AGROFORESTRY REVIVAL

ENGLISH VERSION

πράσινο ινστιτούτο

Reviving Agroforestry landscapes in the era of climate change

for people, nature and local economy

ENoP
EUROPEAN NETWORK OF POLITICAL FOUNDATIONS

Reviving Agroforestry landscapes in the era of climate change: for people, nature and local economy

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Dedicated to the people of the countryside, the creators of the ancient agroforestry landscapes of Greece, a global bio-cultural heritage which is now fading and threatened with extinction.

Dr. Rigas Tsiakiris
Scientific coordinator of the current edition
Green Institute Greece

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© Costas Zissis I Neochori, Lefkada island

PREFACE

Climate change and the global biodiversity crisis are causing both scientists and citizens to have second thoughts about post-war development. Today we are revisiting the post-war certainty about the type of economic growth we called ‘development’, about markets and urban population concentrations.

The Green Institute finds that there are significant existing capacities and dimensions related to combating climate change, many of which were displaced and sidelined in the post-war era. Today we discover that in Greece and Europe there are no coherent agricultural policies including the spectrum of EU agro-ecosystems. There is neither a national strategy nor a national vision adapted to the needs and historical trajectory of agroforestry areas and the country’s particular cultural landscapes. Currently, it seems that the transformations and adjustments imposed after the war make Greece increasingly vulnerable to climate change. Land uses which were segregated after the war, both in cities and the countryside, are now being re-examined. Agroforestry and productive reforestation, which traditionally existed in the Mediterranean, are today juxtaposed against the regime of industrialized agriculture-forestry-livestock.

In recent years, the Green Institute has launched a systematic campaign on such issues, which has met with the impressive and immediate response from the Greek scientific community. The series of conferences in 2021 and the accompanying publication on ‘productive reforestation for living rural landscapes’, with the participation of 20 university and expert scientists, are an important scientific milestone. The publication of the book “Climate Change - Preparing Thessaly” also brings to the foreground the new viewpoint required by the times we live in. The 2022 “Climate Change Regional Adaptation Plans” involved the organization of 4 Regional conferences, with the participation of 24 scientists, academics, NGOs, EU specialists and regional/local government representatives. These conferences highlighted the inadequacies of planning from Region to Region and the outdated logic with which climate change is addressed.

We had the same positive response with the book you are holding in your hands. We planned to develop the theme of revitalizing agroforestry landscapes with 20 authors, but scientific enthusiasm forced us to double these. Why is there so much enthusiasm by the scientific community? One answer is that scientific findings from all disciplines clearly indicate the dead ends of the policies being implemented, but also the need for a new innovative system of ideas and policies to replace the old, maladaptive regime. Scientists realize that today's policies cannot mean greenwashing and business as usual. If this interpretation is true, then there is hope.

The Green Institute deplores the non-implementation of forest sub-measure 8.2. of the Agricultural Development Plan since 2007 for the installation and revival of agroforestry systems. It also deplores the mismanagement of water, the destructive management of agricultural resources, the non-functioning of the National Commission to Combat Desertification and the cancelation of the National Strategy for Forests (2021-2038), which placed a special emphasis on Mediterranean Forestry and was replaced by a 'National Reforestation Program' without any measures to restore the country's agroforestry landscapes. The Green Institute understands and emphasizes the current value of landscape, agroforestry, productive reforestation, agricultural extensions, agricultural education, the careful balance of water supply and demand in hydrological basins, terraces on sloping lands and the key role that local actors can play.

The Green Institute is not only interested in adapting to climate change. It is also interested in increasing the resilience of all life support systems, including the support of local communities.

Ilias Gianniris

President of the Green Institute, Greece


© Yannis Roussopoulos I Olive groves in eastern Crete

© Yannis Roussopoulos I In the valley of the Pamissos river in Messenia - Peloponnesus

FOREWORD

When the European Forum on Nature Conservation and Pastoralism first came together in the early 1990s, its vocation was to provide a narrative bridge between pristine 'nature' (something largely seen

as linked to nature reserves) on the one hand and destructive 'agriculture' on the other. Our message was that, in between those two extremes, a large part of Europe's biodiversity survives, and often thrives, on land used for agriculture, on what came later to be known as High Nature Value (HNV) farmland. In fact, we said, without sustainable HNV farmland and viable HNV farming systems, Europe will fail to achieve its biodiversity goals.

A significant proportion of that HNV farmland consists of tall ligneous vegetation, most especially (these days, but not historically) in the Mediterranean region. Here we encountered a second mental polarisation, this time between 'forest' and 'farmland'. Once more, this was a division which existed first and foremost in the imagination of administrators, but which had then, over a century or more, been enforced on the landscape through all sorts of policies, latterly through the eligibility rules for agricultural area payments. But again the existence of an appropriate and vibrant grazing 'agroforestry' economy at a large scale is essential not only to delivering the objectives of the Habitats Directive, but this time also and even more so in the ever-more difficult struggle against wildfire. Grazing remains the only realistic means of fuel reduction at the landscape scale.

One thing we have found over the last thirty years has been that even if our nuanced description of the situation is truer than the polarised one it aims to replace (the European Environment Agency reckons that around one third of European farmland has significant areas of semi-natural vegation and is managed at low intensity),

** The European Forum on Nature Conservation and Pastoralism brings together ecologists, nature conservationists, farmers and policy makers. This non-profit network exists to increase understanding of the nature-conservation and cultural value of certain farming systems, and to inform work on their maintenance. For more information, see **www.efncp.org***

agricultural, foresty and nature stakeholders often seem happier dealing with the old divisions, and the same is true when it comes to ‘farmland’ and ‘forest’. This needs to change, and quickly.

Are there grounds for optimism? Maybe. We hear that eligibilty rules might be relaxed. We see the word ‘agroforestry’ written here and there in policy documents and legal instruments. Is this a sign of a shift in the mental jigsaw?

Reading the draft Nature Restoration Regulation, the old tropes are still clearly visible – promation of the exclusion of grazing from habitats, the division of the landscape in ways which make sense in Brussels, but often don’t fit reality on the ground. Does ‘agroforestry’ just conjure up visions of rows of poplars in intensive grassland fields or does it now extend to phrygana and maquis?

What about the vocation of grazing for fire risk management? Surely in that case the urgency of the matter will trump institutional inertia? The stories of policy retreat and failure one hears from France – once a leader in the field – make one extreme pessimistic that narratives have truly changed. Meanwhile in other countries, initiatives to manage firebreaks spring up while the pastoral systems which reduce fuel over the whole landscape are neglected and in a state of collapse.

When all’s said and done, the proof of the pudding is in the eating. Will all the new policies lead to woody habitats in better condition at the scale of whole biogeographic zones? To fire risk reduction across the Mediterranean basin? Only a vibrant pastoral economy can deliver these objectives, and policy has a strong role in enabling such an economy of profitable businesses attractive to the next generation to develop.

This book, which shines a light on this neglected area where farming and forestry, nature and fire hazard all come together, thus comes at a key time. Whether there is cause for optimism or not, there’s no doubt that there’s a huge job of awareness-raising and policy transformation to carry out, and anything which helps in that process is very much to be welcomed. It is therefore a pleasure and an honour to be asked to write these few words of introduction.

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AGROFORESTRY - DEFINITIONS

Agroforestry is the name given to a traditional practice of land use in which woody plants are purposefully combined with agricultural crops or pasture/ grazing animals on the same piece of land, concurrently or sequentially. This combination results in the creation of a system with two or more plant species, at least one of which being woody, which yields two or more products, has a productive cycle longer than a year and establishes important economic and ecological interactions among the woody plants and the other components. Agroforestry is neither synonymous with forestry, namely the management of natural or artificial forests, nor with conventional agriculture.

The combinations created by agroforestry are polycultures known as **agroforestry systems**. These systems are artificial because they incorporate humans who manage them based on traditional or new knowledge. When arranged in a specific area along with other natural (e.g. climate, water, soil), geomorphological (e.g. rock, relief, streams) and cultural (e.g. terraces, roads, buildings, water basins) characteristics they form **agroforestry landscapes**.

Although woody plants also include shrubs, trees are the dominant structural element of agroforestry systems, creating the overstory. They may be native or planted forest or cultivated (fruit trees). The other two structural elements of agroforestry systems are agricultural crops or pasture creating the understory, and grazing animals that feed on this and sometimes even the overstory. From the combination of these structural elements three types of agroforestry systems may be derived: silvoarable, silvopastoral and agrosilvopastoral. **Silvoarable** are the systems that combine trees and crops (e.g. arable, horticultural or fodder crops). **Silvopastoral** are the systems that combine trees and pasture/ grazing animals. **Agrosilvopastoral**, finally, are those that combine trees, crops and grazing (usually after the crop harvest). In all these types trees may be scattered across the plot of land, grouped together in small stands or arranged in rows (e.g. hedgerows).

HELLENIC AGROFORESTRY NETWORK

http://www.agroforestry.gr/pages/gr/


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INTRODUCTION

AGROFORESTRY LANDSCAPES IN THE ERA OF CLIMATE CHANGE: FOR PEOPLE, BIODIVERSITY AND LOCAL ECONOMIES

Agroforestry landscapes, defined as the deliberate combination of trees and crops and/or pasture on the same piece of land and at the same time, are recognized as among the most resilient multifunctional landscapes throughout the world, with the potential to successfully mitigate the problems posed by climate change on rural communities. Agroforestry landscapes are among the best carbon dioxide sinks, also playing a key role in tackling global poverty, preserving rural income and maintaining key elements of local cultural identities. Preserving, enriching and restoring traditional agroforestry systems means simultaneously tackling desertification, reducing surface runoff, improving soil productivity and preserving arks of global biodiversity.

In Greece, traditional agroforestry landscapes cover approximately 23% of its overall territory, especially preserved in mountains and islands where the intensification of land use has been limited. These landscapes also retain ancient cultural characteristics, created throughout humanity's long-term coexistence with nature in the Mediterranean and presenting a model of a living, sustainable land use on a local scale. Neglected by mainstream rural and forestry policies, agroforestry landscapes are still in peril: abandonment of land caused by rural depopulation is altering their structure, large scale forest fires are destroying their most valuable elements, such as ancient trees, and the land mosaic is degraded due to agriculture intensification and land reclamation.

