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A Participatory Agrobiodiversity Conservation Approach in the Oases: Community Actions for the Promotion of Sustainable Development in Fragile Areas

Cristiana Peano [1,2], Stefania Caron [1], Mohamed Mahfoudhi [3], Khouloud Zammel [3], Houda Zaidi [3] and Francesco Sottile [4,*]

1 Dipartimento di Scienze Agrarie, Forestali, Alimentari, Università di Torino, Largo Paolo Braccini, 1, 10195 Grugliasco, TO, Italy; cristiana.peano@unito.it (C.P.); stefania.caron@unito.it (S.C.)
2 UNESCO Chair in Sustainable Development and Territory Management, University of Turin, 10124 Turin, Italy
3 Association Persone Come Noi Tunisie, Route de Gafsa, El Hamma du Jérid, Tozeur 2214, Tunisia; mahfoudhimohamed10@gmail.com (M.M.); pcn.tunisie@gmail.com (K.Z.); houda.mohamed.zd@gmail.com (H.Z.)
4 Dipartimento di Architettura, Università degli Studi di Palermo, Centro di Conservazione della Biodiversità di Interesse Agrario, Viale delle Scienze, Edificio 14, 90128 Palermo, Italy
* Correspondence: francesco.sottile@unipa.it; Tel.: +39-091-2386-1200

Abstract: Rural development policies today include significant directions towards ecological transition and sustainability. Biodiversity plays a fundamental role, especially in fragile environments. The North African oases, for example, are socio-ecological structures with delicate balances in terms of natural resources, where the activation of participatory conservation approaches appears today to be very useful, aiming at long-lasting results. This type of approach was applied in the oasis of El Hamma, in Tunisia. The socio-ecological analysis was carried out through semi-structured interviews with different stakeholders of the oasis. The results were used to activate focus groups and to identify, in a participatory way, a conservation strategy for the species and the varieties at risk of erosion or disappearing. From this research, a wide spread of non-traditional date palm and vegetables emerged in a very diverse social context. These products were recognized as highly significant in terms of traditional knowledge by all stakeholders. Therefore, a Maison des semences and a public conservation center for perennial species were created, representing the first step of a participatory conservation model. Seeds of 11 traditional annual species, 10 date palm varieties and, in perspective, many other fruit species and vegetable varieties have been introduced into conservation.

Keywords: agrobiodiversity; oasis; ecosystems; sustainable development; socio-ecological systems

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1. Introduction

Biodiversity is the variety of living beings that inhabit the Earth, and is measured at the level of genes, species, populations and ecosystems [1]. Since the Convention on Biological Diversity (Rio de Janeiro, 1992), this issue has become increasingly of global interest, highlighting, step by step, the strong connections between biodiversity and ecosystems. Agricultural biodiversity, or agrobiodiversity, has been defined by FAO as a subset of biodiversity [2], and with the Treaty on Plant Genetic Resources for Agriculture and Food of 2001 [3], it explicitly became the part of biodiversity directly involved in agriculture and food production that depends on human actions, both positive and negative. In this path, over the years, agrobiodiversity has also included all the studies concerning rural landscapes that represent elements in which human action is decisive through agricultural practices strongly related to agricultural sustainability [4].

The latest FAO reports show that 75% of agrobiodiversity is at risk of disappearance [5], and the cause of this phenomenon is substantially attributable to the processes of globalized agricultural models that have influenced consumer behavior through a strong reduction in the variety of food for the inhabitants of the planet [6]. The strong risk of genetic erosion and disappearance concerns precisely the agrobiodiversity that is the result of more than 10,000 years of adaptation performed by farmers and breeders in the selection and in the development of appropriate systems and production methods [7]. Brush [8] perceives crop genetic resources as the result of collective action by people sharing knowledge, often living in communities in close contact with plant and animal resources, exchanging seeds and accumulating valuable traits in different crop populations. This agrobiodiversity has accompanied the lives of rural communities, especially when distant from urbanized areas, contributing significantly to the development of models that stem from the strong link between farmers and rural areas [9]. From this close relationship between communities of producers, the model of agroecology was developed. It is ultimately based on a systemic approach in which the plants, the animals and the interaction with the community of producers play an extraordinary role in the preservation of the ecosystem and food production.

Agrobiodiversity, therefore, has been attributed over time not only a role related to indigenous species and breeds aimed at food production, but also to everything that finds application in the production of fodder, fibers, fuels and pharmaceuticals, on which the food security and livelihood of many people in the world appear to be dependent [10–13].

Despite international commitments, evidence gathered in 2010 (UN International Year for Biodiversity) indicated that on a global scale, genetic erosion is proceeding at ever more increasing rates [5]. This observation stimulated a series of new goals for 2020, called the Aichi Targets [14], and safeguarding agrobiodiversity is also an important part of the 2030 Agenda Goals [15]. In particular, SDGs 14 and 15 are strongly anchored to the conservation of marine and terrestrial heritage and are closely related to SDG 12, which promotes sustainable production and consumption that, indisputably, now passes through the use of agricultural biodiversity in non-industrial agricultural models [16]. In this regard, it seems increasingly important to emphasize the link of biodiversity with ecosystem functions and services, especially soil, water and beneficial insects [17]. From this emerges a strong connection of agrobiodiversity with a complex and systemic model able to connect every element that contributes to building ecosystem relationships.

