characterized by massive, specialized, globalized and heavily financialized production and consumption [9].

The MTASs are multifunctional, territorialized and sustainable systems because they manage resources responsibly and enable a living heritage to be conserved and conveyed. They are seen in the landscape, which becomes a resource, as well as cultural and environmental heritage. Consequently, such systems take into account the territory's tradition of production while contributing to a sustainable food transition supported by governance mechanisms for territorial development [10].

The concept of MTAS is linked to trends in thought focusing on studying the interrelationships between the territory and local food production systems, among which there are the Anglo-Saxon schools of Agrifood Geography, known as *Alternative Agri-food Networks*, and the ones of Franco-Mediterranean origin regarding *Systèmes Agro-alimentaires Localisés* (Local Agrifood Systems, SIAL) [8]. The approach to studying SIALs mainly involves the strong bond that exists between territories and food [11].

MTASs have several defining characteristics that identify them. Firstly, multifunctionality stands out. Agriculture's deep roots in the territory give the activity a broad multifunctional diversity [12]. Secondly, the MTASs are defined by territorialization processes that connect food products with the spaces, resources and societies where these systems are present [13].

These systems thus foster sustainable food security supported by mechanisms of governance and social mobilization. Consequently, they are related to three components of proximity, as opposed to the long chains in the agrifood industry [4]: (a) proximity and coherence with the ecosphere; (b) proximity in food chains; and (c) proximity in the commercial circuits, with a reorientation of the food supply towards a more abundant, varied and verifiable local supply.

The concept of ecosystem services (ESs) is becoming increasingly used to evaluate the benefits of sustainable land management practices for society and human well-being [14]. The Millennium Ecosystem Assessment [15] defines ESs as the benefits that people obtain from ecosystems. These include the direct or indirect positive contributions that human beings receive from the functions of ecosystems [16]. In other words, ESs can be considered as benefits or, more broadly, as contributions to human well-being [17] provided by ecosystems, places and landscapes.

One of the main challenges today is to identify an ecosystem's capacity to provide services and to know the demand for them [18]. Agrarian ecosystems are often managed primarily to optimize the provision of ESs such as food. Within this process, these systems depend on a wide variety of support and regulation services [19].

Numerous studies have evaluated the ESs provided by agrarian ecosystems, such as the one carried out by Gutiérrez, Suárez and Vidal-Abarca (2016) in the agricultural gardens or *huerta* of Murcia [20]; the one by Ruiz and Cañizares (2018) in the Mediterranean vineyard landscape [21]; and the one by Romero-Díaz, de Vente and Díaz-Pereira (2019) on agricultural terraces [14]. Nevertheless, studies that have specifically dealt with the MTASs in the Valencia Community region are scarce, and it is necessary to analyze the complexity and diversity of the ESs, as well as their contribution to the population's well-being and to the conservation of biodiversity.

In this vein, the research is based on the hypothesis that MTASs generate a relevant variety of ESs for society, such that they provide significant goods and services beyond the traditional function of food production. Thus, these systems with a noteworthy territorial and cultural character exemplify such processes and provide ESs for the population. For this reason, this study focuses on the MTAS of the carob tree (*Ceratonia siliqua* L.) in the

area of Valencia. This is one of the most common dryland species of fruit tree in the Mediterranean basin.

The aim of this work is to identify the main values and ESs provided by the MTAS of the carob tree in the Valencia territory in the context of Mediterranean agricultural landscapes. It is fundamental to identify the ESs provided by agrarian ecosystems in order to draw up proposals to protect, conserve and manage these landscapes [21]. To do so, a multi-criteria quantitative methodological system has been implemented to enable the MTAS' particularities to be evaluated, taking into account key factors such as heritage and landscape quality. Its structure includes a wide variety of indicators so that on applying it, detailed knowledge can be gained about the values and ESs generated by this MTAS. Furthermore, participatory strategies have been rolled out by carrying out a questionnaire targeting the local population in order to learn the community's evaluation of its agrifood system and to characterize its multiple dimensions.

To sum up, this study aims to address various essential questions that guide the research into the carob MTAS in the Valencia area. Firstly, it looks into the main cultural, environmental and economic values associated with the carob agrifood system and how these translate into ESs for society. Furthermore, an understanding is sought of the local community's perception and evaluation of these values and services. It also aims to identify the challenges and opportunities in the conservation and sustainable management of this system, especially in the context of Mediterranean agricultural landscapes. By means of these research questions, the aim is to increase the theoretical understanding of the functions and benefits of the carob tree in the Mediterranean landscape, as well as to provide practical information for drawing up policies and actions aimed at conserving and managing this agrosystem.

1.2. Characterization of the Carob Tree

The carob is an evergreen woody crop in the legume family (subfamily *Cesalpinoideas*). Its scientific name (*Ceratonia siliqua* L.) is derived from the Greek *keras* (horn) and the Latin *siliqua*, referring to the shape and hardness of the fruit's pod. The common name comes from the Hebrew *kharuv*, from which *kharrub* was derived in Arabic, and later, *algarrobo* or *garrofero* in Spanish, *garrofer* or *garrover* in Catalan, *carob tree* in English, *carrubo* in Italian, *caroubier* in French and *alfarrobeira* in Portuguese. It is also known as Saint John's Bread, recalling the alleged use of its seeds as food by Saint John the Baptist, which is where its name in German comes from: *johannisbrotbaum* [22].

The species is traditionally grown in Mediterranean regions, in areas where there are commonly mild temperatures and low levels of humidity and precipitation [23]. The tree is a rustic one that is resistant to drought and tolerant to salinity, requiring little maintenance. Nevertheless, it also has its limitations, such as sensitivity to low temperatures, a slow start to production and varying yearly yield [24]. Figure 1 shows an example of a carob tree.

The origins of the carob tree are uncertain. Many researchers locate its native origins in the eastern Mediterranean, more precisely in the Anatolian peninsula and Syria (De Candolle, 1883; Vavilov, 1951; as cited in [25]). However, Schweinfurth (1894, see [26]) stated that the carob tree was native to the southern Arabian highlands of Yemen. On the other hand, the study carried out by Hillcoat, Lewis and Verdcourt (1980) [27] analyzes the species *Ceratonia oreothauma*, the only known one related to the carob tree. That study points to the origin of the species in southeastern Arabia (Oman) and around the Horn of Africa (northern Somalia), reinforcing the possible eastern origins of this genus. Furthermore, the presence of caulogenic inflorescences and the infrequent flowering time compared to other Mediterranean plants points to a possible subtropical origin [26].

The carob tree has been cultivated since ancient times in the Mediterranean basin as a consequence of its good adaptation to xeric environments and the historical use made of its fruit and pulp [28]. The use of the carob fruit dates back to the ancient Egyptians, who fed cattle with carob pods, and the seeds were used for sizing in bandages intended for mummification. Furthermore, the Arabs also used the carob seed as a unit of weight.

They called it *qirat*, which led to the name of *carat*. Its standard weight became the unit of weight for gold and precious stones [29]. The ancient Greeks introduced the carob tree from the Middle East to Greece and Italy, whereas the Phoenicians and Arabs spread it to the northern coast of Africa and the Iberian Peninsula [30]. It later spread to other geographic areas such as Mexico, Chile, Argentina and California [24].



Figure 1. Carob tree.

Today, the mean world production of carob fruit comes to about 200,000 to 340,000 tons per year, though its cultivation is in decline with a regressive trend in recent years, so these figures are expected to fall lower in the future. Among the different uses for carob fruit today, the ones in the sphere of food are most noteworthy, where it is used as a thickener, preservative, stabilizer, binder or additive, as well as in the paper, textile, tobacco, pharmaceutical and cosmetic industries.

Spain is the biggest producer of carob fruit, accounting for 40% of the total [26], and the second largest producer of its seed, the locust bean, behind Morocco [30]. According to the Spanish Ministry of Agriculture, Fisheries and Food (2023) [31], the Spanish land area used for it covers 40,198 hectares in standard orchards, in addition to 36,119 scattered trees. There is very little irrigation for carob trees, with 97% of this area using dryland cultivation. Spanish production comes to 47,286 tons. It is cultivated mainly on the Mediterranean coastal strip, where the Valencia Community region stands out, taking up 42.9% of the total cultivated area (17,244 ha), especially in the provinces of Valencia and Castellón. However, the area occupied has seen a decline in this region in recent decades: in 1950, there were about 145,000 hectares; in 2000, about 45,000; and in 2010, around 20,000.

2. Materials and Methods

2.1. Area of Study

In the Valencia territory, between the coastal plains and the interior highlands, there are transition zones made up of plains, *campiña* (open farmland), foothills and wide river valleys. The climate, temperature and precipitation are in keeping with the usual values and regimes of the Mediterranean zone. These transition territories have traditionally made up the geographic area for dryland crops, such as olive, carob and almond trees, and even vineyards. The influence of the Mediterranean Sea can still be felt, though in the westernmost lands, the characteristics typical of continental areas are evident.

These areas make up territories in which irrigation systems gradually expanded due to an intensive hydraulic policy that involved building reservoirs and their distribution channels, as well as the exploitation of underground resources through wells. This work began at the end of the 19th century and expanded for decades into the 20th century. Thus, the transformation of the Valencian agrarian system occurred particularly in these transition territories, where orange trees were gaining prominence, and not only on the coastal plains.

Even so, the carob tree is the predominant woody crop in the Valencian foothills. It is a unique feature of the landscape, despite the drive for almond and olive trees in recent decades. In this study, fifteen municipalities located in the Valencian foothills that have kept their territorial continuity have been selected, specifically in the sector of the Mid-Turia basin, which this research focuses on (MTAS territory) (Figure 2).

The area cultivated with carob trees in this zone covers about 4200 hectares. Table 1 shows in detail the area occupied by this crop in the municipalities in the area under study. The municipal areas that stand out are Llíria, Chiva and Pedralba, with more than 500 hectares each; then there is Riba-roja de Turia and Montserrat, with areas of around 400 hectares; followed by Montroi, Cheste, Bugarra and Gestalgar, with areas of between 237 and 331 hectares; and finally, Bétera, Turís and Vilamarxant have between 130 and 150 ha each. The rest of the municipalities in the MTAS territory have smaller such areas. Figure 3 shows the amount of carob tree cultivation area in the municipalities under study.

Table 1. Carob tree cultivation area in the municipalities of the MTAS territory.