Agroforestry should therefore be defined as a climate-smart land use in rural policies related to the CAP Strategic Plans, the Cohesion Fund, the Public Investment Program, as well as the European Platform for Ecological Orientation. Agroforestry is fully in accordance with other European strategies, such as the EU Climate Change Strategy, the European Strategy for Biodiversity, the "Farm to Fork" Strategy, new EU Forest Strategy 2013-2030 and the EU's commitment to zero land degradation by 2030 (Land Degradation Neutrality). It is also supported by the LIFE, INTRERREG and Horizon Europe Programs, and new funding tools such as the Green Deal, the Recovery and Resilient Plan & Mechanism, the Just Transition Fund.

As such. the **aim of the current publication** is to act as both an academic-scientific manual on the urgent need for reviving Agroforestry and as a guide for setting new, EU-wide priorities for climate change mitigation, improving information exchange on this issue among political parties of ENoP members. To achieve, thirty-eight leading scientists were invited to participate and contribute as co-authors, providing us with the latest available data and characteristic examples of these living bio-cultural landscapes, the threats they face and how to revive and create new ones in the frame of the UN decade of ecosystem restoration. In this way and by providing solutions based on the idea of retro-innovation, these ancient and hardy landscapes coming to us from humanity's earliest days could prove to be more resilient and productive in the era of climate change.

Rigas Tsiakiris

Forester, PhD, MSc Ecology
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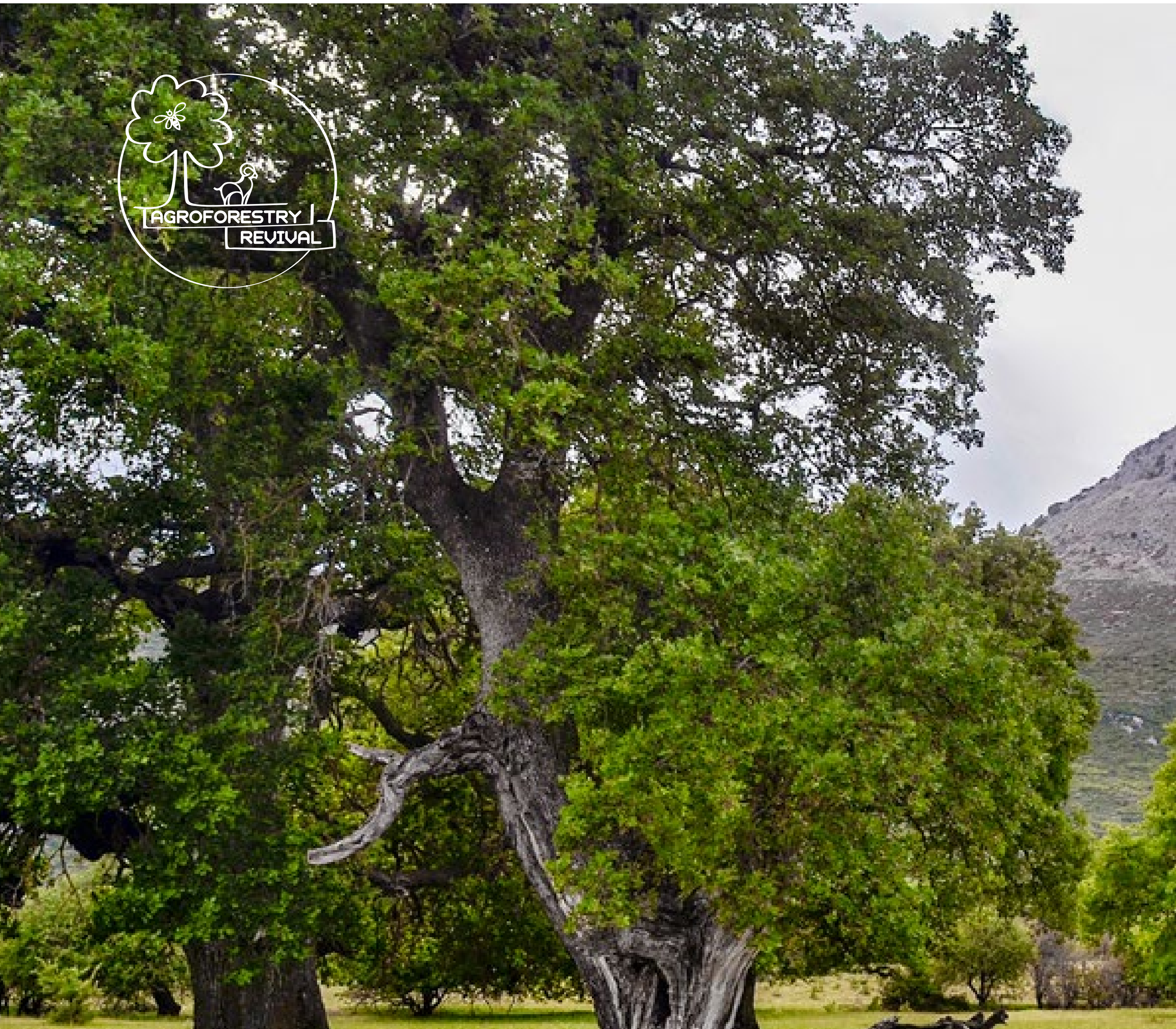
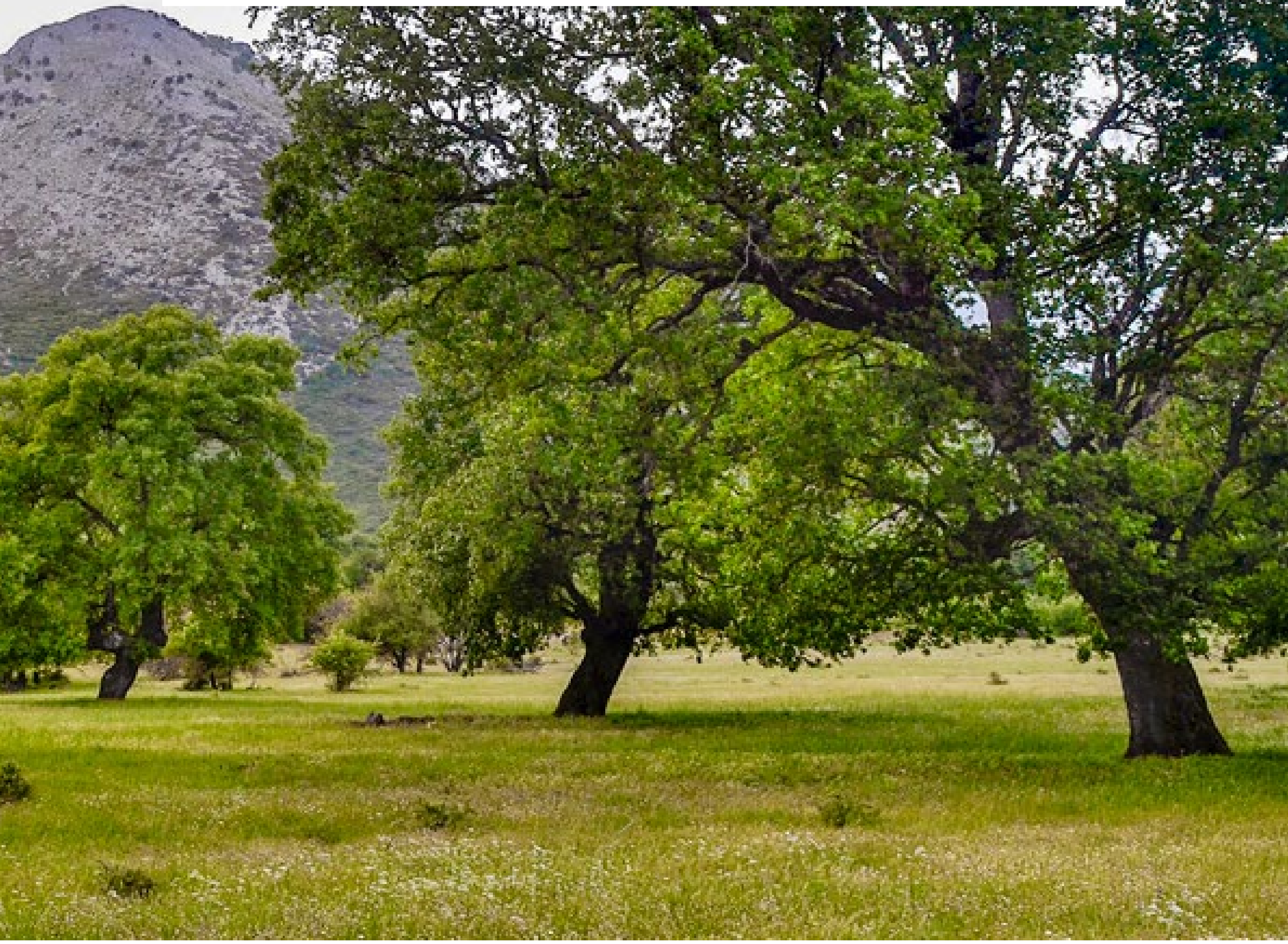
© Yannis Roussopoulos I The valley in the area of Thesprotiko-Rizovouni - Preveza



© Yannis Roussopoulos I Primeval oak stands and fields, in Xiromero, W. Greece

Part A

Agroforestry landscapes in Greece



Traditional agroforestry systems in Greece: past and future

Key words: agroforestry systems represent traditional life style, but also cultural, symbolic and religious values.