Since the Treaty on Plant Genetic Resources for Agriculture and Food, the activity of conservation of genetic resources has been delegated to specific action plans that each state must develop internally. The important part of these plans is the definition of the approach to the conservation of agrobiodiversity of agricultural interest in situ and ex situ [16]. Ex situ conservation has been indiscriminately developed both on natural biodiversity and on agrobiodiversity through the creation of gene banks able to preserve plant material for many years. In situ conservation, on the other hand, is carried out in the areas of origin of biodiversity; when referring to agricultural biodiversity, in many cases, it directly involves farmers who become custodians of genetic resources through specific programs of cultivation and exchange of genetic material.

Each conservation model has strengths and weaknesses that have been extensively studied [18]. Ex situ conservation provides a useful approach to scientific research allowing access to genes and resources useful for research operated by geneticists [19]. Since the 1960s, enormous efforts have been made to collect genetic material, and since the early 1980s, a network of international centers linked to the CGIAR (Consultative Group on International Agricultural Research) for the collection, conservation, evaluation and documentation of crop genetic resources has been implemented [20]. Hundreds of gene banks for storing genetic material have thus emerged, but they require very high management costs that have often represented a critical point [20].

In situ conservation, on the contrary, guarantees the continuous evolution of natural genetic variability closely related to the growing environment [20]. In addition, the involvement of farmers ensures that this conservation process also develops in close connection with traditional cultivation models [21], often related to agroecology that is very well-established in small-scale farming systems, often family-based, which today appear very useful in the conservation of agrobiodiversity [22].

It should also be mentioned that for seed-propagated species, several authors now propose the need to access complementary conservation models, i.e., models that bring together ex situ conservation in conservation centers and in situ conservation with the help of custodian farmers [23].

Such a complex field also requires a series of evaluations that consider different contexts; in specific rural areas, indeed, the involvement of local communities seems definitely useful to achieve a pragmatic goal [24,25] and territorial planning starts from a participatory action based on the existing relationships within a specific territory.

Sustainable development and biodiversity conservation thus require a new vision in cooperation and research projects, moving from monodisciplinary approaches on a local scale to adaptive, participatory and transdisciplinary strategies on a landscape scale, with significant socio-ecological implications [26]. This new viewpoint is based on the need for cooperation between science and society [27], and actively involves policy makers and stakeholders in participatory knowledge approaches and problem solving [28].

In the complex system of conservation of agrobiodiversity in the Mediterranean, a significant role is attributed to the strong relationship that is built between food security and economic and territorial development. In Tunisia, where we have been working for this project, there are many local species and varieties at risk of extinction, and for this reason, in order to protect national biodiversity, the government adopted the National Biodiversity Strategy–Action Plan 2018–2030 [29], a program of conservation and promotion of sustainable agricultural practices that can promote the conservation of local biodiversity, involving local communities for the enhancement of traditional knowledge and know-how, finally providing for agricultural production systems based on agroecological models [30]. Among the most complex environmental systems from the socio-ecological point of view, the oasis represents a fragile system: it is literally "inhabited place", a cultivated space in a desert area close to and dependent from a water resource. Generally, North African oases are identified as collective management systems, characterized by polyculture and animal husbandry in which palm trees predominate, flanked by as many annual and multi-year crops [31,32]. Today, irrigated areas in southern Tunisia show a great diversity of forms and functions, but traditional oases maintain their role as socio-ecological systems [33,34]. These are systems in which the social and ecological dynamics involve multiple interactions between human and natural components in continuous evolution. Traditional oases, as mentioned by Santoro et al. [35], can be considered as agroforestry systems, as reported by the FAO on the basis of ICRAF (International Centre for Research in Agroforestry), and represent an important reservoir of genetic and cultural biodiversity that must be safeguarded for future generations. In fact, it is important to underline how the local genetic heritage, with its diversity and adaptability developed over time, can represent a sort of mitigation against climate change in areas with high fragility and complexity, as an alternative to new irrigation perimeters (monoculture of date palms) based on rational agronomic planning that create high competition for the use of the limiting resource, i.e., water [36].

In southern Tunisia, major transformations of resource management practices are underway, resulting in the reconfiguration of socio-spatial logics and in the functioning of these agricultural territories. These transformations are expressed in contradictory dynamics [37]. On one hand, there is a process of de-territorialism, linked to the development of industrial models based on intensive agriculture oriented to export and mass tourism; on the other hand, there is a process of partitioning resulting from innovative practices, based on the oasis resource heritage assessment model. The latter contributes to restore a diversified family farming system, the preservation of agrobiodiversity and sustainability not only in environmental and agricultural terms, but also from a social point of view [37].

The tradition evidences that oases are occupied by date palms, associated with Mediterranean fruit trees, vegetables and fodder production for livestock. Over centuries of cultivation, many varieties have become indigenous and have allowed the enrichment of the enormous genetic and agronomic heritage that defines this system, characterized by a unique terroir. It should be emphasized that this process is consolidated within the oasis ecosystem, which has pedo-climatic conditions that ensure the survival of only a few plant varieties and animal breeds that, as they are resilient, gain a unique position within the agro-ecosystem [32].

For a territorial planning approach consistent with the preservation of these territories, as fragile as they are in balance, and of their agrobiodiversity, it is therefore necessary for participatory action based on the relationships and intrinsic needs of the communities that inhabit it. Only by considering the territory as a social production that its inhabitants can transform and make more or less attractive and competitive [30,38] is it possible to outline actions that allow agricultural development in accordance with the maintenance of biological and cultural diversity according to a sustainable development perspective.