Municipalities	Carob Tree Area (ha)			Total Cultivated Area (ha)			% Dryland Carob Trees over Total Dryland	% Carob Trees over Total Cultivated Area
	Dryland	Irrigated	Total	Dryland	Irrigated	Total		
Bugarra	233	4	237	342	710	1052	68.1	22.5
Gestalgar	327	4	331	473	198	671	69.1	49.3
Pedralba	501	10	511	757	2187	2944	66.2	17.4
Bétera	127	3	130	314	3141	3455	40.4	3.8
Llíria	529	23	552	2484	6589	9073	21.3	6.1
Náquera	188	3	191	329	841	1170	57.1	16.3
Riba-roja de Turia	412	6	418	434	1291	1725	94.9	24.2
Alborache	60	1	61	214	286	500	28.0	12.2
Vilamarxant	131	2	133	678	2243	2921	19.3	4.6
Cheste	272	4	276	1020	1714	2734	26.7	10.1
Chiva	546	9	555	2013	2863	4876	27.1	11.4
Godelleta	33	2	35	385	1558	1943	8.6	1.8
Montserrat	390	5	395	677	763	1440	57.6	27.4
Montroi	279	5	284	418	919	1337	66.7	21.2
Real	24	1	25	96	446	542	25.0	4.6
Turís	147	2	149	813	2404	3217	18.1	4.6
Total	4199	84	4283	11,447	28,153	39,600	36.7	10.8

Data Source: [32].

As one can see, the carob is a noteworthy dryland crop in the Valencian foothills. Indeed, around 37% of this territory's dryland area is occupied by carob trees. There are municipalities where they are the leading crop by area, occupying over 50% and even 90%: Riba-roja del Turia, Gestalgar, Bugarra, Pedralba, Montroi, Montserrat and Náquera.

However, on analyzing the proportion of carob tree area over the total cultivated area, it is found that it barely accounts for a tenth of the total in these 16 municipalities. This is mainly due to the expansion in irrigation in recent decades so that the carob has given way to other irrigated crops. It is common to find concentrations of carob plots bordering irrigated areas mainly dedicated to citrus trees.

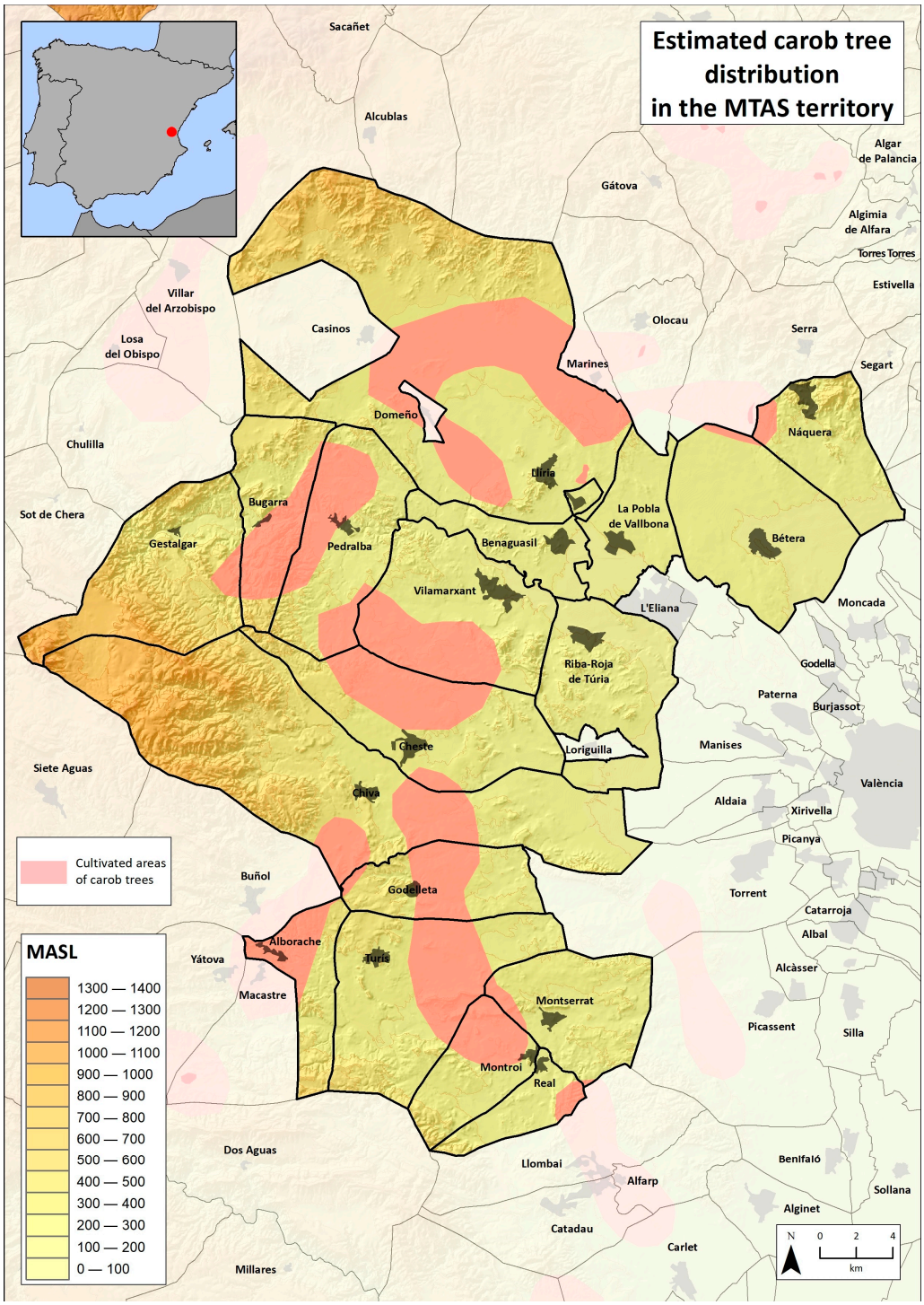


Figure 2. Approximate location of carob trees in the MTAS territory.

Nevertheless, from the point of view of the landscape, the carob tree continues to be a distinguishing feature that contributes to the character of the agricultural space of the foothills. Hence, the carob tree plays a contrasting role in the dryland zones. In fact, in some municipalities, it holds a special meaning, as occurs in Gestalgar, Riba-roja de Turia, Montroi, Pedralba and Náquera.

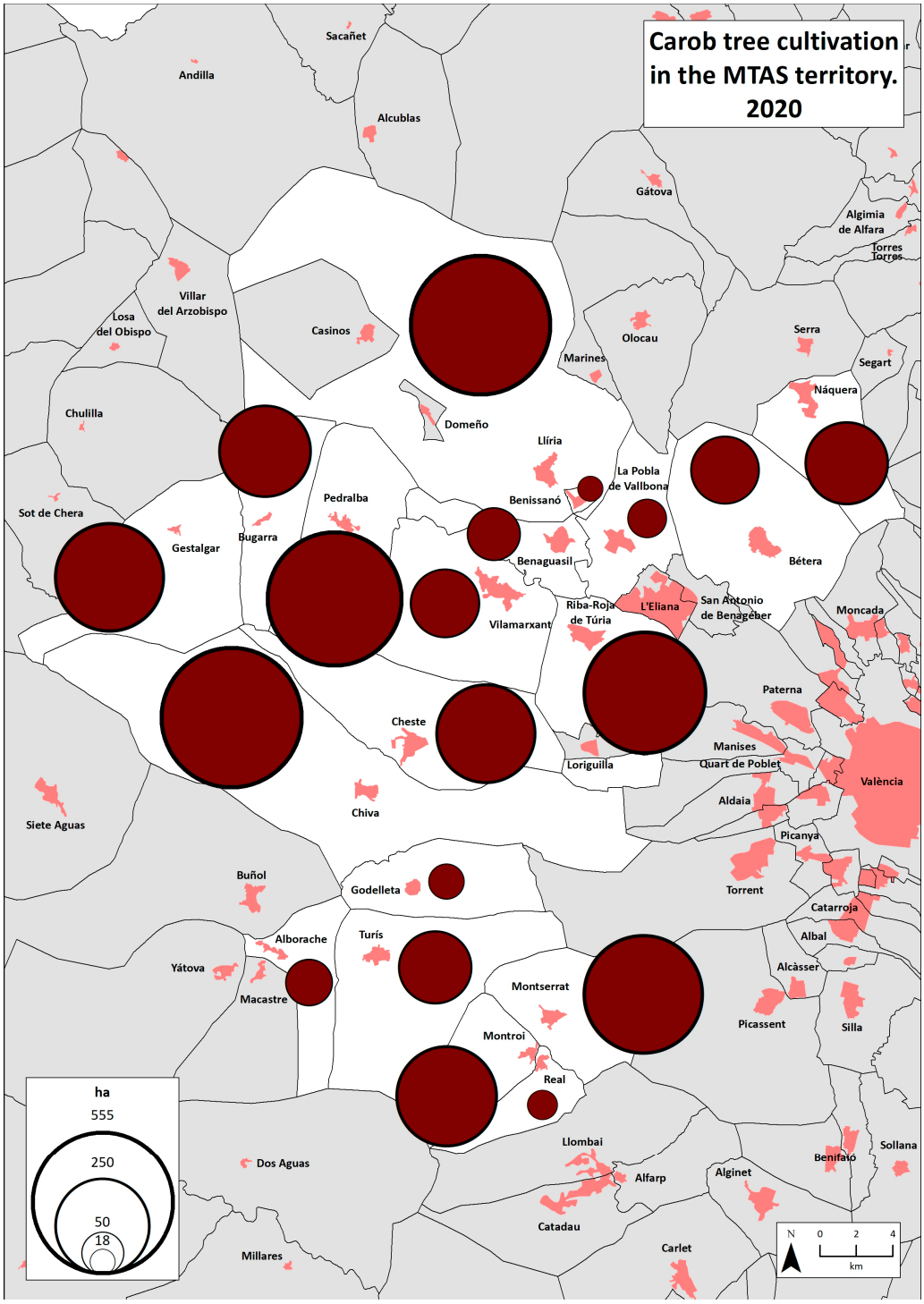


Figure 3. Carob cultivation area in the study area's municipalities in 2020. Data Source: [32].