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© Ioannis Ispikoudis I S. Pindus, Central Greece. Anadendrades ampeli (vines on trees)

ORIGIN OF TRADITIONAL AGROFORESTRY SYSTEMS

Agroforestry is an ancient land use form, which is practiced by farmers in different areas of Greece. The coexistence of forest and/or fruit trees with herbaceous plants (cereals, vegetables, aromatic, medicinal plants, plants for dyes, fibers or fodder) or with woody plants (grapevines), as well as grazing animals, had as its main purpose the most efficient utilization of the limited land and the fulfillment of the subsistence needs of rural families (Ispikoudis 2005, Sidiropoulou 2011). Agroforestry is a relatively new term, which adds scientific knowledge to the empirical one (Shultz et al. 1987).Various types of intercropping have been known since ancient times, such as the fact that wheat, barley and some legumes could be planted at different moments during the cultivation period and often in combination with grapevines and olive trees (Papanastasis et al. 2004). Most of the farmers kept some animals (usually pigs) and/or beehives. Livestock husbandry was of great importance and used land which was not always suitable for agriculture. Agrosilvopastoral systems increased during the Byzantine period, when climatic, environmental, historical and social conditions such as hard and inflexible land taxation, had as a consequence the abandonment of intensive land exploitation through agriculture, the return to nomadic life, the depopulation of the lowlands and the clearing of forests in the highlands, where the lives of people were organized in agrosilvopastoral systems (Kontos 1929, Grispos 1973). Money or products were collected as tax per “stremma” (1,000 square meters), but cultivations with trees were not subject to cadastral censuses, meaning there was no tax interest as was the case in the open cultivated lands (i.e. without trees).The latter was the main tax resource for the Byzantines, as well as for the Ottomans who followed.

Agroforestry systems represent traditional life style, but also cultural, symbolic and religious values

Agroforestry systems were favoured during the Ottoman period, due to the landownership and taxation systems in combination with the fact that Christians were overtaxed. In the Ottoman Empire, buildings and cultivated trees were classed as distinct property, independent of the land. There was also the Vakoufio or "Vakif" ordinance, which according to the Islamic law, consists of an asset dedicated to the fulfillment of an indefinitecharitable cause; in that sense, Vakoufio was considered a Divine Thing, whose benefits belonged to the people. Vakoufia (the plural of Vakoufio), as sacred religious property were deducted from taxation (Grispos 1973). Properties of churches and monasteries were recognized by the Ottoman authorities as Vakifs, as devout charitable trusts equivalent to the Islamic trusts (Kampouridis 2018).

Recognition of Christian Vakoufia from the Ottoman jurists resulted in Orthodox Christians legalizing their donations to the monasteries, in order to avoid some taxes. In a Vakoufio, it was possible that trees belonged to farmers, who used to take advantage of them in combination with cultivation or grazing in organized agrosilvopastoral systems on their own land, which would belong to a monastery or church or some monk or priest, who would allow farmers to cultivate on that piece of land. (Kontos 1929). In this way, taxation was less (only tithe, tax on agricultural production, was imposed, but no land tax) (Grispos 1973).


© Ioannis Ispikoudis I Cassandra, Chalcidice, N. Greece. Active, traditional, agrosilvopastoral system

THE UTILIZATION OF WOODY PLANTS IN AGROFORESTRY SYSTEMS

Two types of combinations, “Ypoklimadentra” (trees under vine) or “anadendradesampeli” (vines on trees), were often used by farmers; in many places, they used to leave grapevines to climb and twist on trees planted for this purpose, creating garlands among them. Earlier on, in documents from Mount Athos, there were detailed definitions of areas, borders, the extent of the estates and the trees they hosted. An example is: “vineyard, of ¼ modio in which trees ypoklima, walnutaʹ” (modio=1 stremma) (Kephalopoulou 2014). In Geoponika (Agronomy), it is reported for the 10th century (Vassos 2008) about anadendradesampeli: ”Anadendrades are of great usefulness to everybody. Because, they produce the best quality wine, which is the sweetest and longest preserved and if they are planted sparse, they allow cultivation every two years on the land between them... Not all trees should be anadendrades, but only those ... whose foliage is not too dense, so that not all the vines are shadowed. And these trees are elms, upright poplars, ashes and sycamores. And they should have a height of thirty feet (10 meters)... Their conformation manner varies from place to place. The system is adaptable on fertile soils and it has the advantage that it facilitates digging and plowing of the field and allows vegetable cultivation in it”. This is a description of a well-organized agroforestry system. In this

© Ioannis Ispikoudis I Volakas, N. Greece, Traditional agrosilvopastoral system.

way, Christians avoided multiple taxation. In the Rodopi area, ypoklimadentra was a usual form of intercropping (Kampa et al. 2008).

Given that in the past, Greek agroforestry systems were very rarely inventoried, a useful index for the recognition of the origin of these traditional agrosilvopastoral systems is the characteristic form of pollarding trees, i.e. trees from which leaf and twig fodder were cut. Traditional tree management is linked with fodder harvesting, which was and still is a basic source of food for livestock in some areas for the winter period. Sometimes leaf fodder production was and is the main object of management in private and/or state forests. Fodder harvesting has significantly affected the landscape ecology of mountainous Greece. Leaf and twig fodder harvesting played a major role in shaping the cultural landscapes and in particular the structure and composition of vegetation, as well as the tree forms (Halstead 1998). Local names such as Kouri, kladaries or kladero (twig fodder) exist all over Greece (Sioliou-Kaloudopoulou and Ispikoudis 2005, see also the paper of V. Dalkavoukis in the present volume).

The result of all this was the creation of distinctive cultural landscapes, where characteristic agrosilvopastoral systems dominate. In recent years, these systems are threatened by gradual abandonment (extentification) or by their transformation to agricultural monocultures (intensification). Since parts of these systems (trees, shrubs and herbaceous plants or agricultural cultivations) are in dynamic balance, any discontinuation of activities that maintain those systems makes them fragile, resulting in the decrease of products and services they provide (Mantzanas et al. 2004). The cessation of fodder harvesting, as a result of the abandonment of extensive stockbreeding and some rigidness of forest management legislation, has resulted in significant loss of our heritage, since pollarded or shredded trees are dying and disappearing from our landscapes, while new such landscapes are not created. Due to their high historical, aesthetic, recreational and ecological value, it is essential to reintroduce traditional pruning techniques to rejuvenate existing ancient, centuries-old trees, as a new start for their long-term management.

© Ioannis Ispikoudis I Vertiscos, N. Greece. Stoppage of fodder harvesting, has as result the death of pollarded trees.

Historic agricultural and stock farming systems in mountainous land; The example of the “kladera” of Zagori, Epirus

Key words: kladera, Zagori, prosumption economy, forest ownership

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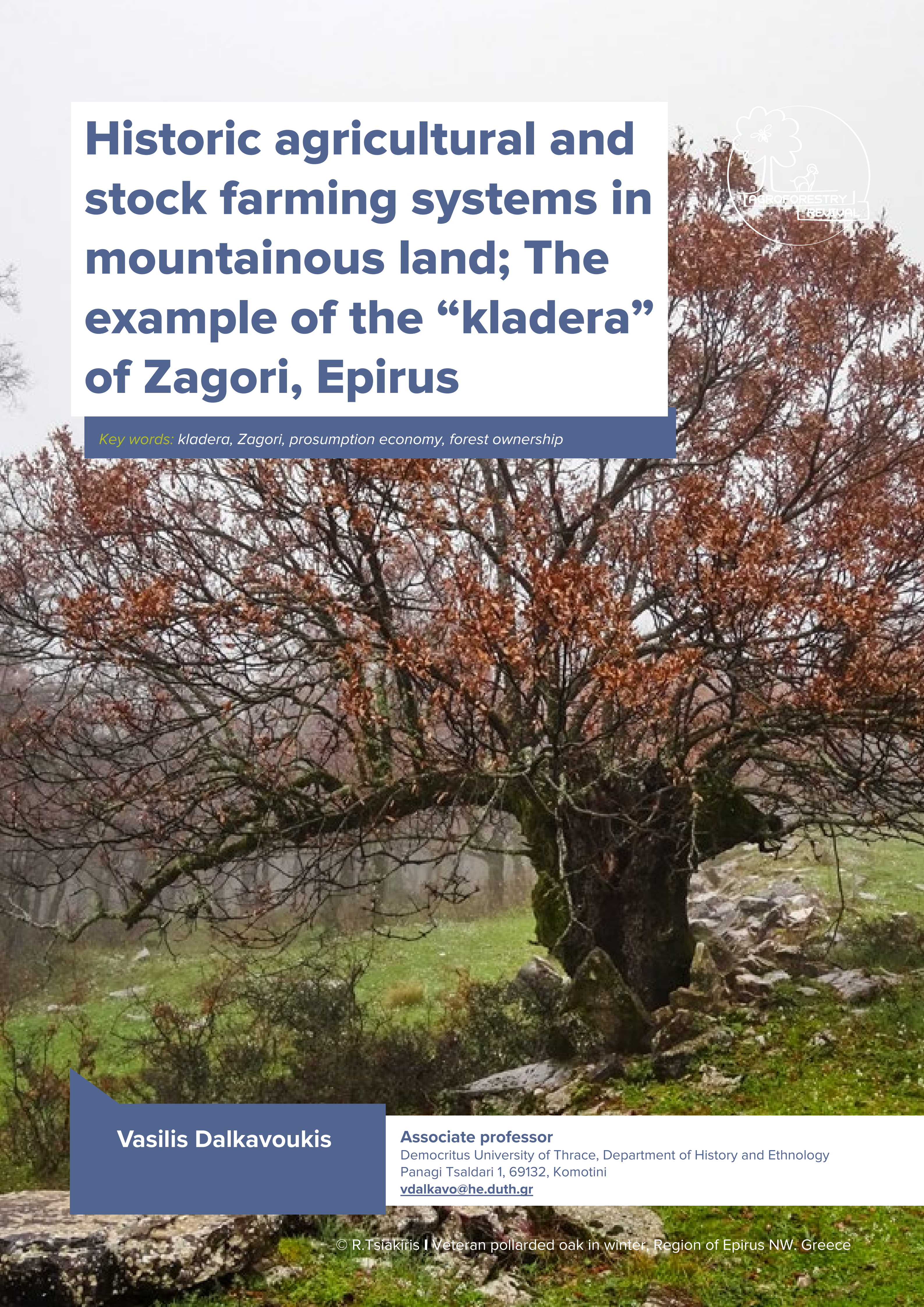

© R.Tsiakiris | Veteran pollarded oak in winter, Region of Epirus NW. Greece

The word “forest” is not always an easy case, especially when dealing with Mediterranean woody vegetation. Going beyond the strictly technical parameters provided by the science of Forestry, definitions of the forest typically include social factors, such as human/social interference and use, as well as legal ones, through which issues of its ownership status or the form of social usage are regulated (Smyris, 2012).

