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Timber vs. Fruit Production: Partitioning of Moth Diversity within a Mosaic-Like Chestnut Forest

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Abstract

In Calabria chestnut woodlands represent an important economic resource exploited since ancient times. The main types representing Calabrian chestnut are orchards for fruit production and coppices for several uses of wood. Taking in account that biodiversity conservation is one of the purposes of the forest management, we studied the diversity of moth communities related to different types

of chestnut woodlands in the Catena Costiera mountains in Cosenza province, the area having the largest surface covered by chestnut in Calabria. Moth communities were sampled monthly from May to November 2015 using light trapping. Nine traps were located in different successional stages of chestnut forest which collected in total 8,164 individuals belonging to 328 species. Mature coppices inhabited the highest value of moth diversity and abundance, orchards for fruit production host moth communities similar to those of just harvested coppices, creating a permanent habitat for heliophilous and termophilic species in a forested landscape. According to our study, the mosaic-like forest landscape seems to promote the biodiversity, guarantying the contemporary presence of different habitats for moth with different ecological needs. Furthermore, coppices inhabit a diversity higher than expected.

Keywords: biodiversity, forest management, nocturnal Lepidoptera

1. Introduction

The chestnut (*Castanea sativa* Mill.) has taken in the past and still plays an important role among the forest formations in Italy. Due to its spread from the Alps to the Sicily, chestnut represented a great economic resource for several uses since ancient times. In fact it is well known the use of chestnut orchards for fruit production and of coppices for timber/harvesting, poles production for agricultural uses, firewood for cooking or heating and also tannins for tanning [1]. Due to this great diversity of products, chestnut forests were gradually expanded by man intervention, replacing mesophilic deciduous forests [2]. After the Second World War, following the industrialization process, chestnut forests were abandoned favoring the onset of two great pathologies, the ink desease (*Phytophthora cambivora* (Petri) Buiss.) and the cancer of cortex (*Cryphonectria (Endothia) parasitica* (Murr.) Barr.) which caused very serious damages in a short time [1, 3, 4, 5]. Since then, in order to preserve the chestnut forests and to raise the lost productivity, most of the chestnut orchards were converted in coppice. During the nineties, there has been an increase in the productivity of the chestnut, thanks to the great demand of fruit in confectionery and culinary use and of wood in agriculture [6].

Along the national woodland surface, chestnut forests are distributed in three main types: treated orchards under cultural practices; other high forests, abandoned and undergoing natural conversion in pure and mixed stands; simple coppices or coppices with standards, specialized in timber production [7]. The Italian chestnut surface covers 788,408 hectares of which 147,586 represented by orchards for fruit production and 605,888 represented by coppices or high forests for wood production [8].

In Calabria, the southernmost region of peninsular Italy, chestnut occupies 101,600 hectares, the 21.1% of the regional woodland surface, divided in high forests (47.3%) and pure coppices (52.7%). The majority of chestnut orchards

(88.3%) belongs to private properties, the remainder 11,7% is under public ownership [9].
The economic value of chestnut in Calabria is represented by both fruit production and timber, related to the different treatment, although during last decades chestnut fruit companies reduced their activity giving priority to wood production [32, 33, 34]. The greatest part of chestnut woodlands are under private ownership, the majority used as coppices without any plan of operation [10]. Rotations of coppice are comprised between 12 and 20 years and the single cuttings have variable extension which in certain cases can be up to ten hectares [10, 11].
The management of orchards and coppices in chestnut woodlands requires different practices, and which of these forest types is more important to preserve biodiversity is still an open question.
The quality of a forest system could be observed using bioindicators. Lots of works investigated the relationships between biodiversity and forest attributes estimating the species richness [12, 13, 14, 15, 16, 17]. Insects, Lepidoptera in particular, are one of the most and critical component of forest ecosystems which are used to describe spatial and temporal patterns of species distribution in forest habitats [18, 19, 20]. In this insect order are included several families, of which the so called "macrolepidoptera" often are used in ecological studies, having a well-defined taxonomy and well-known ecology [21, 22, 23].
Forest moths species have important functional roles as selective herbivores, pollinators, detritivores, and prey for migratorial birds [24]. Woodlands provide a wide range of habitats and niches for several Lepidoptera species with different ecological needs. In a forested habitat, diversity of Lepidoptera ranges from specialists that live in both coppice clearing and canopy to widespread species that prefer glades [25, 26, 27].
In order to verify the contribution of different chestnut wood managements to the biodiversity composition, we sampled woodlands moth communities of a selected area in Calabria. We investigated the chestnut woodlands of the Catena Costiera mountains in Cosenza province where both orchards and coppice treatments are present.