To address the issue of biodiversity preservation in these complex socio-ecological systems, we need, therefore, to adopt a new vision through cooperation and action-research projects, moving from monodisciplinary approaches towards adaptive, participatory and transdisciplinary strategies [39,40]. This new vision allows to consider different and divergent points of view through explicit involvement of stakeholders' knowledge and effective cooperation between science and society [41], actively involving it in participatory knowledge building and problem solving. In this specific context, the main objective of this paper is, therefore, to introduce evidence of the application of this multidimensional and transdisciplinary approach to the preservation and enhancement of biodiversity in the El Hamma Oasis (Tozeur) in southeastern Tunisia.

2. The Case Study: The Oasis of El Hamma

In Tunisia, continental oases comprise 83% of all oases and contain more than 89% of the country's total date palm population, thus contributing to 85% of the national date production. These oases are usually divided into Saharan oases and Mountain oases. Saharan oases are located in north Tunisia, in the Tozeur region (Djerid) and south of Chott Djérid in the region of Kébili, and occupy 76% of the total in the country.

It is also necessary to separate the oases into modern (irrigated areas with monoculture of date palm orchards) and traditional ones. In 2009, the latter accounted for 37%, containing 46% of palms, most of which are common varieties with a relatively low planting density of 166 trees/ha. These oases are characterized by multiple traditional varieties, a high degree of fragmentation and a small size of farms that mostly result from heritage sharing [42].

El Hamma du Jerid (Figure 1) is one of the five delegations of Tozeur governorate with a population of 7028 inhabitants, 80% of which are engaged in agriculture [43]. In 2003, the oasis covered a total area of 423 ha, while today, according to data from the CTV of El Hamma, the total area of this traditional oasis is 391 ha, which is about 2.05% of the total area of all Tunisian traditional oases. El Hamma is divided between 3 Groupements de Développement Agricole (GDA): M'Hareb, El Erg and Nemlet (Figure 2). These GDAs, as their main activity, manage the water from the state boreholes for the irrigation of all plots.

The GDA Nemlet located in the southern and central-northern part of the oasis has 324 adherent farmers and its area covers 178 ha. The GDA El Erg covers the western part of the oasis, with 278 members and 123 ha. The GDA M'Hareb is the smallest both in terms of the number of adherents (188) and its area (90 ha).

Originally, life in the oasis of El Hamma was guaranteed by the presence of springs that created short streams directed towards the Chott El Gharsa. Over the years, the creation of wells and the overexploitation of deep-water resources led to a lowering of their piezometric level and, consequently, to a decrease in the flow rate of traditional water sources [44]. In El Hamma, there are 9 state wells exploited for irrigation by the 3 GDAs and a series of water distribution pipelines that divide the oasis into 13 irrigation sectors. The amount of water available to farmers varies in the 3 GDAs, and the fictional flow rate is between 0.77 and 0.95 L s^{-1} ha^{-1}, enough to cover the minimum standard of 0.75 L s^{-1} ha^{-1} calculated by CRDA for palm cultivation with associated crops. On the other hand, the major problem for tree crops, and especially for annual crops, is the length of the irrigation shift (11–15 days).

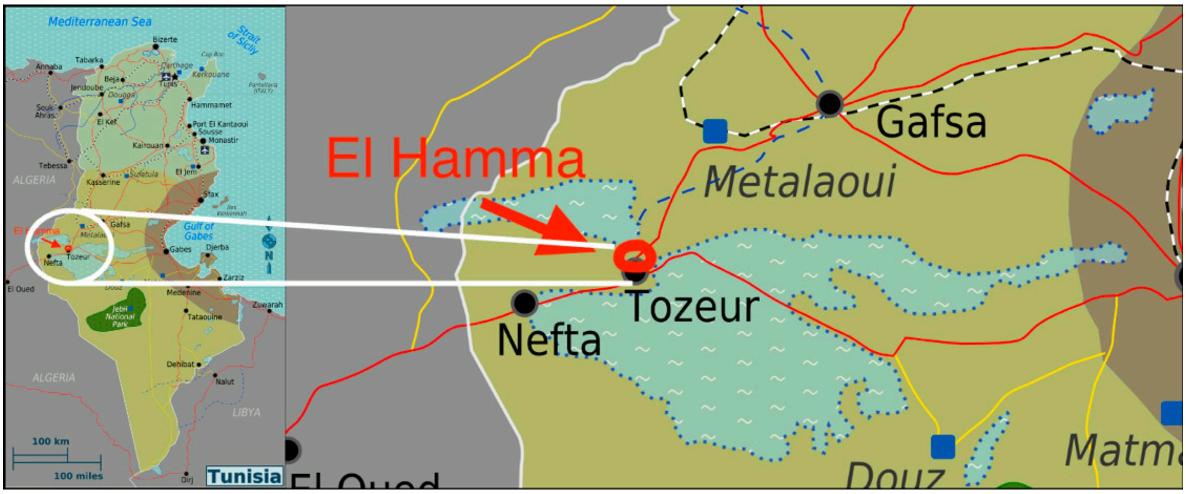

Figure 1. The oasis of El Hamma is located in the southwest of Tunisia in the governorate of Tozeur. According to the FAO agroecological classification, the oasis belongs to the warm/cold subtropical zone. Tozeur has a hot desert climate (Köppen climate classification BWh) typical of the northern edge of the Sahara Desert, with an average annual rainfall of 81.8 mm. Summers are extremely hot (temperature > 45 °C), while in winter, it can sometimes freeze at night when temperatures drop below 0 °C.