2.2. Method for Evaluating the Quality of Landscape and Heritage in an MTAS

It is fundamental to characterize and evaluate agrifood systems in order to conserve, manage and raise appreciation of them. The evaluation method applied in this study is described in the study by Mayordomo-Maya and Hermosilla-Pla (2022) [33], where it was implemented in the agricultural area of l'Horta de València (the market gardens of and around the city). It is a quantitative, multi-criteria system made up of objective, practical parameters that enable an MTAS' heritage value to be known. Its structure is based on several plans by the Cultural Heritage Institute of Spain [34–36], and its indicators take

into account the values of agrarian and agrifood systems, as well as the UNESCO criteria for inclusion as Sites in the World Heritage List [37] and the criteria considered by FAO to select GIAHS [38].

The method's structure has three categories of values: "intrinsic values", "heritage values" and "potential viability values". These three categories are made up of 15 criteria, each of which is broken down, in turn, into three specific variables so that there are 45 attributes that make up the system. Hence, the method has a hierarchical structure of indicators, ranging from general to specific, by means of three levels that allow an MTAS to be evaluated: categories, criteria and variables. The system's complete structure can be seen in Table 2.

Table 2. Method for evaluating MTASs' landscape and heritage quality.

Categories	Criteria	Variables
Intrinsic values	1. Representativeness	1.1. Typological representativeness
		1.2. Representativeness in the territory
		1.3. Representativeness of the crops
	2. Authenticity	2.1. Morphology and traditional image
		2.2. Continuity of the practices and traditional ways of production
		2.4. Measures to manage and recuperate landscape
	3. Ecological integrity	3.1. Agrobiodiversity or agricultural biodiversity
		3.2. Ecological agriculture
		3.3. State of environmental conservation
	4. Visibility and visual quality	4.1. Diversity and harmony
		4.2. Presence of vegetation cover and/or non-productive species
		4.3. Breadth of views or panoramics
Heritage values	5. Historic	5.1. Link with personalities, civilizations, events and institutions of a historical kind
		5.2. Testimonies or vestiges of a long agrarian tradition and specialization
		5.3. Presence of historical human settlements and archaeological sites
	6. Social	6.1. Expression of a living, cohesive and dynamic landscape
		6.2. Culture, social organizations and ways of habitation
		6.3. Know-how and systems of local and traditional knowledge
	7. Symbolic/Identifying	7.1. Folklore representations
		7.2. Feeling of identity and belonging to a group or community. The landscape is in the collective imagination
		7.3. Organization of events, activities and alliances aimed at creating a feeling of identity
	8. Artistic	8.1. Presence of artistic expressions associated with the landscape
		8.2. Picturesque or traditional scenery
		8.3. Aesthetic values
	9. Informative/Scientific	9.1. Presence of inventoried, catalogued or protected cultural assets
		9.2. Presence of bibliographical references and documentary works of a scientific nature
		9.3. Presence of collectives concerned about safeguarding the landscape

Table 2. *Cont.*

Categories	Criteria	Variables
Potential and viability values	10. Food production, security and quality	10.1. Food security for the local community
		10.2. Proximity in food production
		10.3. Quality of agricultural and food products
	11. Awareness among social stakeholders	11.1. Legal situation and institutional recognition of the landscape
		11.2. Investment and action by public administrations and other collectives
		11.3. Strategies and materials for dissemination, teaching and communication
	12. Participation and integration of local communities	12.1. Participation in management of the landscape
		12.2. Participation in processes of documentation, research and interpretation
		12.3. Participative and territorial governance
	13. Socio-economic profitability	13.1. Organization of agrifood chains into networks
		13.2. Sustainable production models
		13.3. Capacity of the landscape itself to develop sustainable economic activities
	14. Vulnerability	14.1. No situation of abandonment
		14.2. No threats linked to unplanned massive tourism or pressure from urban development
		14.3. No threats linked to lack of knowledge or disinterest by part or some sectors of the community regarding the landscape or traditional agrarian practices
	15. Accessibility	15.1. Connection between agrarian elements and accessibility to plots and smallholdings
		15.2. Presence of historical roads, cultural itineraries or routes and approved or educational footpaths
		15.3. Road access

Source: [33].

The category of "intrinsic values" considers the MTAS' specific or inherent characteristics and their significance according to the elements that give it its structure. It also takes into account the values of the landscape perceived by the observer. It includes four criteria: (1) The MTAS' representativeness evaluates its capacity for being the agrarian landscape characteristic of its type or in the territory, as well as the predominance of the crop. (2) Authenticity places a score on the centuries-old maintenance of the agrarian system's productive function, its degree of fidelity to the traditional image and the continuity of traditional modes of production. (3) Ecological integrity considers the MTAS' agricultural biodiversity and its state of environmental conservation. (4) Visibility and visual quality refer to the breadth of the visible territory, its scenic values and the harmony of the landscape unit.

"Heritage values" account for the environmental and cultural attributes that affect and influence the landscape's intrinsic characteristics. They represent a descriptive analysis of the MTAS and are made up of five criteria: (5) The historical value evaluates the cultural and socio-economic evidence of the periods and societies that have lived in the territory considered, as well as the presence of vestiges of a long agrarian tradition. (6) The social criterion places a value on the cohesive nature of the landscape, its collective forms of social organization and the maintenance of traditional knowledge, with knowledge passed on by generations of farmers. (7) The symbolic/identifying indicator considers the emotional bonds and those of belonging, as well as local communities' perceptions of the landscape.

(8) The artistic value gives a score to the aesthetic values of the landscape unit, the MTAS' capacity to generate a picturesque scene and the presence of artistic expressions associated with the territory. (9) The informative/scientific criterion accounts for the landscape's scientific qualities linked to the creation of knowledge and the existence of collectives concerned with safeguarding the agrosystem.

The "potential and viability values" consider the potential value of the landscape unit, referring to its future prospects. They are made up of six criteria: (10) The food production, safety and quality indicator considers the MTAS' contribution to the livelihood of the local community and its responsible consumption, as well as the proximity of the food production and the quality of the agricultural and food products. (11) "Awareness of social stakeholders" refers to the involvement and commitment that territorial stakeholders have towards protecting, conserving and creating an appreciation of the agrosystem by means of legal instruments, investment and other information and dissemination strategies. (12) "Local communities' participation and integration" puts a score on the active participation of local communities in landscape management and in documentation, research and education processes, as well as the presence of entities involved in the social and solidarity economy. (13) "Socio-economic profitability" evaluates the contribution of the landscape unit to the sustainable socio-economic development of local communities via the organization of agrifood chains into networks, sustainable production models and the capacity of the landscape to generate wealth. (14) "Vulnerability" considers the susceptibility of the landscape to undergo modifications due to the existence of external and internal influences as a consequence of situations of abandonment, urban planning pressure or a lack of knowledge of the MTAS' value. (15) "Accessibility" refers to the ease of accessing, viewing and passing through the landscape unit.

The use of the evaluation method takes into consideration the heritage value of the agrosystem from a landscape-heritage perspective but also addresses its contribution to the different types of ESs. In general, four types of ESs are distinguished: provisioning, regulating, supporting and cultural. Below are the criteria for the evaluation method that are associated with each of these types of services:

Provisioning services refer to the tangible resources that ecosystems provide, such as food, water and fuel. In this evaluation method, two criteria are directly related to this type of service: food production and quality, which consider the productivity of the carob crop, and socio-economic profitability, which accounts for the benefits arising from cultivating the crop, such as the jobs generated.

The regulating services include aspects such as climate regulation and air and water quality. Hence, various criteria are linked to this type of service: ecological integrity, which considers the environmental state of the ecosystem, and vulnerability and accessibility, which analyze the crop's resilience to threats and the ease of access to the landscape unit. Furthermore, raising awareness among social stakeholders and participation from the community can foster citizens' participation in sustainable management and environmental conservation.

Supporting services are fundamental for the ecosystems to function and for the production of other services. In this method, two criteria are directly related to this type of service: authenticity and representativeness.

Finally, cultural services refer to the non-material benefits that people get from ecosystems, such as recreation, education and a sense of cultural identity. In this evaluation method, several criteria are associated with this type of ES: historical, symbolic and social values, which reflect the cultural importance of the carob tree in local society, and artistic and informative values, which value the way the landscape can inspire works of art and educational activities. Lastly, visibility also influences appreciation of the territory.

Each MTAS is scored using a simple binary system based on compliance with each of the 45 variables in the method. To do so, if the quality is met, it is assigned the value of 1; if not, 0. There is no weighting. The sum of the scores given to the 45 indicators gives the global score for the MTAS. The result is expressed on a scale of 0 to 10 points,

using six levels of heritage interest: very high (8.6–10); high (7.2–8.5); medium (5.8–7.1); low (4.4–5.7); very high (3–4.3); and no interest (0–2.9). It is also possible to evaluate each category and criterion individually with the aim of analyzing and specifying the most significant values and peculiarities of the agrifood system. The score for each category is calculated by the sum of the scores from their criteria, whereas the score for each criterion is found by summing up the scores of their variables.

2.3. Questionnaire for the Local Population

After the Landscape Character Assessment (LCA) method was drawn up and, subsequently, the European Landscape Convention (CEP) was created, citizens' participation took on significance in terms of the factors associated with the perception of the landscape and the factors linked to decision-making [39].

For this reason, in this study, a questionnaire was given to the local populations of the fifteen municipalities in the study area in order to learn the community's perception and evaluation of the carob agrifood system. The study by Mayordomo, Hermosilla and Fernández (2023) [40] created this questionnaire and used it in the MTAS of l'Horta zone (market gardens) of Valencia city and its environs. The questions are specifically designed to characterize the multiple dimensions of these agrosystems.

In the beginning, it has questions to identify the subject being surveyed in terms of their characteristics of age, sex and educational level. Its structure is then split into two sections.

The first is made up of nine items to measure the inhabitants' favorable or unfavorable opinions regarding the MTAS. The Likert scale was chosen as the technique for measuring attitudes in their responses. Hence, the respondents answered each of the phrases based on five alternatives of progressive intensity, where 0 is very much against, and 4 is very much in favor. The nine items are:

A Cooperatives are an essential and characteristic element of this system.
B The system is environmentally sustainable.
C Local society feels involved and linked to the system.
D Agricultural activities are the most important ones for the system.
E Commerce activities are the most important ones for the system.
F There are related activities, such as tourism, that are linked to the system, which have great potential.
G Ecological, biodynamic and similar work are key to the system's survival.
H The system helps the population remain settled in the territory.
I Climate change is a major threat to the system's survival.

The second section is made up of fifteen closed dichotomous "yes or no" questions, where a possible answer is also "don't know". Questions answered "yes" mean positive opinions. The questions were formulated based on each of the 15 criteria that make up the evaluation system described above.