2. Materials and Methods

2.1 Study area
We investigated chestnut woodlands of the Catena Costiera mountains, Calabria (Italy). The Catena Costiera is a mountain chain that stretches about 70 km on the northern Tyrrhenian coast of Calabria, between the Orsomarso mountains and the mouth of the Savuto river. The geological substratum is mainly of metamorphic origin and most of the peaks does not exceed 1,400 m, with the exception of the prominence of Monte Cocuzzo (1,541 m). The position of the mountain chain, combined with the system of winds that blow mainly from the west loads of humidity, create a microclimate characterized by persistent fog for most part of the year, with high rainfall and cool temperatures. These characteristics favor the development of forest vegetation with the presence, on the Tyrrhenian side of beech

forests from very low altitudes. The East slope is characterized by the abundant presence of chestnut (*Castanea sativa* L.), and other mesophilic species (*Quercus* spp., *Alnus* spp., *Salix* spp., etc.). Chestnut orchards are located mainly close to residential areas, while coppices are mainly distributed far from towns and at higher altitudes [6]. The chestnut orchards are managed from very long time and can be defined the most stable environment.

Moth communities were investigated in 3 triplets of stands (A-B-C) in each of which were identified 3 different types of chestnut woodlands: (1) orchards, with trees older than 80 years; (2) coppices, with stumps 10-20 years old; (3) recent cuttings, open spaces with chestnuts younger than 3 years (Table 1, Figure 1).

Table 1. Location and description of sampling stands

Locality	Site	Coord. UTM E	Coord. UTM N	Altitude (meter a.s.l.)	Silvicultural system
Fiego di San Fili	CC_A1	597305	4354806	720	Abandoned chestnut orchard
Fiego di San Fili	CC_A2	597338	4354031	740	Chestnut coppice
Fiego di San Fili	CC_A3	597282	4353875	740	Chestnut coppice (<3 years)
Bosco dei Gesuiti	CC_B1	597467	4357525	620	Chestnut orchard
Bosco dei Gesuiti	CC_B2	597428	4357562	630	Chestnut coppice
Mandarino	CC_B3	597424	4358610	540	Chestnut coppice (<3 years)
Glicarello	CC_C1	596907	4362576	550	Chestnut orchard
Vallone Argentino	CC_C2	596502	4362680	565	Chestnut coppice
Vallone Argentino	CC_C3	596858	4362840	545	Young coppice with standard

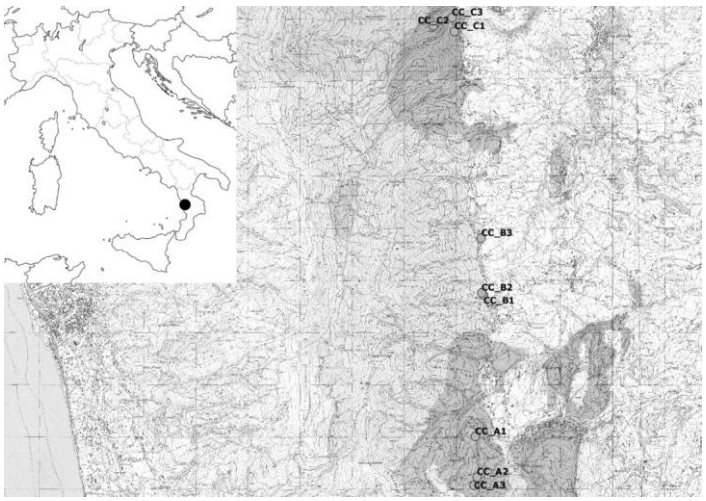

Figure 1. Location of study area of Catena Costiera mountains and triplets of stands.