On the other hand, the concept of “sustainability” or “sustainable development” is derived from Forestry and initially (in the 19th century) concerned regulating the exploitation of forest resources so that the quantity of yielded products (mainly wood) would remain stable, steady, and symmetrical. In the last few decades, the concept has been broadened to encompass the type of development that satisfies the needs of the present, without undermining those of future generations (Athanasakis 1996). The scientific community regards sustainability in a generally positive manner, in the context of an “ecological realism” (which criticizes neoliberal economic assumptions that economic systems are closed and linear), by highlighting that the economy functions solely thanks to the support of its ecological foundations, and is, therefore, subject to natural limitations (Spilanis 1995 and Turner – Pearce – Bateman 1994).

The peculiar use of the forest, in mountainous areas, such as Zagori is a result of the self-government in the region during the Ottoman period

The framework for the discussion of a “sustainable management of the forest” can become even more complex with the addition of a socio-temporal component, namely, that of pre-modern social and economic organization, particularly in the area of Zagori, Region of Epirus, NW Greece. The social management and use of the forest in Zagori constitute a particular case, which stems from the special regime of self-governance that was applied to the area by the Ottoman administration, as was indeed the case with other rural areas (e.g. Agrafa) of the conquered European lands. In local historiographic discourse, at least, this connection is presented as the catalytic circumstance through which “private ownership” of land appears in the area, which also includes forest plots, named with the local term "kladera", the plural of "kladero", deriving from "kladi" or "klados" (in Greek means branch), which is the topic of the present paper/contribution.

But what exactly are the kladera? They are small, cultivable plots that rarely exceed two thousand square meters and are situated between two or more wooded slopes. The farmable part of a single kladero typically produced the "yearly bread" or leguminous crops and vegetables, without ever being able to provide some form of agricultural surplus. In short, it supported a family's household agricultural

Image 1. © *K. Stara: Typical shapes of shredded oaks of a kladero, Region of Epirus NW. Greece*

production for own consumption. The wooded part of the kladero consisted of pollarded and shredded trees and provided its owners firstly with the necessary fuel for heating, cooking, clothes-washing and other domestic activities, and secondly, with branches with fresh leaves either for direct feeding of their domestic, milk-producing livestock or branches with leaves which were left to dry and to be used, in winter, as “kladaries” (bundles of branches tied together) in order to feed cattle in the snowy seasons.

The pre-modern mountain economy was developed taking into account the temporal dimension of the following generations

Image 2. *The kladera in the “Serves” area, east of the village of Monodendri. © Vasilis Dalkavoukis*

However, because the existence of kladera is exclusively related to the vegetation of the “para-Mediterranean zone” (Smyris 2012: 14), meaning the zone of deciduous trees developing in middle mountain altitudes and up to the limits of the fir–beech zone, they were mainly employed as productive units of land in the western and central part of Zagori, since, in the largest part of eastern Zagori bordering the area of Metsovo and Grevena, the vegetation consists largely of conifers.

In reality, each family had more than one kladero under its jurisdiction, which, as a rule, were not all in the same area of the community space. This did, on the one hand, stem from the territorial restrictions within Zagori, where lowland, cultivable plots are small and non-continuous, interspersed with hills, rocks and other mountain terrain formations between them. On the other, it also forced farmers to change the use of their kladera year by year, so that the soil of both their farmable part and their forested sides was renewed.

The pre-modern economy developed by recognizing the limits of its interference in the natural habitat, not through a moralistic lens, but in the context of the prospect of true survival, one which took into account not only the then present social and economic conditions, but also the long-term ramifications for future generations. This constitutes a type of “lived-in sustainability” towards a “natural, conciliatory ecosystem” (Smyris 2012: 14), which not only manifested itself through institutional or religious prohibitions, but also largely concerned the family itself as the nucleus of the community.

Image 3: *Numbered plots indicating the kladera in the “Kondes” and “Boudovo” areas, west of the village of Monodendri. (source Google Earth)*

It is true that claiming that “private property” can safeguard the balance of such an ecosystem today might sound rather incongruous. However, we will have to point out that forest “private property” of this type presents some particular characteristics which set it apart from the meaning the term has gained in the context of capitalist modernity.

Kladera: a model of peculiar egalitarian redistributive communalism based on forest "private property"

First of all, this doesn’t constitute “private property” in the narrow sense of the term, but family property: in their essence, the kladera were one of the basic [living resources] of an extended family in Zagori from which financially active men were systematically absent due to their migration (Dalkavoukis 1999). As a result, the kladera were the preferential space of activity for women, the elderly and children, in the context of a family that worked as a full productive unit. Secondly, they were “private property” controlled collectively, in the context of the community: each family processed about the same number of kladera –to be precise, of equal yield– so as to guarantee its survival through this particular form of management. Finally, they constituted a property that couldn’t be capitalized in any other way other than through specific sustainable management, in the context of this type of mountainous own-consumption agricultural economy.

This particular model of an egalitarian, redistributive communitarianism, based also to an extent on forest “private ownership”, appears to have worked for more than two centuries in Zagori, before being disrupted by the area’s incorporation into the Greek state. The designation of kladera but also of the rest of the plots of this form as “public forests” began to gradually affect the lives of the people of Zagori as early as the 1930s. However, the institutional side of the subject is only one aspect. Another, equally substantive issue concerns the population decline of Zagori during the 1940s and the 1950s, and the serious consequences it had in the management of these particular forest plots. The demographic slump brought about an incomplete usage of the kladera or even their abandonment during the first post-war decades, resulting in a large part of them becoming forested (Saratsi 2005). However, the residents’ primary reaction was the continuation of the usage of the kladera mainly for logging, without the necessary care for their renewal as previously decribed. In this way, the double breakthrough that occurred with modernity in managing them, brought about a kind of lack of laws and rules, the consequences of which were not noteworthy, the reason being that applying the practices of the past concerned no one but a scant number of permanent residents in the villages of Zagori at that time.

In the decades following the fall of the Greek Junta (the period after 1974), touristic development and the abandonment of biomass as fuel pushed the kladera and the discussion about them into the background. Tourism discourse often appears to need to appropriate "nature" in a one-dimensional, consumerist manner in which it is perceived by what Urry (2022) characterized as the "tourist gaze"; this was also imposed on notions of the "forest" as the entire non-built-up, communal area –excluding certain clearly farmable or grazable patches, practically unseen by the tourist–, which stopped being used through the older economic and social logic of communitarianism. It has only been in the last few years, when the economic crisis rendered the use of petrol for facing the nearly nine-month-long winter in Zagori essentially prohibitive, that the discussion surrounding the kladera came back to the forefront. Younger generations are now rediscovering the abandoned family properties of the past and simultaneously reinstating the use of an "emic" -meaning a traditional, local and preserved in the memory of the older generations- cadaster. However, the management of those plots does not presently exhibit the traits it had in its pre-modern context up until the 1950s. On the one hand, they are used almost exclusively for acquiring biomass; on the other hand, the increased needs for fuel, especially in villages with inns and hostels, permanently destroy the balance between the new social usage and the sustainable management of old kladera.

The re-examination of the effective institutional framework, therefore, is more than necessary, especially if a rational social usage of the "forest" is supported, and if the (another word for conceptualization) of "nature" remains of concern to us.

© R.Tsiakiris I Veteran pollarded oak in summer, Region of Epirus NW. Greece

Agroforestry landscapes. The case of century-old isolated trees

Key words: cultural landscapes, sacred forests, management of the commons

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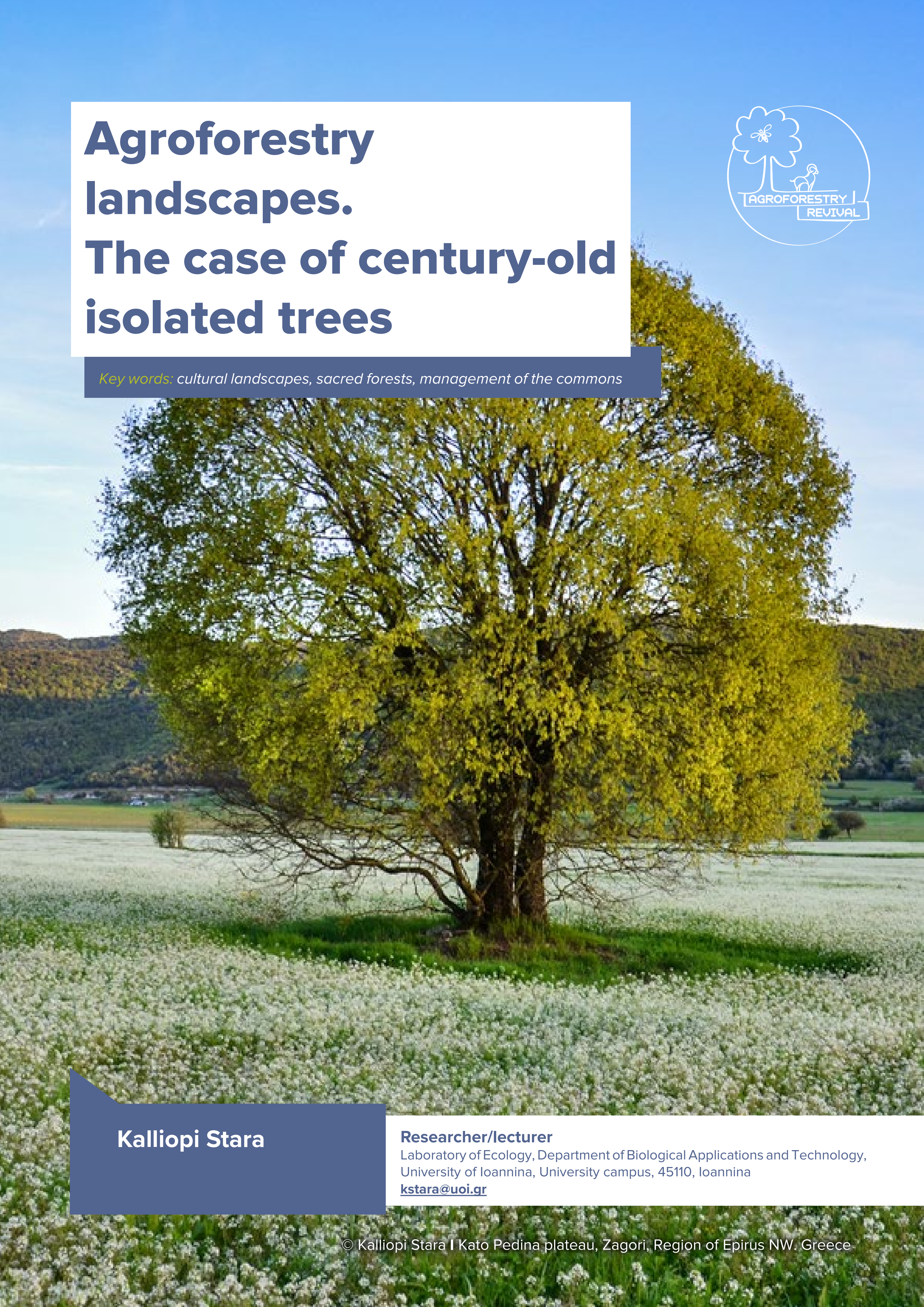