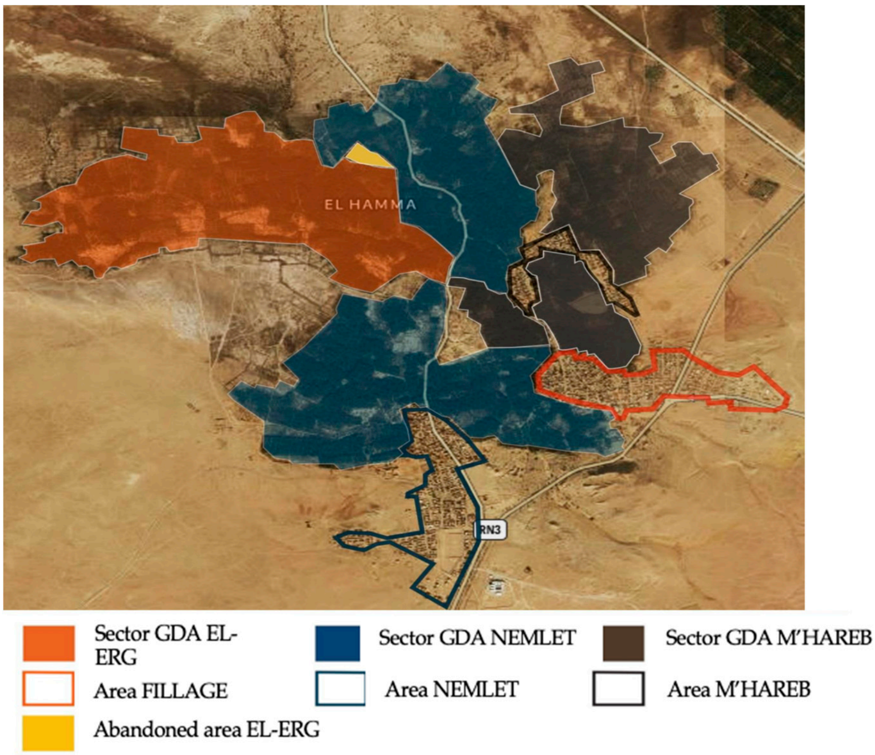

Figure 2. Sectors covered by the 3 Groupements de Développement Agricole (GDA) and districts of El Hamma.

3. Methods

The methodology of analysis was conducted through a specific process (Figure 3) starting from the submission of semi-structured interviews (Table S1). The sample of farmers interviewed (30%) was representative of the owners of the plots in each GDA. In addition, a number of privileged stakeholders were interviewed, (i) the director of the office of "Agricultural Engineering, Water Resources, Irrigation Perimeters, Soil, Statistics and Plant Production" of the CTV (CRDA) in El Hamma, (ii) the chairpersons of the 3 GDAs and (iii) the water managers of the 3 GDAs. Available literature sources were also analyzed [45–48].

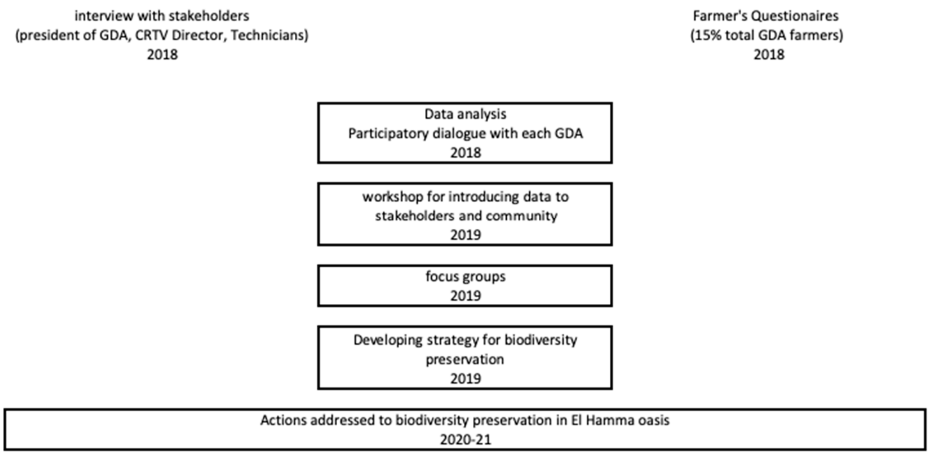

Figure 3. Flowchart of the process for acquisition and processing of information and development of a strategy for the preservation of biodiversity in the oasis of El Hamma.

The choice to use semi-structured interviews was guided by the possibility of deepening, in addition to factual (quantitative) information, contextual (qualitative) data not foreseen by the structure of the interviews [49]. The questionnaire included data related to the farm, to the technical management, to the technical choice and to the use of the natural resources. In addition, data on the opportunity to be involved in an evolution in terms of agroecology choices were also recorded (Table 1). The choice of farmers to be interviewed was entrusted to the GDAs, asking them to provide as heterogeneous and representative sample of owners as possible, whose plots were distributed as evenly as possible over the GDA's area of responsibility. The sample was chosen according to the following criteria of representativeness (stratified sampling):

(a) Geographic distribution of the parcel,
(b) Area of the parcel,
(c) Age of the farmer,
(d) Maintenance status of the parcel.

The questionnaires were submitted to the farmers by two agronomists in Arabic language with the aim of eliminating any interference due to language misunderstandings.