2.2 Sampling methods

Study sites were characterized in a buffer of 20 meters around light traps. Inside the buffer were recorded descriptive parameters such as silvicultural system, the cultural practice in the last 10 years, age of stand, percentage of canopy coverage, bare soil and regeneration coverage, dead wood abundance, slope inclination, slope exposure, herbaceous/shrubby layer coverage, herbaceous/shrubby layer diversity, number of tree species (Table 2). The diameter at breast height (DBH) and the total height (H) were measured for all the trees comprised within each sampled stand.

Moth communities were sampled used UV-LED traps powered by a 12V battery. Traps were positioned at above 1.30 m from soil and equipped with a timer that turned on at the sunset and turned off at the sunrise. In each triplet were positioned 3 traps ($A_{1,2,3}$-$B_{1,2,3}$-$C_{1,2,3}$) for a total of 9 traps, activated simultaneously one night per month from May to November 2015.

Sampled moths were identified and stored in the collection of the Research Unit for Forestry in the Mediterranean Environment (CREA-SAM), Rende, Italy.

2.3 Data analysis

Descriptive parameters of sample plots were used to perform a PCA analysis based on a correlation matrix in order to characterize the stands by environmental variables.

The measurement of diameters and heights were used to calculate the basal area (G) and the volume (V) of wood in each sample plot. Volumes were calculated using volume tables and yield tables established for chestnut and other broadleaved in Calabria [28].

Data about moth community were submitted to (i) diversity analyses computing Fisher, Shannon and Simpson indices by using EstimateS software (Version 7.5.0), and (ii) Cluster Analysis using the Ward's Method with Euclidean Similarity Index computing 100 bootstraps in order to measure the robustness of nodes.

Multivariate analyses were carried out using the free Past software Version 3.08.

3. Results

3.1 Forest attributes

The descriptive variables of each sample plot are resumed in Table 2.

Table 2. Forest variables recorded at the sampled stands.

	CC_A1	**CC_A2**	**CC_A3**	**CC_B1**	**CC_B2**	**CC_B3**	**CC_C1**	**CC_C2**	**CC_C3**
Treatment	nothing	coppicing	cutting	nothing	coppicing	cutting	nothing	coppicing	cutting
Recent cultural practice (last 10 years)	nothing	nothing	coppicing	ground clereance	nothing	coppicing	ground clereance	nothing	coppicing
Age mean (years)	>80	10-20	<5	>80	10-20	<5	>80	10-20	<5
DBH mean (cm)	41.73	9.11	6.00	60.00	6.00	5.00	39.25	14.00	4.00

Table 2. (Continued): Forest variables recorded at the sampled stands.

H mean (m)	19.26	15.35	16.63	13.74	9.5	5.6	12.49	8.00	5.5
Canopy coverage (%)	85,00	90,00	0,00	65,00	95,00	40,00	70,00	95,00	15,00
Bare soil (%)	0	0	15	0	0	10	20	15	10
Regeneration coverage (%)	<5%	<5%	absent	<5%	25-50%	absent	<5%	<5%	absent
Dead wood abundance (%)	absent	moderately abundant	low	absent	low	low	low	low	absent
Slope inclination	45°	20°	17°	32°	50°	15°	37°	62°	20°
Slope exposure	E-NE	E-SE	W-NW	E-SE	E-NE	E-SE	E-SE	W-NW	E-NE
herbaceous/shrubby layer coverage (%)	>60%	>60%	40-60%	>60%	20-40%	>60%	>60%	20-40%	>60%
herbaceous/shrubby layer diversity	high	moderate	low	low	low	moderate	high	low	high
Tree species richness	2	3	1	1	5	2	2	1	1

According to forest data collected in the sample plots, we estimated the basal area (G) and the volume (V) of wood reported for hectare (Table 3). Table 3 reports the average of diameters (DHB) for the coppice shoots and the adult trees measured in each area. The greatest volume of wood is given by the oldest trees, represented by the abandoned orchard CC_A1. In general greater wood production are present in orchards and older coppices because of the great dimension of trees.