1. Is the characteristic or predominant agrifood system in the territory the one that identifies it and differentiates it from other zones?
2. Does the agrifood system keep up its original or traditional character, form and image, even if interventions have been made over time?
3. Is the system in a good state of environmental conservation, and are its habitats and natural or plant resources free from pollution or degradation?
4. Does viewing this landscape improve your quality of life?
5. Does the system show evidence of long traditions and agrarian specialization; for example, does it have historical agrarian elements or infrastructures, well-established systems for dividing the land, ways of organizing the land, etc.?
6. Are the traditional agrarian skills, techniques, practices and knowledge of the system preserved and passed on from generation to generation?
7. Does the system have value in terms of identity or sentiment for the inhabitants?

8. Do the system's crop(s) and their associated elements have a significant role in forming relevant aesthetic scenery?
9. Does the system contribute to scientific knowledge, or is it found in publications of any type (articles, theses, photographs, maps, etc.)?
10. Does the system help sustain the local community; in other words, is the food produced intended for families' self-consumption and local or regional markets or industries?
11. Are the public administrations, institutions or any other group in the territory aware of the system and/or are they making investments aimed at conserving it and spreading awareness about it?
12. Do the local community and territorial stakeholders actively take part in managing, documenting and/or informing about the system?
13. Does the system favor sustainable socio-economic growth and development for the territory (with activities such as commerce, tourism, attracting new residents, employment, etc.)?
14. Is the system free of threats related to abandonment or a lack of maintenance of productive areas, mass tourism, urban pressure, lack of knowledge among the inhabitants, or other types of risks?
15. Is it possible to adequately access the system's agricultural elements and plots via paths and roads in appropriate conditions?

2.4. Work Plan

The work plan is made up of several phases that enable the evaluation method and the questionnaire to be applied in the carob tree MTAS. These tasks are based on similar ones used in various scientific heritage evaluation studies, such as those by Mayordomo-Maya and Hermosilla-Pla (2022), Mayordomo, Hermosilla and Fernández (2023) and Reynard, Perret, Bussard, Grangier and Martin (2016) [33,40,41] (Figure 4).

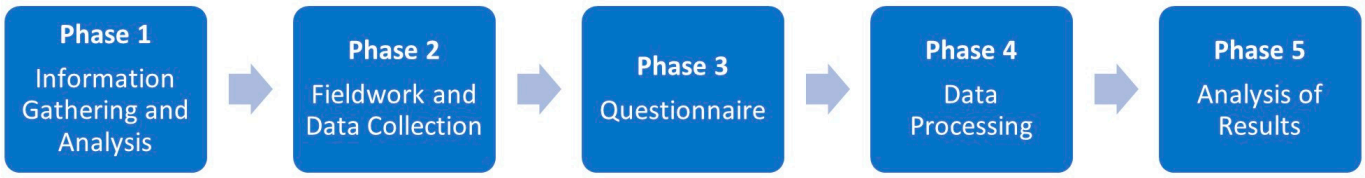


Figure 4. Flowchart of the research process.

(a) The first phase consists of searching and consulting information sources related to the carob tree MTAS, such as bibliographic references and other documents of interest. By analyzing them, a detailed study can be made of the agrosystem's features and particularities in order to correctly assign scores to the variables that make up the evaluation system.

(b) The next stage is based on fieldwork. This involves carrying out different visits to the study area's territory. Observation and direct contact with the landscape are necessary to adequately score the method's various indicators. In this phase, inquiries were also made with local specialists and technicians, farmers, producers, cooperatives, agricultural or agroindustrial companies and other groups related to the MTAS.

(c) The third phase was to carry out the questionnaire. This work was performed by an external company specializing in carrying out these techniques. The universe of analysis included inhabitants aged 18 years or older residing in the study's municipalities. The information was gathered into age and sex profiles as equitably as possible.

The technique for gathering information was based on a blended method with a digital survey via an opinion panel and a face-to-face survey using a team of interviewers. The sample has been calculated for a 95% confidence level and a 6% margin of error, with the granularity based on the population census of the municipalities under study. The base population takes into account exclusively the inhabitants of legal age, so the company made an approximate calculation. The number of surveys required was 266 questionnaires.

The survey period was two weeks in May and June 2022. The final sample included 268 people. Table 3 shows the number of inhabitants surveyed and the population of each of the municipalities in the MTAS territory in order to verify the surveys' representativeness.

Table 3. Universe of analysis and number of people surveyed.

Municipality	Inhabitants Surveyed	Population (2021)
Bugarra	1	728
Gestalgar	1	542
Pedralba	2	2852
Bétera	56	25,423
Llíria	44	23,648
Náquera	28	7301
Riba-roja de Turia	29	22,799
Alborache	6	1283
Vilamarxant	16	10,097
Cheste	10	8871
Chiva	30	15,769
Godelleta	3	3714
Montserrat	24	5017
Montroi	7	3069
Real	4	2250
Turís	7	6910
Total	268	140,273
	Total base population (10%): 126,246	

Data Source: [32].

(d) In the fourth phase, the information obtained in the preceding phases was processed. Based on the documents analyzed and the information attained in the fieldwork, scores were assigned to each variable in the evaluation system. Work was also conducted on the data provided by the company specializing in conducting surveys. The information obtained was entered into a spreadsheet, and the relevant statistics were calculated.

(e) The last phase of the work plan was to analyze the results and statistics obtained. The information processed was introduced into a geographic database, and maps were created. Finally, the results were interpreted, and the study's reports were written.

3. Results and Discussion

3.1. Technical Evaluation

The technical evaluation of heritage carried out on the carob MTAS can be seen in Table 4. Each of the 45 variables that make up the system was assigned the figure of "1" or "0" depending on whether or not it complied with the statement. Then, the scores were tallied for each category. The global score obtained here was 7.6 points, which represents a high heritage interest according to the six levels of evaluation proposed. Likewise, each category also has high scores. Indeed, the intrinsic values reach a score of 8.3 points. Next the heritage values, with 7.3 points, and finally, the potential and viability values, with a similar score of 7.2 points. The results from applying the method to each of the criteria it is based on are analyzed and described below, then interpreted and compared with previous studies.

Representativeness

The carob tree is one of the most characteristic, typical dryland fruit tree species in the Mediterranean basin. In fact, it is only found in territories with a Mediterranean climate in temperate latitudes with dry summers and some influences from humidity. Thus, it is one of the most characteristic and dominant trees in the lower zone of the Mediterranean evergreen *maquis* shrubland [22] and is a distinctive feature in the traditional dry Mediterranean landscape.

The largest producers of carob are the coastal countries of the Mediterranean basin, generally in this order: Spain, Italy, Portugal, Morocco, Greece, Türkiye, Cyprus, Algeria and Lebanon. In the Iberian Peninsula, it is mainly cultivated in the Mediterranean coastal strip. Moreover, the Valencia Community region takes up 42.9% of the total cultivated area in Spain, such that in this area, its landscape is of manifest significance [26]. In fact, in the territory of the Valencian foothills, the carob is the predominant woody crop, despite the drive in recent decades for almond and olive trees.

To sum up, the representativeness criterion has been scored positively for its three variables. From the point of view of the landscape in the zone under study, the carob tree is a distinguishing feature that contributes to the character of the foothills' agricultural landscape. In the dryland, this species acquires a prominence that sets it apart.

Table 4. The proposed evaluation method applied to Valencia's agricultural gardens.

Categories	Criteria	Scores		
		Variables		Categories
Intrinsic values	1. Representativeness	1.1.	1	8.3: High (10/12)
		1.2.	1	
		1.3.	1	
	2. Authenticity	2.1.	1	
		2.2.	1	
		2.4.	0	
	3. Ecological integrity	3.1.	1	
		3.2.	1	
		3.3.	1	
	4. Visibility and visual quality	4.1.	0	
		4.2.	1	
		4.3.	1	
Heritage values	5. Historic	5.1.	1	7.3: High (11/15)
		5.2.	1	
		5.3.	0	
	6. Social	6.1.	1	
		6.2.	1	
		6.3.	1	
	7. Symbolic/Identifying	7.1.	0	
		7.2.	1	
		7.3.	0	
	8. Artistic	8.1.	1	
		8.2.	1	
		8.3.	1	
	9. Informative/Scientific	9.1.	1	
		9.2.	1	
		9.3.	0	

Table 4. *Cont.*

Categories	Criteria	Scores		
		Variables		Categories
Potential and viability values	10. Food production, security and quality	10.1.	1	7.2: High (13/18)
		10.2.	1	
		10.3.	1	
	11. Awareness among social stakeholders	11.1.	0	
		11.2.	0	
		11.3.	1	
	12. Participation and integration of local communities	12.1.	1	
		12.2.	1	
		12.3.	1	
	13. Socio-economic profitability	13.1.	1	
		13.2.	1	
		13.3.	1	
	14. Vulnerability	14.1.	0	
		14.2.	0	
		14.3.	1	
	15. Accessibility	15.1.	1	
		15.2.	0	
		15.3.	1	
Global score		7.6—High (34/45)		

Authenticity

This criterion has been scored favorably in two of its variables: those relating to the centuries-old maintenance of the ways of production and the degree of fidelity to the traditional image of the landscape's scenery.

Carob tree cultivation still maintains the use of traditional techniques and practices [23]. Pruning is carried out regularly in periods of 4 or 5 years. This species is undemanding in this regard since it is a long-living tree that bears fruit on old branches. Soil maintenance is traditionally carried out by harrowing. In some orchards, weed control is performed using the mixed "tillage–herbicide" system, based on using herbicides in the rows and tillage in the alleys. Even so, little fertilizer treatment is used [42]. Harvesting is performed by hand using *vareo* with the help of poles or reeds with nets spread on the ground since the small size of the orchards restricts mechanical harvesting. The fruit is gathered and packaged in bags until it is taken to the warehouses, which must be cool, ventilated and humidity-free [26]. Figure 5 shows traditional chores for maintaining carob cultivation in the MTAS territory.

Two consecutive stages can be distinguished in processing the whole carob fruit: chopping and industrial processing. Chopping involves physically separating the two main components, pulp and seed, and this is carried out in agroindustries and cooperatives. The industrial processes can be very different depending on the part of the fruit and the target market [22].

Before carob agriculture transformed the land, the Valencian foothills were occupied by thermophilic kermes and holm oaks. In order to establish this crop in much of the Valencian thermal territory, extensive zones were plotted out and terraced, modifying the natural landscape by creating a new one that has maintained its traditional morphology today [26]. However, in this MTAS territory, there is no evidence of activities and measures

aimed at managing and recovering this landscape and its traditional agricultural practices, which is why this variable has been scored negatively.