The data derived from the semi-structured interviews after inferential statistical processing were validated with 3 meetings with all members of the 3 GDAs. The three different discussion groups were informed about the data collected during the research by the project team, according to the following scheme:

(a) Presentation of the statistical data related to the GDA to the farmers present.
(b) Discussion among the GDA members regarding the data.
(c) Observation of the discussion (issues addressed, interactions, perceptions, reactions) and its outcomes by the project team.

The participatory process of data validation was followed, finally, by a phase of participatory discussion with civil society, local governments and stakeholders to whom it was possible to present, in addition to the technical framework obtained on the oasis, the actions possible, soliciting their contribution of proposals in terms of opinions, suggestions and initiatives through focus groups.

Table 1. Main topics included in the semi-structured interviews submitted to growers from the 3 GDAs in the oasis of El Hamma.

Analysis of the Actual Data	Availability for an Evolution
Farmer data	
Parcel size and location	Increase plots under management
Technical and labor management	
Parcel description	
Number and type of date palm trees	Increase date trees
Number and type of perennial fruit trees	Increase fruit trees
Number and type of annual vegetables	Increase in vegetables
Presence and types of breeds	Introduction of breeds
Parcel management techniques	
Irrigation resource	Introduction of localized irrigation
Drainage	Creation of micro-basins
Mechanization	Increase organic fertilizers
Soil working	Reduction in the use of synthetic chemical products
Fertilization	
Weed control	
Phytosanitary defense	
Wild boar damage	
Economic issues	
Parcel management costs	Creation of a cooperative for collective purchasing
Supply channels for cultivation inputs	Creation of a cooperative for machinery management
Products sale channels	Creation of a cooperative for collective marketing

4. Results and Discussion

4.1. Data Analysis

More than half of the farmers interviewed in the three GDAs are over 50 years old, and this phenomenon is probably related to the symbolic and identity importance of heredity in the transfer of ownership. The land market is particularly rigid in the GDA of M'Hareb, where all the plots of the interviewed owners were obtained by heredity, while in El Erg and Nemlet, a portion of the plots visited were purchased by the current owners. The static nature of the land market in M'Hareb can be interpreted if one considers that this social fraction of the oasis has always been more or less isolated from the rest of the population of El Hamma. The strong fragmentation of the property is due to a division of the land following the death of the parent owner and a resistance of the heirs who are often co-owners of the plot and refuse to sell the inherited parts. This phenomenon is quite common to the rest of the traditional oases of the Djérid [50] and represents a complex social and relational approach. A considerable fraction of the parcels visited presented an area of less than 1 ha, especially in the GDA of Nemlet, but also in that of El Erg. However, it is common for farmers to own or exploit several plots, usually 2 or 3, not necessarily in the same GDA: this is the case for more than half of the owners interviewed. Despite this, land fragmentation in the oasis remains a widespread phenomenon, although on average less significant than in the rest of the country's oases [51]. In fact, small ownership is still preserved in traditional oases and the affective and symbolic attachment to the land results in a blockage of the land market [52], creating a significant limitation to the revitalization of agricultural production [35,53].

The most common management of the land in the three GDAs consists of direct labor by the owner. Only in M'Hareb did a portion of farmers resort to sharecropping, a practice less frequent than in the past in all Tunisian oases [43,54]. As a result of this situation of change in the way the property is managed, the use of more or less specialized labor is very common: more than two thirds of the owners use laborers to perform specific seasonal operations such as pollination and harvesting, which represent the most complex and expensive phases of cultivation. For about half of the sample of owners interviewed in M'Hareb and Nemlet, agriculture represents the main source of income, a situation shared only by a small fraction of landowners in El Erg, who, as the last to have dedicated themselves to cultivation in El Hamma, live on average further away from their plots than members of the other two GDAs.

4.1.1. Agrobiodiversity Assessment

The results provide a first assessment of the biodiversity still present in the oasis of El Hamma. The area is the smallest and most recent of the traditional oases of the Djérid: there is an important agrobiodiversity allowing a high qualitative level but, on the other hand, the most significant quantity of dates produced in the oasis is related to the allochthonous cultivars (Deglet nūr, Alīg and Kentišī) planted since the 1960s [55] and occupying more than two thirds of the entire cultivated area of the oasis. Thus, the commercial value of dates seems to assume more importance on farmers' varietal choice than 'productivity' and 'quality' factors: the Deglet nūr variety, even though it has a generally lower productivity than the other common varieties, remains the most cultivated one because of the economic value of production, as commonly found in many oases of southern Tunisia [56].

In 2003, Rhouma et al. [47] reported 55 date palm varieties in the oasis, as shown in Table 2.

Table 2. Date palm cultivars present in the El Hamma oasis in 2003: 40 ecotypes are present throughout the region, while 15 (indicated with * in the table) are specific to the oasis of El Hamma. (Modified from Rhouma et al. 2003 [47]).