Table 3. Forest data collected in the sample plots and estimates per hectare (N=number of individuals; G=basal area; V=volume).

Stand	Age	N coppice shoots	N trees	N tot	G coppice shoots	G trees	G tot	V coppice shoots	V trees	V tot
	years				m^2	m^2	m^2	m^3	m^3	m^3
CC_A1	>80	80	374	454	0.55	44.22	44.77	3.58	482.54	486.12
CC_A2	10-20	4,908	127	5,035	37.40	3.83	41.22	263.30	43.83	307.13
CC_A3	0-5	8,401	-	8,401	16.50	-	16.50	168.02	-	168.02
CC_B1	>80	-	80	80	-	23.21	23.21	-	250.93	250.93
CC_B2	10-20	5434	772	6,206	17.34	11.36	28.70	138.87	146.75	285.62
CC_B3	0-5	10,899	32	14,901	29.80	6.70	36.50	222.45	73.25	295.69
CC_C1	>80	1,424	143	1,567	13.06	24.49	37.55	87.51	266.99	354.50
CC_C2	10-20	1,734	16	1,750	30.74	1.12	31.87	237.95	13.09	251.05
CC_C3	0-5	7,796	-	14,296	28.07	-	28.07	155.93	-	155.93

3.2 Moth communities

A total of 8.164 individuals were captured, belonging to 328 species. The community as a whole shows a fairly even distribution of relative abundance. In

fact, no species represents more than 15% of the sample and 15 species are necessary to reach the 50% of captured individuals, represented by *Peribatodes rhomboidaria* (Denis & Schiffermüller, 1775), *Clemathada calberlai* (Staudinger, 1883) , *Paracolax tristalis* (Fabricius, 1794), *Dysauxes famula* (Freyer, 1836), *Eilema caniola* (Hübner, 1808), *Idaea aversata* (Linnaeus, 1758), *Pseudoterpna coronillaria* (Hübner, 1817), *Idaea rubraria* (Staudinger, 1901), *Campea margaritata* (Linnaeus, 1767), *Rhoptria asperaria* (Hübner, 1817), *Selenia lunularia* (Hübner, 1788), *Hypomecis punctinalis* (Scopoli, 1763), *Noctua pronuba* (Linnaeus, 1758), *Idaea seriata* (Schrank, 1802) and *Dysgonia algira* (Linnaeus, 1767). Among these species the most frequent have an Asian-European distribution and are related to nemoral or sub-nemoral environments. Almost all are related to herbaceous plants or to plant debris, with the exception of *Campea margaritata*, *Rhoptria asperaria*, *Selenia lunularia* and *Hypomecis punctinalis*, that are related to broad-leaved trees. Particularly important is the abundant presence of *Clemathada calberlai*, an endemic species of central-southern Italy. 68 species are represented by one individual.

Very important from the faunistic and conservation point of view is the presence of some Italian endemics *Clemathada calberlai*, *Nychiodes ragusaria* Millière, 1884, *Hemistola siciliana* (Prout 1935), *Megalycina serraria* (A. Costa, 1882) and *Xanthorhoe vidanoi* Parenzan & Hausmann, 1994. Also were captured four species new from the Calabrian fauna: *Hypomecis roboraria* (Denis & Schiffermüller, 1775), *Phragmitiphila nexa* (Hübner, 1808), *Apamea scolopacina* (Esper, 1788) and *Rhizedra lutosa* (Hübner, 1803). We note finally the presence of *Euplagia quadripunctaria* (Poda, 1761), a priority species of the Habitats Directive (92/43/CEE, annex II).