© Kalliopi Stara I Kato Pedina plateau, Zagori, Region of Epirus NW. Greece

INTRODUCTION

Century-old isolated trees stand as characteristic figures of many agroforestry landscapes. Such trees, as living guardians of history and time, can drive us on a journey into the past and help us to understand both the recent history of Greece's cultural landscapes and the long-lasting interaction between human societies and natural ecosystems that is mirrored in them (Figure 1). The term "agroforestry landscapes", if given without further explanation, sounds rather unfamiliar to non-specialists. However, if we think of iconic or even imagined landscapes in modern Greek literature and Folklore, we will easily understand how familiar they are; the royal oak, queen of the stories of Alexandros Papadiamantis (1851-1911); the isolated pine in the plain of Zacharias Papantoniou (1877-1940); the oaks that grew from the blood drops of a dragon mortally wounded by St Donatos, to ensure safe access to drinking water in Thesprotia (W. Greece), all these lead to the same image of open landscapes where centuries-old trees dominate.

Agroforestry landscapes used to be multifunctional management systems of the commons

Figure 1. *Centuries-old Macedonian oaks in the community forest of Mesovouni, Zagori, which functioned as a community pasture, shade trees and for collection of acorns for animal feed, © Kalliopi Stara.*

CENTURY-OLD TREES AND AGROFORESTRY LANDSCAPES

Agroforestry landscapes used to be multifunctional systems, simultaneously serving different uses and functions. Their centuries-old trees were associated with specific functions: trees of rest and respite during the pre-industrial agricultural period, shade trees used by shepherds for their flocks during summers' hottest hours (Figure 2) or places of celebration hosting rural festivities and ceremonies in outlying church yards. Some of them, as socialized cultural elements of the environment, were preserved due to beliefs that associated them with appearances of the supernatural. In such cases, gigantic or "demonic" trees were often purified by their dedication to the Church via the construction of icons or churches next to them. With this praxis people tamed wild nature and ensured the common use of important natural resources for all community members, often providing a solution to long-standing ownership problems that used to plague neighboring communities for years (Nitsiakos et al. 1998).

Figure 2. *Oak tree used for its shade tree in the outlying church of St Athanasios in Konitsa, Region of Epirus NW. Greece © Kalliopi Stara.*

At least in Epirus, NW Greece, the primary activity that maintained agroforestry landscapes open was extensive grazing. Grazing formed landscapes suitable for the production of other staple goods used or consumed by families: leaf fodder, forest fruits and nuts, aromatic and medicinal plants, mushrooms, honey, game and others, today known as "Non Timber Forest Products". The term "Non wood" or "Secondary forest harvests", as they are named by the Greek Administration, indicates the great importance that has been given to timber and wood. Such policies, which began to be implemented in Europe from the 18th century, attributed multifunctional forest or agroforestry landscapes exclusively to industrial forestry (Serinidou 2014) and only recently is there a tendency to redirect this trend (Martínez de Arano et al. 2021).

Agroforestry landscapes are part of our natural and cultural heritage

"SACRED FORESTS" AND "MEADOWS"

Agroforestry landscapes used to be management systems of important common resources. In Epirus (NW Greece), sacred forests maintained by communities functioned as such management systems in order to protect settlements from natural disasters or to secure/safeguard important natural resources, such as precious potable water. They were also kept as reserve forests for times of crisis. At such times, a fair and controlled use of sacred forests ensured grazing, shredding and logging for firewood or even timber for important community projects, such as the construction of schools or churches (Stara et al. 2016). Although the above uses were considered unacceptable in sacred forests, social pressures often imposed a shift from absolute protection to controlled management on these socio-ecological systems. In such cases, on the "untouched" forest and only on a case-by-case basis, it was possible to collect dead wood, remove bushes from the understory, often through "ritual rule-breaking" and to implement controlled grazing, all resulting in the making of open forest landscapes. For example, the feast day of St Nikolaos on May 20th (the day of transfer of his relics) marked the opening of the grazing period in the sacred forest of St Nikolaos in Livadakia of Vitsa (Zagori), kept intact until then, in order to host the community festival (Figure 3). Similarly, in other villages located in higher altitudes, this date was postponed, following other celebrations, such as the feast of Prophet Elias on July 20th. This controlled management kept the understory free of woody vegetation, maintaining a typical open forest type and protecting it from the risk of a catastrophic fire. The beginning of the permission to roam given on the day of the saints' feasts guaranteed acceptance by all community members.

Interestingly, many sacred forests are called locally "livadia" (literally meadows) and at least 11 have been detected only in Zagori. The etymology of the word livadi is related to the ancient Greek word 'livas', meaning water drop or stream, as these forests were related to water management (Stara and Tsiakiris 2010) (Figure 4). Although today many livadia have the form of dense forests, a careful examination of their oldest trees, the age of which reaches 300-350 years, shows that they initially grew up in an open environment, which over the years was flooded with younger and often different species of trees.

Figure 3. *Outdoor service in the forest of St Nikolaos in Livadakia of Vitsa, Zagori, Ioannina prefecture, Region of Epirus NW. Greece © Kalliopi Stara.*

CENTURIES OLD TREES, OPEN LANDSCAPES AND PEOPLE

In the treeless landscapes of the past, trees were considered as precious assets. Even if memory and nostalgia embellish the past, locals talk about privately owned trees of great economic value, such as huge centuries-old prickly oaks that were shredded during the winter or others associated with personal stories such as that of the "tree of names" in Kapesovo in central Zagori, that grows in the protective sacred forest of Gradista, above the village. All the boys in the village, as soon as they entered into puberty, used to carve their name on this tree trunk; because of this, the tree has a special place in the collective memory of the community.

In the past people used to be more familiar with open agroforestry landscapes. Thus, unlike "the green" or "the forest" which is perceived positively by residents of large urban centers when visiting the mountainous countryside, afforestation, especially of the formerly domesticated productive landscapes, is perceived particularly negatively by locals. Locals also associate abandonment, sometimes going as far as desolation, to demographic aging and to a voracious vegetation that swallows what human labor created, both theirs and that of their ancestors, along with their past, youth and property.

Active management is the only approach to keep agroforestry landscapes alive

The latest point is because Greek law specified until recently that if former agricultural land, especially when it is owned under customary law, is afforested due to land abandonment, it was subject to a regime of "informal public ownership" and the owner lost the right of use, i.e. logging, clearing and cultivation, if they did not initiate a judicial procedure for the revalidation of their property rights (Damianakos et al. 1997). The issue has recently come to light again after the objection period during the process of ratifying forest maps, as often elderly citizens did not submit requests to correct the mistakes of the administration regarding "forested fields" and subsequently realized that their property was transferred to the Greek state, which had led to new amendments to forest legislation, but has not resolved the issue definitively.

CONCLUSIONS - PROPOSALS

Agroforestry landscapes are today part of the natural and cultural capital of our country, Europe and the Mediterranean region. They can support a small-scale rural economy, while supporting new values such as the maintenance of the cultural landscape and the conservation of biodiversity. However, their future is predicted to be rather uncertain as they have to contend, like most cultural landscapes, with two opposing forces; on the one hand, their intensification and conversion to industrial uses and infrastructure and, on the other, their abandonment. The abandonment of agricultural uses, both in mountainous and island marginal areas, turns them into forests or, better, into impenetrable flammable "jungles", as those who know them well say, making them extremely vulnerable to forest fires. Recognizing their value and actively managing them is the only way to keep them alive, as part of our natural and cultural heritage.

Figure 4. *Hornbeams in the sacred protective "livadi" of Manassis, Zagori, Ioannina prefecture, Region of Epirus NW. Greece © Kalliopi Stara.*


© Kalliopi Stara I Bosnian pines in mountain Flega, Region of Epirus NW. Greece

Classification of cultural landscapes in the Natura 2000 protected areas network: the importance of agroforestry

Key words: cultural landscapes, culturalness, protected areas, landscape assessment, cultural ecosystem services

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INTRODUCTION

Cultural landscapes refer to semi-natural and natural formations that have been shaped over long periods of time by traditional human land uses. Most cultural landscapes also include agroforestry with various vegetation types that are largely dependent on traditional rural land management, including agricultural and livestock grazing activities. This brief review presents cultural landscapes in the EU Natura 2000 network sites of Greece and emphasizes the important role of agroforestry systems in their inventory and management.

The abandonment of traditional land uses degrade the long - term mosaic diversity of the landscapes

In the last 50 years, there has been widespread abandonment of traditional land uses in Greece (e.g. mountain agriculture, traditional terraced crops, transhumance livestock grazing, etc.) as well as extensive changes due to agricultural intensification, urban sprawl, road expansion and many other changes that often degrade the quality of landscapes. In many cases, the agroforestry systems that are important in shaping cultural landscapes have also changed and lost their original integrity. The identification, evaluation and mapping of cultural landscapes are cornerstones for the proper management of biodiversity and for sustaining the multiple values of landscapes, especially in Mediterranean-type climate areas (Ispikoudis 2005, Vlami et al. 2017).