Figure 5. Traditional chores for maintaining carob cultivation in the MTAS territory.

Ecological integrity

The landscape and environmental value of the carob tree in the Mediterranean area is a fundamental aspect of its preservation and conservation. According to [42], the carob crop should be an essential instrument for ecological evaluation, with functions aimed at conserving heritage and protecting the soil and hydrogeological balance. Hence, this species may provide a future solution to the increasing climate crisis, both from an ecological and economic point of view [29].

The carob does not require excessive care and can grow in poor, shallow soils, so orchards of this crop can help combat soil desertification [43] and are useful in areas threatened by erosion [25]. Indeed, according to Spina (1989) [44], there is currently a tendency to use the carob tree as a forest species on poor, dry soils in order to protect soil and landscape degraded by fires. Thus, this crop has significant ecological value in preventing erosion and regenerating the soil. It is also used as a firebreak due to its capacity for regrowth in the agroforestry ecosystems of Mediterranean countries.

Moreover, its ecological function as a refuge for beneficial fauna is also relevant [30], and it helps mitigate the effects of global warming since it is very effective as a carbon dioxide sink [45]. Furthermore, the study by Esbenshade and Wilson (1986) [46] recommends carob orchards as wind barriers. This cultivated tree may also be a relevant species in the environmental modeling of coastal areas and as a buffer for noise from factories or roads thanks to its dense foliage [22].

Visibility and visual quality

The visibility and visual quality criterion was scored favorably in all three of its variables. The carob tree MTAS shows a considerable degree of openness or visibility because it is possible to observe large swathes of the landscape from different places, which fosters its scenic quality. Hence, there is relevant prominence of the carob tree in the Valencian foothills, where the low, varying densities of the trees stand out with their rectangular orchards.

This indicator also evaluates the existence of different cultivated species or polycultures in the territory since they have a positive effect on the observer's score. In this landscape, intercropping commonly occurs with species such as olive trees, vines and almond trees [22]. It is also common to find concentrations of carob plots bordering irrigated areas mainly dedicated to citrus trees.

The quality of diversity and harmony takes into account the integration of traditional agrarian elements in the scenic landscape. In this MTAS, typical agricultural elements are combined and related, such as the presence of extensive terraces and plots that can be accessed via traditional paths, as well as other components representative of agricultural activity. This composition and balance between the elements of the unit creates a harmonious scene of notable visual quality.

Historic

The carob is one of the oldest cultivated trees in the world, and it has been cultivated since the civilization of Ancient Persia, especially in the Mediterranean area [25]. There are very ancient records of this species showing the presence of cultivation for centuries, with its greatest splendor towards the end of the Middle Ages, a time in which its fruit was taken from the Mediterranean basin to other European countries to make sweets and medicines, for distillation and making alcohol, and above all, for human and animal nutrition [44]. The carob tree, then, has an extensive cultural history of noteworthy economic importance due to its diverse uses.

In the Valencia territory, there are references to the cultivation of the carob tree by the Moors, who considered it one of their main crops. In his work, Cavanilles (1795) [47] mentions the "carob forests" in numerous municipalities, emphasizing the presence of trees scattered throughout the territory. He calculated the global production of Valencian carob to be about 58,200 MT.

The historical function of the carob tree within the Valencian agrarian and economic system has basically been to serve as feed or fodder for draft and work animals. This would explain the spread of carob cultivation throughout the 18th, 19th and first half of the 20th centuries, during which its orchards grew at the same rate as the herds of working livestock increased. However, since the second half of the 20th century, a regressive trend has been seen in the crop's production and area [23].

Social

The social criterion obtained positive scores in its three variables. The carob tree MTAS provides testimony to ancestral cultural techniques and practices in which the traditions and knowledge passed on from generation to generation are maintained. The carob is one of the most relevant ancestral crops since it was part of the traditional Mediterranean agricultural system.

Indeed, carob production has a long tradition in the Mediterranean area [22]. The crop was a source of energy for draft and work animals, as well as an economic resource since its production and sale created a trade mechanism based on the need to feed work animals [26].

Equally, the landscape has retained its functionality and is a living space with an active social function since it is conceived as a territory for citizens' enjoyment and leisure, fostering social cohesion. Furthermore, in this landscape, it is common to see typical architecture and traditional forms of habitat adapted to the climatic and cultural conditions of this zone. These structures reflect local history and building practices, as well as the need to adapt to an often arid and resource-limited environment.

Symbolic/Identifying

This criterion has been scored positively in one of its three variables related to the bonds of identity, symbolism and emotion that the local population feels towards the MTAS. The landscape generates a feeling of collective belonging so that the community maintains sentimental and spiritual bonds with the territory. In fact, the carob tree was a subject of

religious veneration by both Muslims and Christians in Syria and Asia Minor as a result of the plant's features and fruit. Furthermore, it was related or associated with Saint George in symbolic or religious terms, so numerous tabernacles dedicated to the saint were often built in the shade of this tree [44].

The variable pertaining to the presence of folkloric representations in the landscape unit was scored unfavorably. Indeed, there is no knowledge of popular activities being held, such as dances, songs or crafts related to MTAS. Similarly, the indicator evaluating activities being organized that are aimed at creating a sense of identity obtained a negative score. Within the study territory, there is no evidence of activities being organized with the intention of fostering a feeling of belonging to this agrifood landscape.

Artistic

The artistic criterion was scored positively in its three variables referring to the aesthetic values of the landscape, the picturesque or traditional scene generated by it and the presence of artistic expressions.

The landscape of carob trees has a characteristic beauty, where the trees' intense greenish tones combine with the typical soil of Mediterranean areas. The powerful trunks of the carob tree branch out into a wide crown, which appears as a shiny, dense, leafy and ostentatious mass, giving this tree a significantly suggestive appearance. The main branches adopt a practically horizontal bearing that reaches a length of 6 m, while the diameter of the crown can stretch to over 10 m. The wood is hard and whitish when the tree is young, whereas, in adulthood, it acquires a beautiful faded red color [44].

The MTAS also generates a picturesque scene of relevant aesthetic quality by combining vernacular agricultural practices with typical drystone constructions or with traditional trails and paths. Thus, the agrarian cultural components of this space form a coherent whole adapted to the natural environment. Figure 6 shows a carob tree landscape in the MTAS territory.



Figure 6. Carob tree landscape in the MTAS territory.

The carob landscape has inspired artists from various disciplines over time. Indeed, there is a variety of pictorial and literary representations. Let us mention some of the most

relevant examples. In terms of painting, the artwork *The Carob Tree* stands out, painted by the great Sorolla at the end of the 19th century. There is also the significant *Cantata of Grandfather Carob Tree* (*Cantata del Abuelo Algarrobo*), a vocal musical composition based on a poetic work by the Argentine writer Antonio Esteban Agüero. There are also popular novels, such as a recently published work by Diego Galera entitled *Una familia como cualquier otra o la casa del algarrobo* (*A family like any other or the carob tree house*) in 2021, and the novel *Los algarrobos también sueñan* (*Carob trees dream too*) by Virgilio Díaz Grullón in 1977.

Informative/Scientific

This criterion was scored positively in two of its variables. The first one, scored favorably, evaluates the MTAS' scientific qualities, meaning that the system generates knowledge in any discipline, as well as the presence of bibliographic references and other scientific works that expressly mention the landscape of carob trees. The study by [22] confirms the existence of numerous classic works produced by scientists in the first half of the 20th century and towards its end from countries such as Spain, Portugal, Italy and the United States. Similarly, in recent years, there has been a proliferation of research focusing on the importance of the carob tree and the numerous benefits it generates [29,45,48,49].

The second indicator, also scored favorably, evaluates the presence of cultural elements in the landscape, referring to the existence of cataloged or protected assets mainly linked to agricultural activity. The General Inventory of Valencian Cultural Heritage [50] includes a list of 43 Assets of Cultural Interest (BIC in Spanish) in the study area.

Finally, the variable considering the presence of groups concerned about safeguarding the landscape was scored unfavorably. There is no evidence of the existence of groups or organized associations engaged in preserving and enhancing the carob agrifood system in the MTAS territory.

Food production, security and quality

The carob fruit is a product with numerous applications. Humans have been using it as a food source and for medicinal purposes since ancient times. The traditional use of the pulp was to feed horses, which was the reason it was traded. Its seed, the locust bean, was used at the beginning of the 20th century in the English textile industry and in Italy as a thickener for ice cream, and as of the 1930s, it served as mucilage for the manufacture of paper. Carob fruit flour was also a substitute for wheat flour in times of scarcity [23].

The carob is considered one of the most valuable fruit and forest species today due to its multiple applications in various spheres and sectors of activity, mainly in the pharmaceutical and food industries. There are numerous studies analyzing the benefits of carob fruit on the health of human beings. In this regard, the study by Dahmani et al. (2023) [51] provides a complete, detailed description of the carob tree, including its taxonomy and the biological significance of the species. The study points out the relevance of carob fruit in the development of both traditional and contemporary drugs due to its diverse uses. These include antioxidant, antibacterial, anti-inflammatory, antimicrobial, anti-cancer, antidepressant and antihyperglycemic applications in particular.

Furthermore, the high content of dietary fiber and bioactive compounds in carob fruit, together with its beneficial effects on various diseases, means that products from it are used as food ingredients to develop a wide variety of products. It has functional, flavoring and nutritional properties [29]. It is also commonly used as a food thickener, preservative and protein foodstuff.

Pulp is obtained from the carob fruit, accounting for 90% of its weight, as well as its seed, known as the locust bean (*garrofín* in Spanish).

The pulp has pharmaceutical properties due to the tannins it contains, so balanced consumption of it has beneficial properties against gastritis and digestive, liver, lung and gum problems, in addition to reducing cholesterol and developing muscles [25]. Furthermore, Dpinitol extract is obtained from the pulp, with anti-cancer, anti-diabetic, antioxidant and anti-aging properties [52]. In addition, it is rich in proteins and essential

amino acids, vitamins and minerals and has low calorific and lipid content, with quality fats such as Omega-3, Omega-6 and Omega-9 acids [30].

Moreover, the pulp has traditionally been used as livestock feed. It is also used to manufacture fodder, either as an additive or as one of the main components. When chopped up, it is used for cattle, sheep, horses, goats and rabbits. In its crushed form, it is used to fatten calves and pigs [24].