In general, the sites that have recorded the highest number of species and individuals are those relating to old coppices. Among the chestnut orchards, however, only CC_A1 showed equally high values. On the contrary, as it was in the expectations, young cuts showed the lowest values. This trend is also confirmed by the values of the indices of biodiversity, both for individual sites, which when calculated on the union of the sites with the same type of treatment ($CC\_A_1 \cup CC\_B_1 \cup CC\_C_1$; $CC\_A_2 \cup CC\_B_2 \cup CC\_C_2$; $CC\_A_3 \cup CC\_B_3 \cup CC\_C_3$).

The same data derived from the union of the merged sites to triplets (CC_A1,2,3; CC_B1,2,3; CC_C1,2,3), show values comparable between sites B and C, located at lower altitudes, both for the number of species and individuals captured that for the diversity indices. The A sites, located at higher altitudes showed lower values (Table 4).

Table 4. Diversity indices of moth communities for stand, locality and type of treatment

	N° individuals	N° species	Fisher α	Shannon	Simpson
Stand					
CC_A1	1,029	150	48.42	3.86	15.13
CC_A2	987	145	46.87	3.90	19.05
CC_A3	507	121	50.32	3.82	17.77
CC_B1	651	143	56.62	4.17	34.22
CC_B2	1,649	193	56.70	4.37	44.24
CC_B3	452	120	53.39	3.97	26.88
CC_C1	665	137	52.33	4.14	36.45
CC_C2	1,601	172	48.87	4.04	27.62
CC_C3	623	118	43.1	3.76	18.45
Locality					
CC_A	2,523	209	54.09	4.07	19.56
CC_B	2,752	234	61.10	4.43	41.92
CC_C	2,889	234	60.10	4.19	29.26
Treatment					
CC_1	2,343	233	64.3	4.29	27.88
CC_2	4,237	271	64.53	4.34	34.45
CC_3	1,582	203	61.91	4.12	23.07

3.3 Relationships among moth communities and forest variables

PCA analysis groups the stands according to environmental variables we described in Tables 2 and 3 (Figure 2). First 2 axis explicate the 60.38% of total variance, axis 1explicates the 40.90%. In figure 1 can be observed that the stands are grouped by treatment. Along the component 1 the stands are distributed according the canopy coverage, in fact the sites representing the recent cuttings show very low canopy coverage and age. Component 2 is more influenced by the shrubby/herbaceous layer coverage.