N°	Cultivar	N°	Cultivar	N°	Cultivar	N°	Cultivar	N°	Cultivar	N°	Cultivar
1	Khalt gbir *	11	Lagou	21	Fehal *	31	Arichti	41	Khalt dhahbi	51	Tazerzit safra
2	Deglet senegua	12	Remtha	22	Bidh hamam	32	Gabouri *	42	Sabounia *	52	tazerzit soda
3	K'sseba	13	Gasbi	23	M'ghaiba *	33	Yatima	43	Om laghlez	53	Kenta
4	Aligue	14	Hamra	24	Yemyouli	34	Bent telba *	44	Om kassab *	54	Bouaffar
5	Khouat aligue	15	Cheddakh	25	Karroubi	35	Khonfes *	45	Chekenet essed *	55	Malti
6	Kentichi	16	Halwaya	26	Boufegous	36	Mokh begri	46	Angou		
7	Gondi	17	Bejou	27	Meftah *	37	Ras hanech*	47	Khalt jallouli *		
8	Ghars mettigue	18	Deglet nūr	28	Sbaa arous	38	Besser ragga *	48	Ennafakha		
9	Ammari	19	Guerguiti	29	M'ouachem	39	Deglet zaouch *	49	Boumerzoug		
10	Besser helou	20	Kadhraya	30	Sebaa bedhraa	40	Khalt sokkar *	50	Om lan		

Compared to 2003, the proportions have moderately changed (Figure 4), and the presence of other rare and common varieties remains important in this oasis, which justifies our perspective to maintain and enhance this biodiversity.

The survey carried out in 2019 shows the following breakdown:

- Main varieties: *Deglet nūr, Aligue, Khouat aligue, Kentichi, Besser Hilou*.
- Common (and rare) varieties: *Ammeri, Legou, Goundi, Ghars mettiga, Tozeurzeid, Boufegous, Hamra, Horra, Tronja, Gasbi, Bidh hmém, Choddekh, Kenta, Sbaa arous, Fhel, Aoum léghlez, Khadhraya, Rimtha, Tekirmiste, Khalt gbiir, Mnekher*.

It thus emerges that the most widespread variety of date palm in the El Hamma oasis, as in the rest of the country [50], is Deglet nūr, although in the El Erg GDA about a third of the cultivated palms are Kentišī variety. On average, the latter turns out to be the second most common variety in the oasis and is valued as it is very productive. Moreover, it is the only variety of date with dry consistency, unlike the remaining varieties which produce soft or semi-soft fruits. This factor determines, together with the high content in sucrose, an excellent suitability for conservation. The Alīg variety produces semi-soft dates, slightly larger and sweeter than the Deglet nūr [46] and, together with Kentišī dates, is the most commercialized variety in local markets. The Khwat'alīg date variety is the richest in mineral salts, which give it a different flavor than the other varieties [46], and is on average less common than the varieties described above. The same is also found for the Bişr ḥalū cultivar, which is the least suitable for long storage because it is rich in amino acids but poor in total sugars and because it is normally consumed in its initial stage of ripening [46]. The other common cultivated varieties, marginally spread in the three GDAs, are often placed in unfavorable points of the plot because of their limited commercial value, and they are generally used in a symbolic or self-consuming family function. Rare and common varieties, although having an interesting productive potential (tolerance to unfavorable climatic and edaphic conditions, lower production costs, high production potential, etc.), are no longer cultivated as in the past.

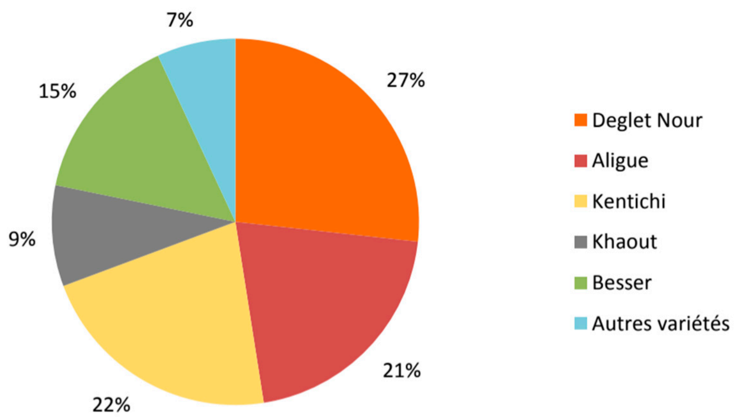

Figure 4. The main date palm cultivars in El Hamma oasis and their participation (%) in the whole production.

In general, in the oasis of El Hamma, there are reduced production levels, probably due to excessive density (about 250 plants/ha) typical of traditional oases in Tunisia [49]. The GDA of Nemlet is the only one which differs from the others for three specific characteristics: (i) the origin of the plots (about half of them are purchased), (ii) the reduced average density of cultivation and (iii) the relatively more uniform varietal distribution of palms.

If we compare the average productivity of the three GDAs (M'Hareb 7.7 t/ha, El Erg 11.7 t/ha, Nemelet 10.5 t/ha) with that calculated by the FAO in 2017 for the country as a whole (4 t/ha), it is clear that, although these values are lower than those found in modern oases [57], the oasis of El Hamma does not manifest conditions of low productivity that, on the contrary, are reported in many other traditional oases of Tunisia.

As regards fruit tree species, in the 3 GDAs, olives (*Olea europaea* L.), figs (*Ficus carica* L.) and pomegranates (*Punica granatum* L.) are reported, but they remain as limited in number as they were in 2003. In general, even if these three crops are present in the great majority of the plots, the density of the crops is quite low and never exceeds 10–15 plants/ha. Fruit trees are generally poorly managed, especially in the operations concerning pruning, phytosanitary protection, fertilization and their positioning within the plot: trees generally fail to increase their size, often due to the excessive shading caused by the upper crop layer occupied by palms. The resulting low production relegates these productions mainly to self-consumption, as in many other traditional oases in the Tunisian hinterland [55].

The low density of fruit trees in each GDA, especially fig and pomegranate, does not allow farmers to obtain good productivity, which is very low and secondary in importance to that of date palms.