Carob flour is obtained by crushing, roasting and grinding the pulp. It is made up of 46% sugar, 7% protein and small amounts of numerous minerals and vitamins, making it a very nutritious product used for human consumption [53]. It is also used as flavoring, aroma and as a natural sweetener. Although the fruit contains a large amount of sugar, it does not increase the levels in blood since it has active balancing ingredients. It is used as a substitute or ersatz for chocolate, which is why it is widely included in confectionery to make pastry, ice cream, cakes and drinks. In fact, the work by Spina (1989) [44] includes a recipe book for making pastries and cakes made from carob flour. Furthermore, although it has a high sugar content, it is a healthier alternative to cocoa. In this vein, carob flour does not contain caffeine or theobromine and has stabilizing properties as well as a low level of fat and sodium, in addition to fewer calories than chocolate [28,54]. In addition, the crushed form can be used to obtain sugars and syrups and for the production of alcohol [24]. It is even possible to use it as a coffee substitute by roasting the pulp and seeds.

Typical products are made from carob flour in different regions and countries [44]. In Türkiye, it is mainly consumed in the form of snacks, molasses and as a refreshing liquor called sharbat. In the Middle East, a particular sweet roll is made by mixing crushed carob pulp with wheat or corn flour. In Greece, it is used to obtain honey. By producing caramelized sugar, pastry is also made in Bari, cakes in Cyprus and carob pastries in Sicily. In Arabic countries, sorbets are made with it, along with licorice, raisins and other fruits. Furthermore, according to Brassesco et al. (2021) [29], jams and liqueurs are made from carob in various Mediterranean countries and regions, such as Malta, Portugal, Spain and Sicily.

The carob seed has specific applications and is used in the textile, chemical, pharmaceutical and agrifood industries, among others. It is a food of high nutritional value for both people and animals. In this regard, it has a high content of natural sugars and generates beneficial effects on the body, such as the production of glycogen [44]. Moreover, it is rich in mannans and galactans, compounds with antidiarrheal properties. In the food sector, it serves as a natural stabilizer and thickener and is mainly used in the production of pastries, essences and drinks [51]. Other uses can be found in the manufacture of necklaces, rosaries and other jewelry.

The locust bean is made up of three parts: the peel, endosperm and germ. The peel is mainly used in extracting tannic, gelling and coloring substances; the latter is used for fabric dyeing. In addition, it is used in producing activated charcoal.

The main use of the carob seed or locust bean is the gum obtained from the endosperm, which is especially used in the food industry as an additive, emulsifier, thickener, binder, gelling agent and high-quality stabilizer, known with the standardized code E-410 (LGB—Locust Bean Gum) [30]. This gum takes up approximately one-third of the seed's weight. Chemically, it is a polysaccharide, more specifically a galactomannan. It forms a creamy white powder that is obtained by grinding the endosperm. It also has a high-viscosity gel structure with a wide pH range [54].

In the food industry, the gum is used in various areas [23,44]: (a) ice creams: as a binder, stabilizer and thickener; (b) making sauces and condiments: as a thickener, emulsifier and stabilizer; (c) fish: as a stabilizer for agar and gelatine; (d) confectionery and pastry: in order to preserve the swelling of dough and sweets; (e) packaging: to reduce weight losses during storage; (f) cheeses: to help separate the casein; (g) tea and spices: as a binder; and (h) fresh cream: as a frothing agent. It is also used in preparing food for pet animals.

Other applications for the gum can be found in the cosmetics industry to make emulsions and shaving foams [51]. It is also used in the pharmaceutical industry for

children's gastroesophageal reflux [55], for diarrhea in infants and children, and in the production of ointments. Likewise, the locust bean is used in the textile, chemical, paper, tobacco, oil, plastic and ceramic industries.

The locust bean germ has a high nutritional and protein value. It is used in human nutrition, specifically in dietary preparations. The locust bean is also the basis for flour used as an additive in preserved foods and in the manufacture of pastry, bread and extracts for soup broths. In animal feed, it is used to prepare compound fodder [23].

In addition to the applications described above, recent studies have analyzed more types of uses and benefits of this species. Not only that, the carob tree is an alternative and renewable source of bioenergy [45]. According to Vourdoubas (2002) [56], the carob tree is a biomass rich in sugars that can be used to produce biofuels. Indeed, various studies indicate the use of carob pods to produce bioethanol [57–59] and biohydrogen [60].

The wood is hard and heavy, which is why it is also appreciated in cabinet-making, marquetry and as a fuel providing quality charcoal [24]. The leaves are used for tanning leather, while both the leaves and flowers are used in the pharmaceutical industry as antidiarrheals, astringents, gastrointestinal soothers, detergents and vulneraries [44]. The trees are also used in gardening for ornamentation and landscaping due to their significant aesthetic value [22].

Awareness among social stakeholders

This criterion has negative evaluations in two of its variables related to the legal situation of the landscape and the investment made by the public administrations aimed at the preservation and viability of this agricultural space. In the study zone, there is no institutional recognition of the carob tree landscape nor instruments or legal entities for the purpose of protecting or managing it. Similarly, the investments made by public administrations or other entities for the viability of the system are considered to be scarce and insufficient.

However, the indicator evaluating the existence of strategies and materials for information and dissemination obtained a positive score. Some initiatives are particularly noteworthy in this regard. For example, in 2022, an ethnobotanical workshop called "Carob in the cup" was set up, taught by the "Protected Landscape of Sierra Escalona" as part of the first "Somos Campo de Salinas" ("We are the Countryside of [San Miguel de] Salinas") conference organized by the "Archbishop Loazes" Chair of the University of Alicante in collaboration with the San Miguel de Salinas City Council. In this workshop, carob sponge cakes and chocolate were cooked to be eaten afterward. Similarly, the Generalitat Valenciana regional government, in collaboration with the Environment Department of the Pilar de la Horadada City Council, organized a meeting in 2020 called "The humble carob tree", for which different activities were organized to learn about the resources provided by cultivating it. In addition, in 2019, the Chera-Sot de Chera Natural Park created an educational itinerary to learn about the centuries-old carob trees of Sot de Chera, their traditional uses and how to make carob cream [61].

Participation and integration of local communities

This criterion obtained positive scores in all three of its variables. The indicator linked to participatory and territorial governance takes into account the forms of social and solidarity economy, in addition to collective network organization processes in order to generate local synergies.

In this sense, various stakeholders play a part in the Valencian carob sector:

- The carob farmers, who are the ones who usually carry out the harvesting tasks.
- Cooperatives, which enable the supply of carob production to be partially concentrated. In the province of Valencia, there are around thirty municipal cooperatives that work with carob, of which twenty-five are associated with the second-tier cooperative Fruitsecs, based in Chiva. This initiative channels about 4 million kg a year and has two other points of reference in the second-tier cooperatives in Mallorca and Tarragona.

- The intermediaries, brokers and warehouse operatives who channel part of the production in order to then send it for industrial processing. Figure 7 shows a carob warehouse.
- The choppers, who carry out the first industrial processing. There are currently four companies in Cheste, Bugarra, Turís and the Fruitsecs cooperative itself in Chiva. The main task they perform is to separate the pulp from the seed or locust bean.
- Industrialists, who carry out the grinding of the pulp and seeds to obtain locust bean gum for subsequent processing by food industries. It is common for multinationals to be involved in the industrial processing. Most of the locust bean gum is exported. Today, the locust bean industrial companies can be identified in Turís (Torres, with Valencian capital), Silla (Dupont-IFF, North American capital) and Tarragona (a Swiss company).



Figure 7. Carob warehouse.

On an international level, most companies that produce carob seed gum belong to the Institut Europeen des Industries de la Gomme de Caroube (INEC), set up in 1972. This is an independent, non-profit association. Its main aims are [62]: to carry out scientific studies related to the research, production and applications of carob seed gum; represent the interests of the locust bean gum industrial sector, its derivatives and related products in the European Union and other international organizations; and provide members with information about the research, applications and health aspects of this product.

There is also the non-profit organization Mondial Carob Group (MGC), which was founded in 2000 at the first General Assembly held in Valencia. It is made up of cutters from the main carob fruit-producing countries like Spain, Morocco, Portugal, Italy, Turkey and Cyprus, with a total of 21 members. Its main objectives are [63]: to defend the carob sector; improve global market information; periodically monitor global harvests; foster transparency in the carob sector; improve relations between associates; and promote research and development into carob and its derivatives.

The other two variables of the criterion evaluate the participation of the local community in the system's management processes, as well as in tasks involved in research, documentation and local knowledge. It has been confirmed that there are studies and projects linked to the carob tree. For example, in 2016, the Balearic Islands' Department of Agriculture granted the family business Es Garrover of Mallorca a project to study the properties of the six major varieties in that territory. Another pioneering study was conducted by a team from the Mediterranean Institute for Advanced Studies (IMEDEA) to analyze carob pollination [28].

Socio-economic profitability

This criterion scored positively in two of its variables. It values the landscape's capacity to carry out sustainable socio-economic activities and the organization of agrifood chains into networks associated with family farming, small agrifood companies and SMEs and short trade circuits.

As mentioned above, there are various stakeholders in the Valencian carob sector: carob farmers and producers; cooperatives; intermediaries, brokers and warehouse operatives; the cutters; and industrialists.

Pulp processing consists mainly of the roasting process intended for fodder. The Torres company from Turís produces about 24 million kg a year. Dehydration of the pulp is also carried out, as is the case of the Pérez company in Bugarra.

The price of the carob fruit is characterized by its continuous fluctuations, affected by the evolution of the supply of national or imported carob fruit and by demand. In 1990, the price of carob fruit was about EUR 0.70/kg; in 2012, just EUR 0.20/kg. Recently, price fluctuations have been experienced again, affected by the demand for locust beans. In 2020, the price was EUR 0.70/kg; in 2021, EUR 1/kg; and in 2022, EUR 1.5/kg. Furthermore, carob fruit that had been stored about 6 months after the harvest (August–September) reached EUR 2.5/kg.

The locust bean's market value is the decisive factor since the star product is the flour extracted from the carob seed. It is known as locust bean gum (*goma de garrofín*), and approximately 1 kg of such gum is obtained for every 3 kg of ground beans. In 2015, the price of locust beans was about EUR 2/kg; in 2016, EUR 3/kg; and in 2022, EUR 28/kg. The price of the pulp was about EUR 0.30/kg in 2022.