An important problem in Greece regarding the cultural landscape and agroforestry systems in particular is the lack of a complete inventory and classification framework. The term "classification" refers to the organized categorization of areas, landscapes and administrative units (e.g. protected areas) for the purpose of their inventory, monitoring, management and protection. The aim of classification should include the provision of a practical framework for synthesizing and analyzing multiple sources of information. This process and the products it creates (conceptual models, maps, etc.) helps increase understanding and facilitate proper management of complex multifunctional landscapes.

Such research and management needs have a high degree of complexity and there is inadequate experience in Greece. This also results from the fact that there was almost no tradition of managing traditional cultural landscapes as protected areas in Greece. The reasons for this long-standing conservation "omission" relate to the anachronistic view which supports that biodiversity in the Mediterranean basin must be strictly related to "natural" or mainly forested areas. Shortly before 2000, the core management theory was that the entire Mediterranean basin is dominated by "ruined landscapes" that were degraded by the destructive succession of civilizations and no longer have anything to do with the primordial nature of the region. This simplistic view is incorrect (as discussed in Rackham & Moody 1996 and Grove and Rackham 2001). Many typical Mediterranean landscapes are rich in biodiversity because of the complex small-scale traditional land uses; and, these landscapes often include many patches of "wild nature" as well. Calls to develop a new approach to the management of traditional cultural landscapes combined with the support of biodiversity have been gaining attention in recent years (Catsadorakis 2007).

Agroforestry systems are cultural landscapes. Their inventory and classification must be completed

Until recently, cultural landscapes have been little explored in protected areas. In Greece, simple cartographic analyses have shown the true nature of the country's protected areas. A rough dichotomy between "cultural" and "natural" landscapes utilizing simple geographical criteria proves how pervasive the presence of human land uses is within the Natura 2000 network of Greece (Figure 1). As expected, nearly all protected areas in Greece are dominated by several varieties of cultural landscapes. These cultural land cover formations show the high level of "culturalness" within Greece's protected areas.

The concept of "culturalness" is a geographical attribute where humans have influenced the long-term evolution of land cover formations, habitat types, or even entire areas. It was developed and applied for the first time in our review of Natura 2000 terrestrial protected areas (Vlami et al., 2017) in Greece (Figure 2). The complete inventory of culturalness attributes is certainly more complex than this screening-level analysis shows, but this evaluation and classification provides a heuristic method for developing broad scale interpretations. To get more deeply involved in the "cultural-biophysical" nuances and conservation-relevant management of each protected area requires a narrower spatial scale at the level of individual landscapes.

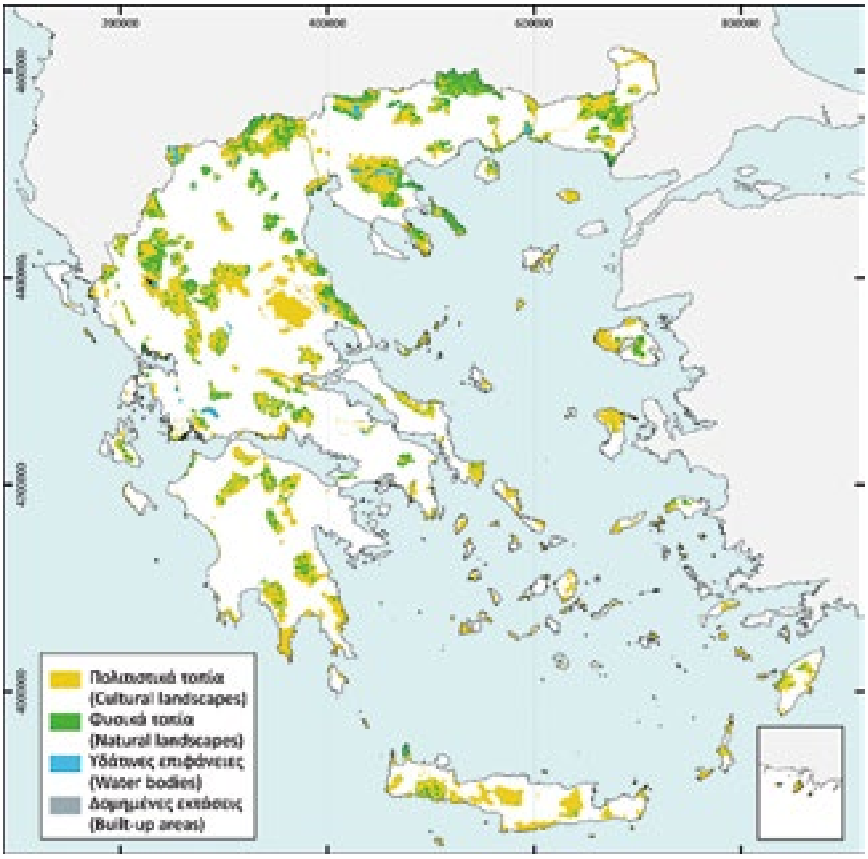

Figure 1. *The distribution of cultural and natural landscape formations in the terrestrial part of the Natura 2000 network of Greece. Classification is depicted using specific land-cover categories (scrubland, grasslands, agricultural land, etc.) as indicators of cultural landscape modification. At the time of this assessment 66.7 % of the terrestrial Natura 2000 network cover of Greece's network was covered by cultural landscape formations (Vlami et al. 2017). © Vassiliki Vlami*

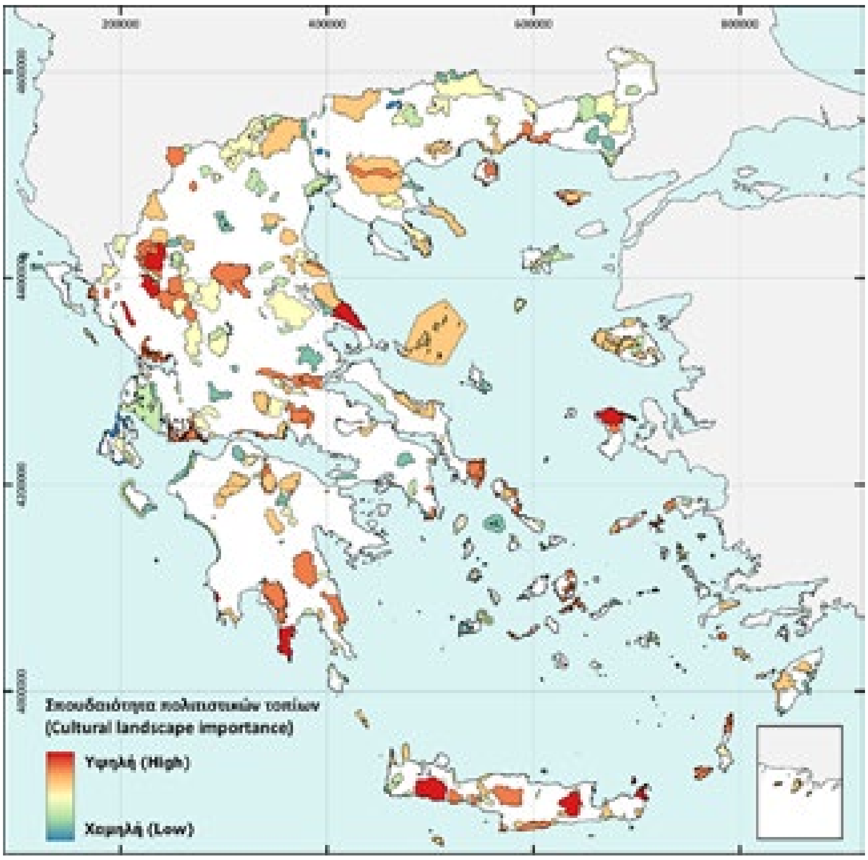

Figure 2. *Classification map of the Natura 2000 network based on the degree of cultural values (e.g. traditional land uses, livestock grazing, active rural villages, high nature value farming). The exercise of multi-criteria analysis results in a degree of "culturalness" for each protected area (high to low). Classification steps are discussed in Vlami et al. (2017). © Vassiliki Vlami*

EXAMPLES

Classifications at the spatial level of landscapes are a complex aspect of inventory, assessment and management. The challenge lies in the fluid and multidimensional concept of landscape. The landscape also includes the recognition of characteristics and values "as viewed by humans", the perceptual approach. The perceptual dimension of the landscape is important because it is in itself a transcendence beyond the familiar spatial polygons and geographical patches relatively easily mapped using satellite images. Often in surveys and mapping there is a need for evaluation (or prioritization) and this is a form of classification as well. The use of tools related to cultural ecosystem services (CES) is often combined in such cartographical analyses. Many cultural ecosystem values offered by landscapes must also include the perceptual dimension of the landscape, and this also refers to the aesthetic value and various other intangible values (Vlami et al. 2019; Song et al. 2020).

Cultural landscapes with agroforestry systems have various geographical and topographic features that can help their identification, classification and evaluation at the spatial level of landscapes. These usually include the following examples:

- Existence of small settlements where agricultural and livestock activities are practiced in ways and methods that are or resemble traditional land uses. In many cases, human activities in active rural villages form heterogeneous agricultural and forest lands or landscapes with a dynamic multifunctional agroforestry character.
- Agricultural practices that support high levels of native biodiversity (including High Nature Value Farming). Important criteria are the proximity of agricultural land to natural formations (wetlands, hedgerows, thickets) and/or the fragmentation of agricultural land by natural areas or natural formations (e.g. streams with natural riparian zones, well-developed hedgerows, forest patches, etc.).
- Livestock grazing in coexistence with the local fauna and a variety of natural/semi-natural vegetation patterns. The positive presence and intensity of animal husbandry is evaluated in relation to its effects on natural habitat features and a range of species of flora and fauna (e.g. coexistence with large fauna species, grazing-dependent habitats, etc).
- Natural stands of trees, natural vegetation patches and wild patches or even wilderness areas in proximity to small agricultural settlements, pastures and agricultural areas.