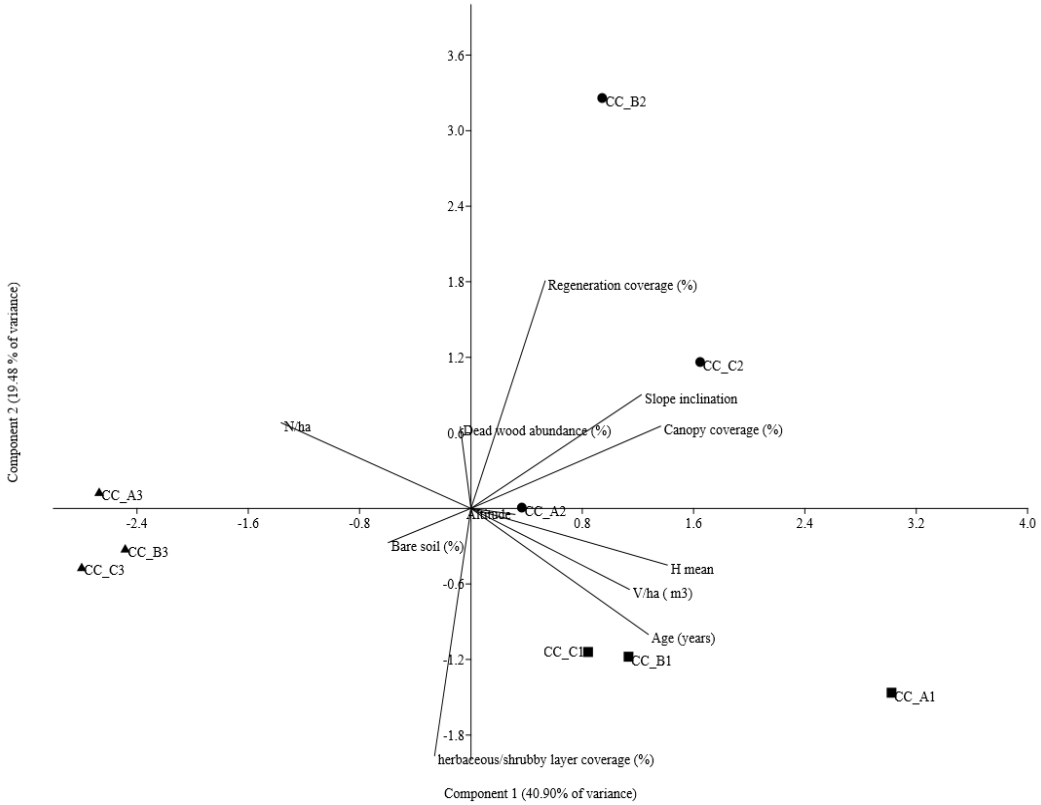

Figure 2. PCA analysis scatter plot (correlation matrix) shows how the stands are grouped according to environmental variables.

The Cluster Analysis (Figure 3) highlights two major clusters: in the first cluster, the communities belong to orchards and recent cuts, united by a very low canopy coverage, representing semi-open and more perturbed habitats. In this group, the thermophilic *Rhoptria asperaria*, *Dysauxes famula* and *Eilema caniola* showed relative abundances about three times higher than in the second group in which are clustered communities belonging to stands having higher canopy cover. Communities of the second cluster, represented by older coppices and one abandoned orchards and with the highest values of biodiversity (Table 4), are characterized by *Idaea deversaria*, *Idaea rubraria* and *Tephronia sepiaria*, showing relative abundances three times higher than in the first group.

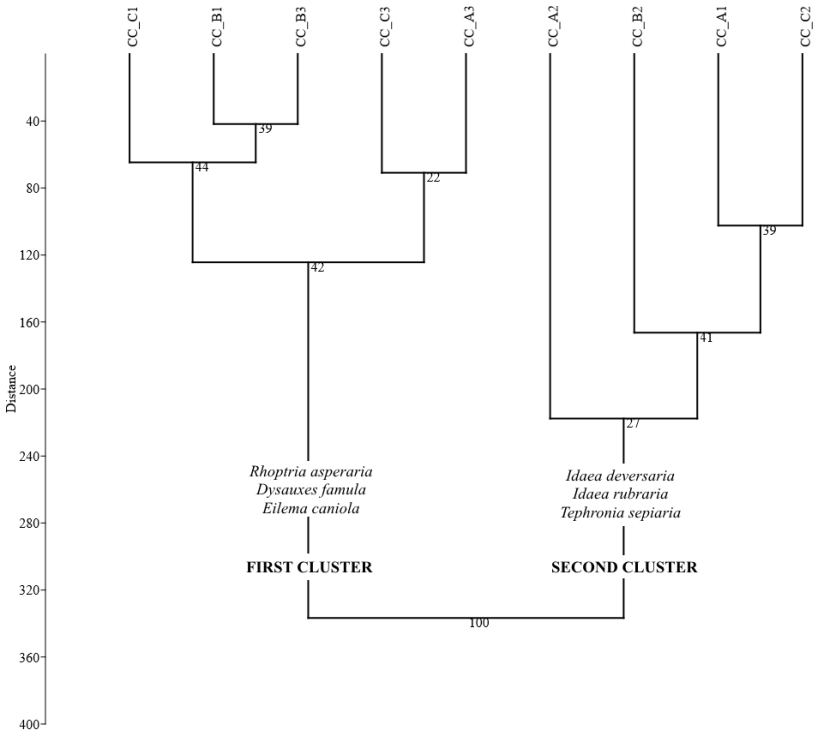

Figure 3. Cluster analysis groups the stands with the similar ecological characteristics. The most representative species for each cluster are entered on the relative branch.