These prices have led to a change in the trend in carob tree cultivation. It is possible that this trend of halting its abandonment and recovering its cultivation will continue for some time, as several factors confirm this. It has been demonstrated that the recovery of abandoned lands has taken place, and the re-conversion of dryland and even irrigated croplands for new carob tree orchards.

Several processes are accompanying these initiatives: on the one hand, there has been a significant rise in complaints of thefts and robberies of carob crops (the Valencian Farmers Association valued these at around EUR 25 million in 2022), while on the other hand, stocks of seedlings in specialized nurseries are being depleted, given the rise in demand for new orchards. Nevertheless, it is very likely that the price of carob will fall again in the coming years. The increase in prices is usually compensated by alternative products being introduced: substitutes for locust bean gum like guar, pectins and tara.

Vulnerability

After its expansion during the 19th century and the first half of the 20th century, the area covered by carob trees has undergone a notable decline in the area occupied and for production in the territory of Valencia. In 1950, there were about 145,000 ha; in 2000, about 45,000 ha; in 2010, around 20,000 ha; and today, it stands at 16,000 ha [32].

This process of regression is a consequence of various socio-economic factors that occurred as of the mid-20th century, among which the following are particularly noteworthy [23]: (a) the mechanization of work in the field; (b) competition from other dryland commercial crops, such as almond and olive trees; (c) competition from new irrigation and the expansion of citrus trees, coupled with these changes; (d) the abandonment of carob cultivation for years due to its low profitability, the evolution of prices and the lack of generational replacement; (e) lack of knowledge about possible outlets for the carob fruit; (f) the proliferation of tourist and residential areas and road networks.

The lack of profitability means that in many municipalities, this crop is being occupied by natural vegetation in stages of degradation, which also destroys the agricultural structures of the territory. Thus, from a landscape point of view, the disappearance or impoverishment of this MTAS could be dramatic since it is also one of the resources of energy, food and industry for the Valencian territory [26].

As a result, two of the three variables for this criterion have been scored unfavorably, linked to a lack of interest in traditional agricultural practices, as well as the abandonment and reduction of the crop's area.

Accessibility

The landscape unit has adequate connections and accessibility to the agricultural elements and the plots via roads, paths and trails, which helps transit through them for both farmers and pedestrians and for the machinery intended for agricultural work. Likewise, the roads and motorways that provide access to the territory under study are in good condition and allow for quick access for potential visitors. However, there is no evidence of the presence of cultural or educational itineraries aimed at disseminating the landscape's values.

3.2. Population Surveys

3.2.1. First Part: Characterization of the Carob MTAS

The first part of the survey consists of nine items referring to aspects linked to the carob tree MTAS. Figure 8 shows the mean scores obtained for each of them. The highest scores are seen in the items "A. Cooperatives are an essential and characteristic element of this system", with 3.34 points, and "I. Climate change is a great threat to the survival of the system", with 3.30 points.

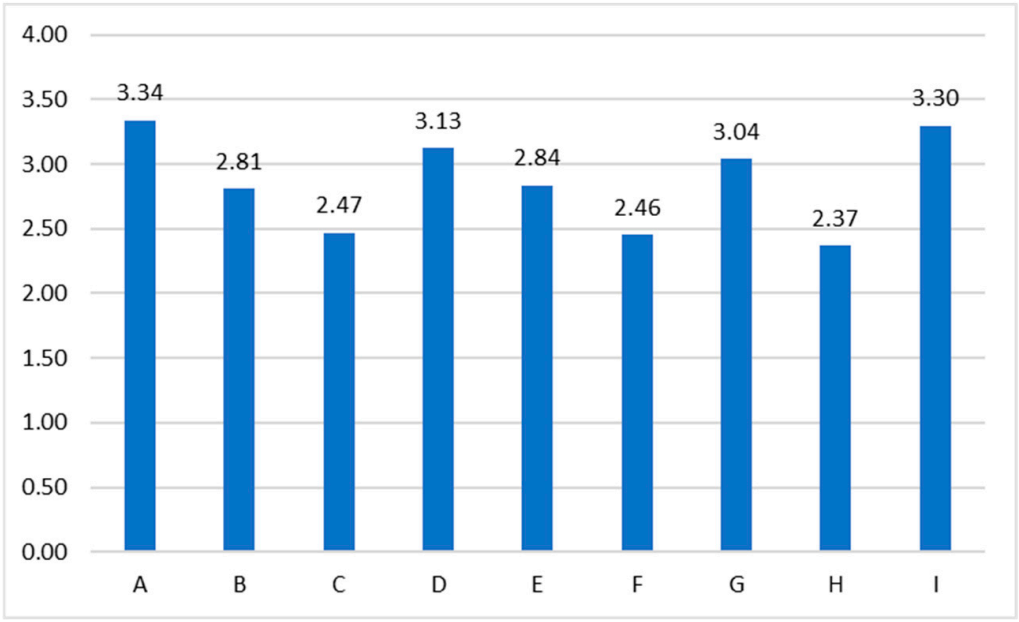


Figure 8. Mean scores obtained in the nine items of the first part of the survey.

The work of cooperatives is fundamental in the MTAS under study since they make it possible to concentrate the supply of carob fruit. As previously noted, in the province of Valencia, there are around thirty municipal cooperatives that work with this fruit, most of which are associated with a second-tier cooperative. Tous's research [42] indicates that carob fruit is mainly sold through cooperative organizations and private trade. In other words, producers sell their products jointly in the market, which helps to access better conditions and business opportunities. This essential work by cooperatives in maintaining the agrosystem is widely recognized and appreciated by the population surveyed.

The inhabitants in the study area also show a high degree of awareness about the effects of climate change on agricultural activity. Numerous studies have analyzed the impacts and risks that this phenomenon will entail in the Mediterranean area. In fact, Giorgi (2006) [64] states that this geographic area is one of the regions most vulnerable to its effects. The study by Iglesia, Quiroga and Sotés (2011) [65] states that, due to the

interactions of the agricultural sector with the natural environment, climate change will imply significant changes in agriculture. Likewise, Iglesias and Medina (2009) [66] address the consequences of the phenomenon for agricultural activity, underlining the need to prevent and adapt to its main impacts. In this vein, Olcina (2021) [67] emphasizes the need for Iberian societies to adapt to the effects of climate change since it is the most relevant challenge in the Mediterranean region in this century.

The items that obtained the lowest scores are: "H. The system helps the population remain settled in the territory", with 2.37 points; "F. There are related activities, such as tourism, linked to the system, which have great potential", with 2.46 points; and "C. Local society feels involved and linked to the system", with 2.47 points. These poor scores are the result of the notable decline experienced by the carob tree zone and its production in the Valencian territory in recent decades, mainly since the second half of the 20th century. The study by Guillén et al. (2018) [26] points to the decline in this crop in recent decades, mainly in the Valencian territory, where there has been a drop in yield per hectare, as well as uncontrolled falling of carob trees and a decrease in cultivated land. The local populace has observed this progressive decrease in the area and production of carob trees in recent decades, which is why they do not think this agrifood system helps the population to stay settled, nor is it linked to relevant economic activities. Similarly, the surveys reveal society's detachment from this MTAS, which is linked to the crisis in the agricultural sector, among other factors.

Table 5 shows the average scores in the responses to the nine items according to the age of the people surveyed. The global means do not vary significantly with the age ranges. The highest scores are observed in people between 46 and 55 years of age, with 2.97 points, while at the other extreme, there are the youngest inhabitants (18–25 years old), with a slightly lower average score of 2.74 points.

Table 5. Mean scores obtained in the nine items of the first part of the survey according to the participants' age range.

Items	18–25	26–35	36–45	46–55	56–65	66–75	>75
A. Cooperatives are an essential and characteristic element of this system.	2.96	3.18	3.28	3.42	3.58	3.47	3.60
B. The system is environmentally sustainable.	2.36	2.72	2.56	2.94	2.84	3.47	3.27
C. Local society feels involved and linked to the system.	2.28	2.24	2.26	2.76	2.70	2.42	2.53
D. Agricultural activities are the most important ones for the system.	2.80	2.88	3.09	3.23	3.30	3.37	3.40
E. Commercial activities are the most important ones for the system.	2.80	2.56	2.70	2.71	3.07	3.37	3.47
F. There are related activities, such as tourism, that are linked to the system, which have great potential.	2.64	2.80	2.78	2.77	1.95	1.68	0.93
G. Work on ecology, biodynamics and similar matters is key to the system's survival.	3.12	3.06	3.02	3.03	3.05	2.95	3.07
H. The system helps the population remain settled in the territory.	2.56	2.46	2.61	2.56	2.09	1.89	1.47
I. Climate change is a major threat to the system's survival.	3.12	3.38	3.30	3.27	3.28	3.32	3.47
Mean	2.74	2.81	2.84	2.97	2.87	2.88	2.80

Table 6 shows the mean scores for the nine items according to the participants' sex. Women obtained a higher global mean. However, on analyzing the scores for each item, certain differences can be seen. For example, in the first five items, from A to E, men gave higher scores, whereas in the remaining items, women assigned higher scores. The most pronounced differences between the scores by sex are recorded in the items: "F. There are related activities, such as tourism, linked to the system that have great potential" and "I. Climate change is a major threat to the survival of the system", where women gave noticeably higher scores.

Table 6. Mean scores obtained in the nine items of the first part of the survey according to the participants' sex.

Items	Man	Woman
A. Cooperatives are an essential and characteristic element of this system.	3.36	3.34
B. The system is environmentally sustainable.	2.88	2.76
C. Local society feels involved and linked to the system.	2.54	2.43
D. Agricultural activities are the most important ones for the system.	3.16	3.10
E. Commercial activities are the most important ones for the system.	2.95	2.76
F. There are related activities, such as tourism, that are linked to the system, which have great potential.	2.11	2.68
G. Work on ecology, biodynamics and similar matters is key to the system's survival.	2.86	3.16
H. The system helps the population remain settled in the territory.	2.16	2.50
I. Climate change is a major threat to the system's survival.	3.02	3.48
Mean	2.78	2.91

Finally, Table 7 shows the scores according to educational levels. The highest scores are found among residents with secondary education (2.91), followed by participants with primary education (2.85). Lastly, there are the respondents with higher education, with a score of 2.84. However, as can be seen, the differences are not very big.

Table 7. Mean scores obtained in the nine items of the first part of the survey according to the participants' level of formal education.