The abandonment of traditional agroforestry can have serious negative implications for biodiversity conservation in Europe (Halada et al. 2011). After abandonment there is often an abrupt regeneration of woody vegetation; this is not always beneficial to local biodiversity. In the Natura 2000 network in Greece, the low scrub and grassland habitats that are important for biodiversity constitute a rather low percentage of cultural formations, i.e. about 17.5% of all cultural formations in the Natura 2000 network before 2017 (Vlami et al. 2017). Due to the reduction of livestock grazing and farming, the area of woody scrubland has expanded at the expense of various grassland and meadow habitats. Furthermore, with the abrupt abandonment of traditional land uses, the chances of mega-wildfires and “exploitation” initiatives may increase (including pressures from industrial wind farms, tourism, road construction, etc.).

Culturalness is a geographical attribute relating to long term human modification that has affected land cover, habitat types or entire areas

Interpreting change in cultural landscapes is sometimes complicated: abandonment has favored many “forest” elements of biodiversity, but the bioculturally rich mosaic of many landscapes has been significantly degraded due to the rapid and widespread trend of rural abandonment throughout much of Greece.


© Vassiliki Vlami I Mystras Laconia, Peloponnese, Greece

CONCLUSIONS - SUGGESTIONS

The inventory and assessment of cultural landscapes is challenging. There are various methods of inventorying and classifying landscapes. Here we promote the inclusion of agroforestry systems in such inventory and classification work.

For protected areas in Greece, some suggestions are summarized in the following flow chart (Figure 3):

- The cultural landscape should be investigated with mixed methods research for comprehensive identification, inventory and cartography.
- Cultural Ecosystem Services may help in inventories, analyses, and assessments.
- Increasing knowledge and understanding of agroforystry systems should help manage protected areas with new initiatives to protect and promote various types of cultural landscapes.

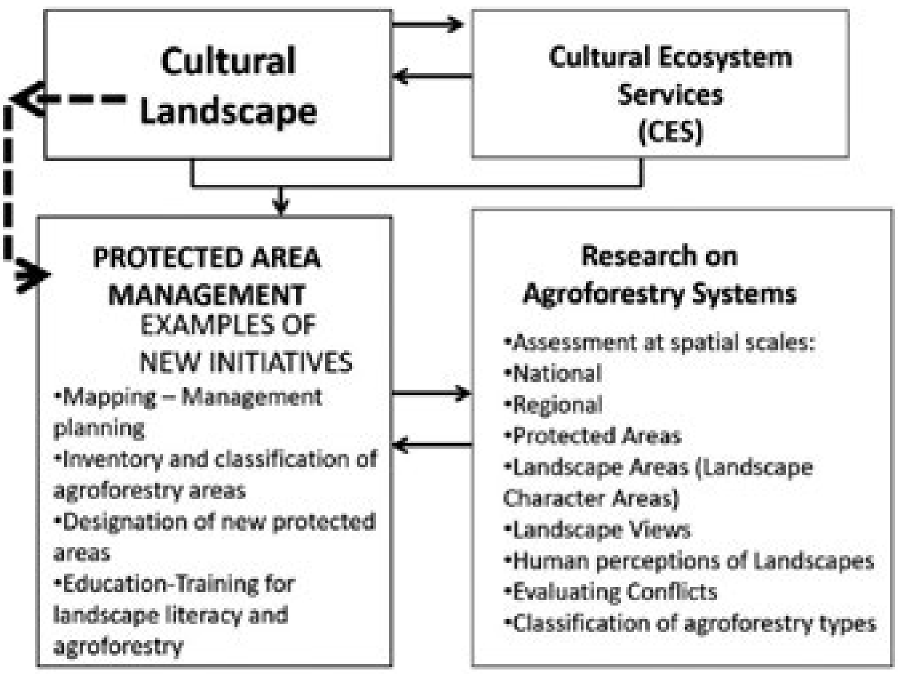

Figure 3. *Flow diagram showing proposed relationships between cultural landscape and protected area management (left). This is linked to cultural ecosystem services (right) and the influence of agroforestry systems research.*


© Vassiliki Vlami I Dadia Evros, NE Greece

Finally, the landscapes of the Mediterranean are by their nature complex and “multifunctional”, something like a palimpsest that includes natural and cultural formations and their myriad combinations. Greater understanding of the presence and functioning of agroforestry systems should play an important role in the protection of cultural landscapes.


© Vassiliki Vlami I Soulinari Messinia, Peloponnese

Mediterranean landscape mosaics and biodiversity: the case of the enduring history of Dadia National Park

Key words: heterogeneity, forest densification, biodiversity decline, wild ungulates

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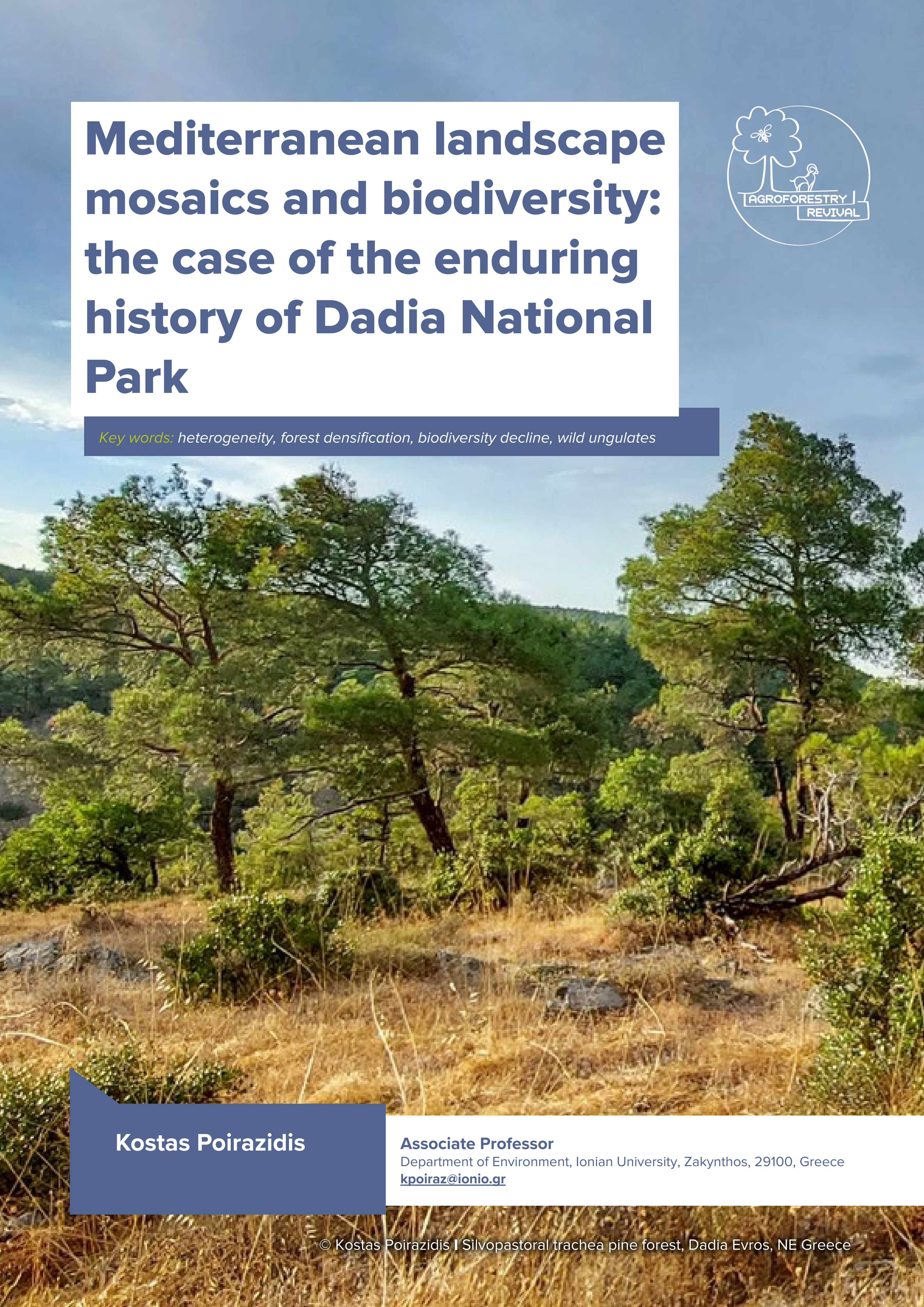


© Kostas Poirazidis I Silvopastoral trachea pine forest, Dadia Evros, NE Greece

INTRODUCTION

Ecosystems in Greece (and more widely in the Mediterranean) co-evolved along with a human presence in them, for at least the last 10,000 years, when domestication of wild animals began. Many stochastic (random) factors have played and continue to play a guiding but also a decisive role in the differentiation of landscapes. Extensive grazing, the cultivation of mountainous/semi-mountainous fields, uncontrolled logging, but also small-scale natural or man-made forest fires, had created - especially in the semi-mountainous zone - landscapes of single or scattered islets of dense forests, sparse forests, scrublands, small and larger plots, and meadows. In this mosaic of landscapes, open areas dominated because of extensive livestock activity, as can be seen from old aerial photographs. Today, the mountainous agricultural economy has drastically shrunk in Greece and many other European countries, with the direct consequence of forest expansion and the homogenization of the once heterogeneous rural landscapes (e.g. San Roman Sanz et al. 2013). The abandonment of the traditional rural economy is directly linked to the loss of critical habitats for biodiversity and the potential to provide multiple ecosystem services and goods to humans (e.g. Queiroz et al. 2014). The positive relationship between landscape heterogeneity and biodiversity conservation is now scientifically documented (Schindler et al. 2013).