4. Conclusions

The aim of our research was to evaluate the contribution of chestnut forest management, orchard and coppice, to the distribution of moth diversity.

According to regional regulation (Prescrizioni di Massima e di Polizia Forestale for Calabria region PMPF, 2008) [29], woodland management are different from forest types and tree species. In general, the regulations governing forest cuttings are intended to ensure biodiversity conservation, soil and slopes stability and improvement of ecosystemic services without compromising the evolutionary potentialities of the woodland.

In high forest, cutting is planned with silvicultural criteria. The interventions should improve the woodland structure, favoring the compositional and structural diversity, increase the stability of stands, favoring the natural regeneration. Concerning chestnut woodland, it could possible proceed to cutting reserving a minimum commission of 250 m^3/ha. In order to favoring the natural regeneration, in woodlands older than 60 years, little groups selection cuttings are allowed, with

a cutting period of 10-15 years. For chestnut orchards it is allowed the extirpation of herbs and shrubs intrusive, and the total cleaning of the surface in order to facilitate the collection of fruits; pollarding of senile and adult plants in order to reinvigorate the foliage and the young ones to prepare the grafts; dead plants and those decaying can be removed, provided that the holes are early filled with the ground and the plants are soon replaced.

Concerning the coppices, cutting should be made during the resting of the vegetation, which in Calabria is planned from September to May for chestnut woodlands. For pure coppices, the minimum period of rotation is 12 years. In coppices, the surface of cutting cannot exceed 10 hectares, 5 hectares in woodlands with slopes greater than 30%. In chestnut coppices with standards, must be preserved at least 30 standards per hectare [29].

The majority of chestnut woodlands of Catena Costiera are under private ownership without any plan of intervention [10]. The forest areas involved by sampling show a relatively high number of moths species, especially given the strong impact of the prolonged and intensive management. The highest value of biodiversity was reported in the stands representing the old coppices. The Cluster Analysis showed a significant separation between stands with high canopy coverage and semi-open and more perturbed woodlots, due to the change of relative abundance of species composition. Conversely, the use of chestnut for the production of fruits needs for continuous cleaning operations of the undergrowth which diminish the plant biodiversity and interfere with the ecological succession. It is not accidental that in this cluster is also the site CC_A1, an abandoned fruit production chestnut wood, so with more similar characteristics to old coppice.

The lowest values of biodiversity recorded in a stands can be explained by the geographical location of this triplet. In fact, these are the three sites located at the highest altitude. The other sites, in addition to being placed lower down, look directly on a hot and arid valley, characterized by open herbaceous formation, olive groves and gullies. This has increased the turnover of species into the B and C communities of thermophilic and Mediterranean distributed species which are more prevalent at lower altitudes.

The coppice management should be guarantee the formation of different patches of woodland with different age, from young cutting to mature trees, in order to maintain a high level of woodland diversity. The creation of a variety of habitats (structure and vegetation species composition) as a result by coppicing has been identified as an important way of increasing the moth diversity within woodlands [25, 26]. Forests managed just for timber harvesting, with no history of coppicing, should be not coppiced, as they are likely to require a continuity of habitats for some species strongly related to natural forest patches [30]. Several works suggest

the importance of leaving some patches of mature woodlands in a coppice matrix in order to maximize moth diversity and to provide a source for colonizing new areas of suitable habitats [25, 31].

In the investigated areas, we found that the presence of a mosaic-like forest landscape composed by young and old coppices and chestnut orchards for fruit production (Figure 4), promotes the conservation of biodiversity, even when the woods are deeply exploited and managed for a long time.

Figure 4. Mosaic-like chestnut woodlands of Catena Costiera. (Ph. Bernardini V, 2016)

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