Items	Primary Education	Secondary Education	Higher Education
A. Cooperatives are an essential and characteristic element of this system.	3.49	3.39	3.28
B. The system is environmentally sustainable.	3.17	2.93	2.65
C. Local society feels involved and linked to the system.	2.46	2.73	2.32
D. Agricultural activities are the most important ones for the system.	3.37	3.13	3.07
E. Commercial activities are the most important ones for the system.	3.23	3.00	2.65
F. There are related activities, such as tourism, that are linked to the system, which have great potential.	1.74	2.39	2.66
G. Work on ecology, biodynamics and similar matters is key to the system's survival.	3.00	3.04	3.05
H. The system helps the population remain settled in the territory.	1.91	2.32	2.51
I. Climate change is a major threat to the system's survival.	3.31	3.24	3.33
Mean	2.85	2.91	2.84

3.2.2. Second Part: Method for Evaluating the Carob MTAS

The second part of the survey is made up of fifteen questions, formulated based on the criteria that make up the MTAS evaluation method. As mentioned above, the questions are closed dichotomous ones, where the possible answers are "yes", "no" and also "don't know". The questions answered with "yes" represent favorable opinions of the agrifood system.

The participatory scores for each indicator are calculated by means of the relationship between the number of favorable responses and the total number of responses without considering the "don't knows". The results have been converted into a value between 0 and 10 points, and the six levels of heritage interest considered have been used. By doing so, it is possible to make comparisons with the technical evaluation scores.

Table 8 shows the distribution of the number of responses for each of the 15 questions. Based on these data, the scores for each criterion and category assigned by the inhabitants have been calculated, as well as the global MTAS score for the carob tree.

Table 8. Distribution of the number of responses for each of the 15 questions in the second part of the survey and scores obtained by criteria.

Questions	Criteria	Answers			Scores		
		Yes	No	Don't Know	Criteria	Categories	Global
1	Representativeness	189	20	59	9.0	7.2	6.9
2	Authenticity	153	64	51	7.1		
3	Ecological integrity	94	113	61	4.5		
4	Visibility and visual quality	189	46	33	8.0		
5	Historic	182	20	66	9.0	7.9	
6	Social	161	55	52	7.5		
7	Symbolic/Identifying	181	41	46	8.2		
8	Artistic	168	47	53	7.8		
9	Informative/Scientific	102	41	125	7.1		
10	Food production, security and quality	166	47	55	7.8	5.8	
11	Awareness among social stakeholders	76	93	99	4.5		
12	Participation and integration of local communities	80	65	123	5.5		
13	Socio-economic profitability	114	87	67	5.7		
14	Vulnerability	77	113	78	4.1		
15	Accessibility	155	52	61	7.5		

The global mean participatory score is 6.9 points, which represents a medium interest in heritage. However, relevant differences can be seen in the scores for the different indicators. The category with the highest score is the one for heritage values (7.9 points), as it was in the technical evaluation, too. Next are the intrinsic values (7.2 points), and finally, there are the potential and viability values (5.8 points).

Relevant differences can be seen depending on the criteria. The highest scores are seen in the indicators of "1. Representativeness" and "5. Historic", with 9 points each. The population is aware of the role played by this woody crop in the landscape of the Valencian foothills and its centuries-old presence in this area. This fruit species was widely cultivated in the Mediterranean basin at the end of the Middle Ages [44] and is one of the most typical in this region [24]. In the Valencia territory, there are references to the carob tree by the Moors, who considered it to be one of their main crops. Furthermore, during the 19th century and the first half of the 20th century, it expanded notably in the Valencian foothills [23]. The research by López (2022) [68] confirms its notable presence in the mid-basin of the Turia River in the mid-20th century, a period where the main activity was dryland agriculture, divided up between herbaceous and tree crops of olive, almond and carob trees.

The lowest score was obtained by the criterion of "14. Vulnerability", with only 4.1 points. A relevant proportion of the people surveyed consider the MTAS to be threatened by various risks mainly linked to the abandonment of the crop. Since the second half of the 20th century, the carob tree area has suffered a notable regression in the Valencia territory due to several causes, such as the decrease in the animal census, the expansion of irrigation, the proliferation of urbanization and infrastructure and agrarian mechanization [23]. This problem is not exclusive to the Valencia territory, although, in this zone, it is particularly significant. As a result, although it is a traditional crop, its lack of profitability has led to its abandonment and disappearance [26].

Criterion "3. Ecological integrity" also has a low score, with 4.5 points. In fact, more than 40% of the people surveyed believe that the carob tree MTAS is not in a good state of environmental conservation and that its habitats and natural or plant resources are polluted and degraded. It is true that the carob tree is of high ecological value and useful for preventing erosion and regenerating the soil since it is resistant to fires (Spina, [44]). Moreover, it helps mitigate climate change since it is effective as a sink for carbon dioxide emissions [69]. Nevertheless, this low score given by the populace is probably a result of the progressive reduction in the cultivated area occurring in recent decades. The inhabitants are aware of the decline, and they notice carob trees being replaced by other more profitable crops or even by degrading phases of natural vegetation. This perception may also be influenced by a lack of awareness about the ecological benefits of the carob tree. Finally, the indicator "11. Awareness of social stakeholders" also obtained a low score of 4.5 points. Numerous people surveyed are of the opinion that the public administrations, institutions or other collectives in the territory are not aware of the MTAS and/or are not making sufficient investments aimed at conserving it and raising awareness about it.

4. Conclusions

The concept of MTAS has emerged as an alternative to the hegemonic agrifood and mass production models. MTASs are multifunctional, territorialized and sustainable systems that consider the territory's tradition of production and contribute to a sustainable food transition. These systems contribute to sustainable food security, supported by mechanisms of governance and social mobilization, and can be seen via the landscape.

Ecosystem services (ESs) are made up of the benefits or positive contributions that ecosystems, places and landscapes give to human well-being. This study is based on the hypothesis that MTASs generate various ESs for society in addition to traditional food production. The aim of this work is to identify the main values and ESs provided by the carob tree MTAS in the Valencia territory in the context of Mediterranean agricultural landscapes. It is essential to identify them in order to draw up suitable territorial preservation and management proposals.

The carob tree is a species traditionally cultivated in Mediterranean regions. In Spain, it is mainly grown on the Mediterranean coastal strip, most notably in the Valencia Community region. The geographic area in this study is made up of fifteen municipalities in the Valencian foothills that maintain a territorial continuity, specifically in the sector of the mid-Turia basin. These transition spaces have traditionally been the geographic zone for dryland crops, so the carob tree is the predominant woody crop, forming a distinctive element in terms of the landscape. However, in recent decades, there has been a progressive reduction in the cultivated area.

In order to learn the values and ESs generated by the carob tree MTAS, in this study, a multi-criteria quantitative evaluation system has been carried out to enable an evaluation of the heritage of these agrifood systems. The method's structure consists of multiple indicators, so by applying them, we have been able to learn the MTAS' main features and peculiarities in detail. The method has a hierarchical structure of indicators ranging from general to specific by means of three levels: categories, criteria and variables. It uses a binary scoring system based on whether or not each variable is met.

In the research, a questionnaire was carried out, targeting the local population in order to learn the community's perception of their agrifood system. Its questions were drawn up based on the evaluation method criteria.

The global scores obtained are high, which implies significant value attached to the agrifood system. The scores for each indicator have also made it possible to specify the agrifood system's most relevant attributes, as well as identify the numerous ESs that it provides. The overall MTAS score obtained reaches 7.6, representing a significant heritage interest. The intrinsic values stand out, with a score of 8.3. The criteria of representativeness and ecological integrity have the highest score. Next are the heritage values, with 7.3 points. The indicators with the best scores are the social and artistic ones, resulting from the

importance of the crop for centuries. Finally, there are the potential and viability values, with 7.2 points. The progressive reduction in the cultivated area, together with the waning involvement of territorial stakeholders, leads to low scores in the values of vulnerability and awareness among the community. The high overall scores denote the relevant heritage and landscape interest in the carob agrosystem, which may contribute to its institutional and social recognition in favor of ESs in the MTAS.

In addition to its historical usage as food, carob has found new applications in various industries, such as pharmacology and the modern food industry. Recent research underlines the carob fruit's antioxidant, antibacterial, anti-inflammatory and anti-cancer properties, which have led to its use in developing drugs and functional food products.

By carrying out the questionnaire, we were able to learn the inhabitants' perception of this agrifood system. There were 268 people from fifteen municipalities consulted. The scores obtained are relevant, showing the existing social consideration towards this MTAS. The population is aware of the relevance of local cooperatives in the way the system works, as well as the effects of climate change on agricultural activity. Moreover, they value the centuries-old prominence of this woody crop in the landscape. However, some detachment can be seen by society from this MTAS, most certainly a consequence of the shrinkage of the cultivated area occurring in recent decades and the decline it has undergone. Hence, greater involvement from social stakeholders is essential to preserve this system and foster its uses.

To sum up, the carob MTAS offers a wide range of ESs that are fundamental for human well-being and environmental balance. This crop has numerous properties and offers an outstanding variety of uses in multiple sectors, where it has noteworthy value as a multifunctional natural resource.

Besides the results obtained, it is necessary to refer to the limitations and problems that arose. In this vein, the sample size of the survey carried out is noteworthy. The compilation of 268 surveys enabled valuable information to be obtained. However, this may not be completely representative of the diversity of opinions in the Valencia territory. Furthermore, there is the possibility of bias in selecting the respondents, which could influence the results obtained. Hence, it is advisable not to generalize the survey results to the population as a whole.

Finally, several future lines of research have been identified. For example, the authors recommend carrying out a more detailed analysis of the factors that influence the local perception of carob cultivation by means of the consideration of demographic and socio-economic variables. Alternative approaches to collecting the data could also be made, such as in-depth interviews or focus groups, so as to obtain a more complete and contextualized understanding of local attitudes and perceptions. Finally, it would be useful to expand the geographical sample, which could provide a more representative perspective, and to apply this evaluation system to other crops in different regions.

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Institutional Review Board Statement: Ethical review and approval were waived for this study due to the survey being conducted anonymously. This methodology ensured the protection of participants' privacy, eliminating the need for formal ethical approval. Additionally, participants were informed

about the anonymous nature of the survey, thus ensuring their informed and voluntary consent to participate in the study.

Informed Consent Statement: Participants were informed about the anonymous and voluntary nature of the survey before participation. Verbal consent was obtained from all subjects involved in the study.

Data Availability Statement: The original contributions presented in the study are included in the article, further inquiries can be directed to the corresponding authors.

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