Together with palm date groves, the most relevant part of the land is usually explored by annual plants, both fruit and leafy vegetables. Semi-structured interviews found that 39% of farmers maintain horticultural crops, generally on a small part of the plot, and in all 3 GDAs, horticulture accounts for between 2% and 4% of the total area. The most cultivated crops are okra (*Abelmoschus esculentus* L. Moench) for 37%, local chili (*Capsicum* spp. L.) for 19% and molokhia (*Corchorus olitorius* L.) for 17%. Other crops (chard, onion, parsley, etc.) occupy very limited areas. About 20% of the farmers sell fresh molokhia in bunches or dried and chopped on the local market. Already in 2003, a strong contraction was reported for these species due, mainly, to the strong competition on the market from allochthonous productions.

Despite the low importance of horticultural production [52] today, the climatic and edaphic conditions of the El Hamma oasis are favorable to the cultivation of a wide range of horticultural crops and, according to farmers, until the 1980s, the oasis was an important production area. According to the majority of farmers interviewed, especially from the El Erg GDA (where only 15% of farmers grow vegetables), the main problems that discourage the presence of these species are related to the presence of wild boar and the reduced frequency of water turns during the summer, to which are added the stagnation of water, the presence of weeds and the strong shading in some plots. Nevertheless, the situation of the horticultural sector within the El Hamma oasis is more developed than in the rest of the Tozeur Governorate, where this productive sector does not exceed 11% of the total vegetable production [52].

4.1.2. Focus Groups Approach and Strategy Assessment

The important presence of rare and common varieties of date and the presence of fruit plants and annual crops (vegetables and fodder) were an important element in the discussion with administrators, civil society and farmers in the focus groups. The interest of the El Hamma community for the enhancement of this immense heritage was evident. From many sides, voices were raised not only related to its maintenance but to the need for its enhancement in order to create an added value and distribute it fairly among the various actors of the system. In fact, within the oasis of El Hamma, biodiversity not addressed in marketing is not adequately valued by farmers. This phenomenon is directly related to the policies of integration of rural communities with markets, undertaken by the Tunisian administration since the 1980s [58]. The issue of the connection between agrobiodiversity and markets also concerns the two crop levels below date palms.

Traditionally, the fruits and vegetables produced within the El Hamma oasis have had two functions: self-consumption and social. What is produced extra is usually donated to friends or neighbors; this approach to cultivation, apparently undervalued according to questionnaire data, actually has a relevant social function that cannot be directly quantified in economic terms. In order to enhance the value of fruit trees and annual crops, during the focus groups, the need to find and propagate local varieties was highlighted, especially for vegetables, in order to enhance their adaptability to the difficult soil and climate conditions of the area. Several examples of participatory approaches in conservation, reproduction and varietal selection by local farmers can be found in the literature [59], and this appeared to be an important starting point for the enhancement of agrobiodiversity in the El Hamma oasis.

4.1.3. New Actions for Agrobiodiversity Conservation

The need to implement a participatory conservation model emerged during the focus groups and suggested in the oasis of El Hamma the development of a Maison des semences (house of seeds) for the preservation of the agrobiodiversity, as well as of a demonstration field for perennial species with a dissemination and at the same time conservation function.

In the case of annual species, the presence of the term "House" undoubtedly refers to the idea of a physical place, a structure that can play the role of collection and distribution of seeds in strong connection with the farmers; at the same time, it would be a structure capable of collecting and storing seeds reproduced by particularly virtuous farmers and intended for other farmers interested in joining. Finally, the Maison des semences is seen as a physical meeting point for people aiming at a serious exchange of knowledge, either through the simple sharing of ideas and opinions, or through information days and seminars.

Beyond this identification as a physical place, the "Maison des semences of El Hamma" is today, in short, a way of collective organization for the management of cultivated biodiversity, born from the need to proclaim the fundamental rights of farmers over seeds and to build, together, an alternative to industrial varieties not suitable for small-scale agriculture, incompatible with a systemic model expressed by agroecology and, finally, often the cause of loss of agrobiodiversity.

Among the 420 producers involved in the project, more or less half of them are producing vegetables or fodder on their plot, in the winter or summer season. Given the difficulty in finding local seeds that are well-adapted to the complex pedoclimatic conditions of the oasis, the farmers, in relation to the project agronomists, have activated a pathway for its implementation since 2019.

The collection of the seed was carried out through exchanges between farmers within the project, the involvement of local elderly farmers and taking advantage of the actions of census of the varieties present on the territory and their characterization developed by the agronomists. Therefore, a dynamic seed management was activated with 20 more available custodian farmers (10 from Nemlet, 5 from El Erg, 5 from M'Haleb) through the field cultivation of the collected genetic material, which is very heterogeneous, thus allowing the populations to express their variability through various evolutionary mechanisms (natural selection, genetic drift, mutation, migration and spontaneous outcrossing).

The general characteristics of the species to be sent for conservation and subsequent reproduction have been described thanks to the observation of custodian farmers who are fully aware of the agronomic, gustatory, nutritional, cultural and morphological qualities. In the years 2020 and 2021, the seeds of the species in Table 3 were produced with a quantity that represents the sum of 10% of the seeds produced by the individual farmers involved and included in the first approach by the community of farmers is provided. These quantities appear to be an extraordinary result in an oasistic environment where the idea of biodiversity conservation has never been considered as a participatory action between public and private bodies but only as an effect resulting from traditional cultivation. Participatory action means a shared vision that supports a virtuous path that has beneficial effects on ecosystems and plant heritage, without neglecting the strengthening of policies to improve social and economic sustainability.

As regards the conservation of perennial species, a 1 ha plot has been made available by the Municipality of El Hamma, where 140 date palm plants (Degelt nur 60 trees, Dokkar (male variety for pollination) Khwet 5 trees, Alig 5 trees, Kentichi 5 trees, Metigui 5 trees, Goundi 5 trees, Tozeur zeit 5 trees, Tantabiht 5 trees, Bidh Hamem 5 trees) and 200 citrus plants (local ecotypes) have been planted and, concerning the annual species, carrot and okra have been sown. The realization of the field, in fact, has followed the systemic principles of agroecology in which agriculture comes into balance with natural resources and the multifunctionality of space is determined through the association between annual and perennial species.

This demonstration field stems from the idea that partnerships and participatory approaches between researchers, farmers and other stakeholders (the local municipality and NGOs) integrate ecological and socioeconomic research towards a greater understanding of the agrobiodiversity guardian system [60].

In El Hamma, as well as in many other territories [61], a certain shift in agriculture towards intensive models, i.e., with a high application of inputs based on non-renewable resources, has already developed, but it is necessary, today, to verify how to reverse the trend and how agrobiodiversity can lead towards sustainable development. Indeed, traditional varieties provide yield stability, are resistant to biotic and abiotic stress, are adapted to low-input agriculture and are a key component of the natural resource base of the countryside in many parts of the world [62]. For these reasons, there is growing interest in traditional varieties, especially when their conservation is attributed to custodial farmers, and their potential for reuse [63,64].

Table 3. First approach for implementing the Maison des semences with local traditional annual species and quantity of seeds produced by farmers for this purpose (2020 and predictive 2021).

Species	2020	2021
	kg	
Okra	10	12
Chili	4	6
Alfalfa	1	2
Salad	2	3
Chard	10	14
Celery	0.5	1
Molokhia	12	15
Parseley	1	2
Carrot	0	2
Fava bean	0	6
Onion	0	1

5. Conclusions

Assuming that the relevance of agrobiodiversity is especially linked to the need of mitigation of the climate crisis and with the strengthening of resilience of rural areas, in Tunisia, the strong pressure of industrial agriculture has determined a deep contraction of the biodiversity that is at the base of traditional knowledge. This has become evident for those species that can have a relevant economic interest. In complex systems such as oases, perennial and annual crops are at serious risk due to over-exploitation of the non-renewable groundwater reserve, inefficient irrigation techniques, continuous increase of irrigated areas [65] and the loss of the traditional practice of cultivation at three layers [66]. Sustainable development of oases must be conceived from ecological (conservation and economical use of resources), social (acceptability and responsibility), economic (profitable activities) and cultural (human values and qualities of resilience, solidarity, generosity and patience) perspectives. The challenges of local, regional and national development are pushing researchers, local actors and decision-makers to strengthen initiatives that consider resources, constraints and mutual interests. Based on this assumption, we highlighted the opportunity to address the issue of biodiversity conservation not through conventional top-down scientific methodologies, but through mechanisms for bottom-up creation of scientific knowledge and for sharing this knowledge with wider society.

This process can be defined as a 'socio-ecological experiment' that goes beyond a simple participatory action, not only involving stakeholders in the research process, but also simultaneously manipulating socio-economic and ecological processes in real field conditions to provide a pragmatic path to sustainability [67].

Through this approach, the links between biophysical and social systems, typical of oases, are recognized and emphasized, which nevertheless represent an element of criticality and extreme fragility [68]. This approach has two main advantages: the proposed dynamics can be continuously improved through real-time adaptive management, and their results are available to decision-makers (in this case, farmers) mainly through their direct involvement [69]. The evidence-based results of such experiments can provide a useful contribution to effectively implement context-dependent local policies and, at the same time, encourage more stakeholders to become involved in experiments to evaluate agrobiodiversity management strategies. Policymakers and decision-makers, especially in fragile territories, need practical, scientifically sound and real-world evidence-based information to manage systems sustainably.

Community-based seed conservation initiatives have existed for about 30 years [68]. They have been designed and implemented to conserve, restore, revitalize, strengthen and improve local seed systems, as highlighted in our study. The multiple initiatives, which have acquired different names over the years, have all had the objective of regaining and maintaining farmers' and local communities' control over seeds and strengthening the dynamics of cooperation among farmers. In addition, as mentioned by Bellon in 2004 [70], there have been numerous initiatives that emphasize the need for on-farm in situ conservation programs, and as sub-emphasized by Bennet in 2016 [71], in the case of natural resource management and conservation, even for the management of local agrobiodiversity conservation programs, the involvement of the local community is of paramount importance. This assumption has more and more relevance in specific fragile environments such as oases, small islands and isolated mountainous areas, where the strong relationship between social, ecological and environmental issues is extremely important in order to ensure resilience to the local communities and to traditional knowledge [72,73].

This path is destined to continue over the years so that through the careful work of the local communities, it is possible to build a continuous adaptation of the indigenous biodiversity. In the specific case of this research approach, a step of further development, once the path of building the Maison du semance is consolidated, will be to develop more structured participatory breeding programs [74] in agreement with local agronomists, in order to ensure as much as possible the contribution of environmental pressure in the development of resilient and sustainable agricultural models.

Supplementary Materials: The following are available online at https://www.mdpi.com/article/10.3390/d13060253/s1, Table S1: QUESTIONNAIRE FOR SEMI-STRUCTURED INTERVIEWS TO FARMERS.

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