The abandonment of traditional agriculture is directly linked to the loss of critical habitats for biodiversity

DADIA – LEFKIMI – SOUFLI NATIONAL PARK (DADIA FOREST):

THE CONTINUOUS DEGRADATION OF ITS HETEROGENEITY OVER TIME AND THE IMPACT ON ITS ECOLOGICAL VALUE

Forest densification leads to a reduction in biodiversity and the occurrence of mega-fires

The National Park (NP) of Dadia – Lefkimi – Soufli (generally known as Dadia NP) is located in the semi-mountainous areas of central Evros (NE Greece) and shows a wide variety of land cover and land use, which makes it globally renowned for its ecological value. The factors that contributed to the creation of this mosaic (such as extensive grazing and cultivation of mountainous/semi-mountainous fields) were maintained in the area until the early 70s. This, combined with the diverse terrain (with ravines and rocky outcrops) and reduced human presence, constituted an ideal environment for the presence of high biodiversity of many different groups of fauna and flora. Of particular importance was the presence of birds of prey. Thirty-six (36) out of 38 European species have been recorded in the Dadia NP, of which 19-21 species breed in this forest in large numbers, including the unique Balkan colony of the black vulture (*Aegypius monachus*). In 1980, the Dadia forest was declared a Protected Area to preserve its ecological value, but although traditional activities such as extensive grazing and existing small-scale agriculture were allowed, they gradually began to be abandoned.


© Kostas Poirazidis I A pair of black vultures in Evros, NE Greece

CHANGES IN LIVESTOCK ACTIVITY OVER TIME IN THE DADIA NP AND EFFECTS ON AFFORESTATION

Extensive livestock activity was one of the pillars of the economy of the Prefecture of Evros and the Dadia NP, but after the 1980s it began to steadily decline, especially in the last decades. Surveys carried out in 1998 and 2016 (Poirazidis et al. 2018) identified a large decline in all qualitative and quantitative characteristics of livestock farming/activity. In 1999, in the boundaries of the Dadia NP, 60 active owners of livestock farms were recorded, while in 2016 the number had fallen to 30 (a 50% decrease). The number of grazing animals followed an even greater downward trend, reaching a 60% decrease. In 1999, a total of 13,976 heads of all three livestock species were recorded (with goats making up 79% of the animals), while in 2016, out of a total of 5,505 heads, goats accounted for 82% of the total (Figure 1).

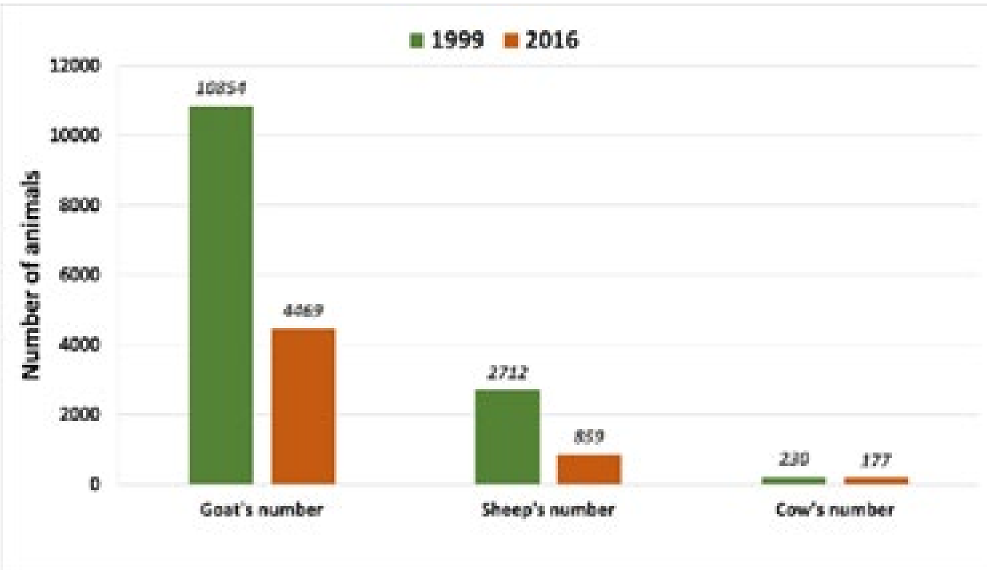


Figure 1. *Change in the number of free-grazing livestock in Dadia NP in 1999 and 2016 (Poirazidis et al. 2018).*

The sharp decrease in livestock numbers resulted in a corresponding decrease in grazing in the areas of the Dadia NP, where areas with intense grazing were observed in 2016 only to the south of the NP (Figure 2). This decrease has continued to be even more pronounced in recent years. In 2023, livestock farming in the area has practically disappeared, with few animals remaining in the Dadia NP.

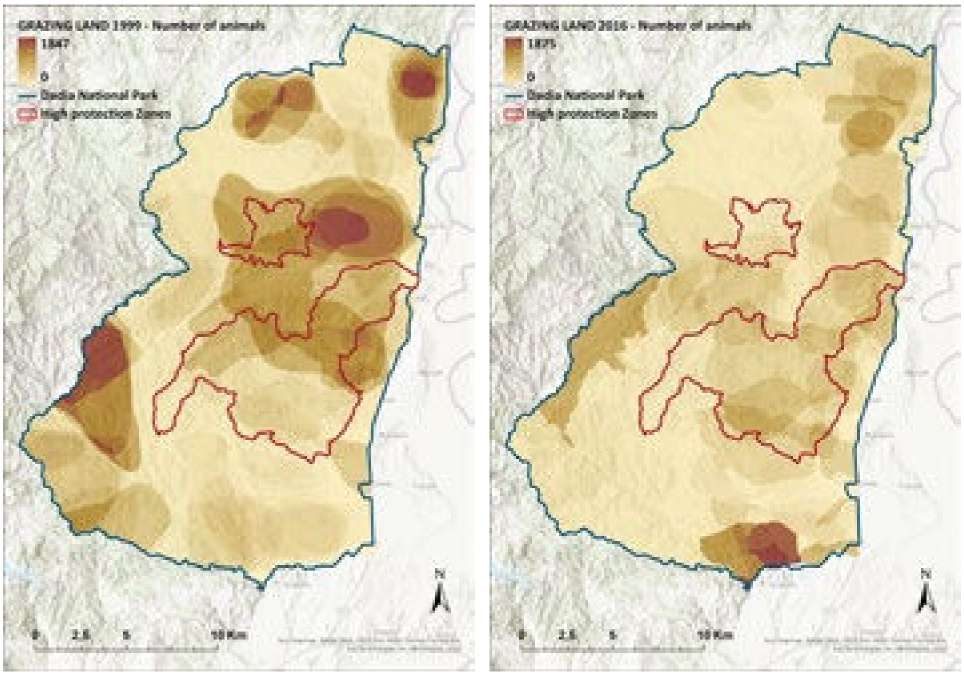


Figure 2. *Pasture loading (grazing pressure) maps for the years 1999 and 2016. © Kostas Poirazidis*

AFFORESTATION AND BIODIVERSITY

The sharp decline in livestock activity has resulted in the afforestation of small or larger forest gaps in the Dadia NP, the reduction of landscape heterogeneity and severe impacts on local biodiversity (Poirazidis 2017). According to Triantakonstantis et al. (2006), only 46% of the Dadia NP was covered by forest in 1945, reaching 54% in 1973 and 72% in 2001. The densification of forest areas (with a corresponding decrease in open areas) has shown a continuous upward trend in recent years and is found throughout the entire area of the NP, regardless of the degree of protection of each part of the area (Figure 3).

An example of the effects of forest densification on the birds of prey habitats is the case of the lesser-spotted eagle (*Clanga pomarina*). According to Poirazidis et al. (2019), the species maintained a relatively stable population of 15-20 pairs for the whole 1979-2012 period in Dadia NP (Figure 4). However, notable changes were observed in the areas of its breeding habitat, with a loss of suitability of the entire semi-mountainous western zone of the Dadia NP and a concentration of the breeding population mainly in the eastern region in the immediate vicinity of agricultural crops (Figure 5). The reduction of suitable habitat led the species to less

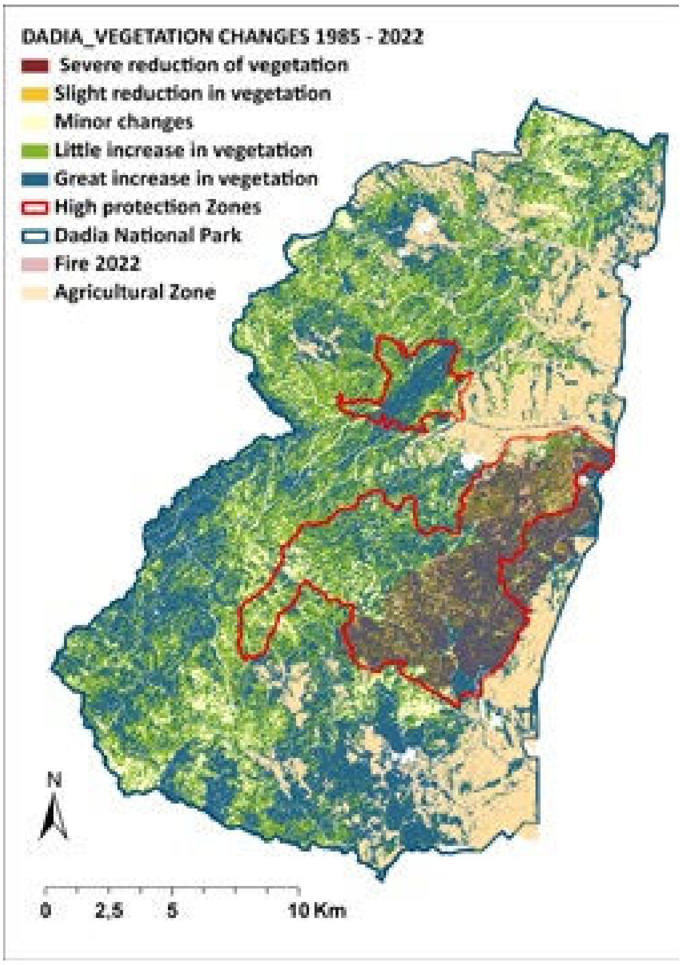


Figure 3. *Change in the values of the NDVI (Normalized Difference Vegetation Index) vegetation index in the Dadia NP in the period 1985 - 2022 (with shading, in the central-eastern part, the burned area from the fire in late July 2022). © Kostas Poirazidis*

optimal areas for breeding, with a large population decline already recorded in the 2020 periodic surveys (monitoring data from the Management Unit of Evros Delta and Dadia National Parks – Bakeas et al. 2021). Successive forest fires in 2011, 2020, 2021, and especially in the summer of 2022 burned almost all of its current breeding area, with unknown consequences for maintaining its population (Figure 5).

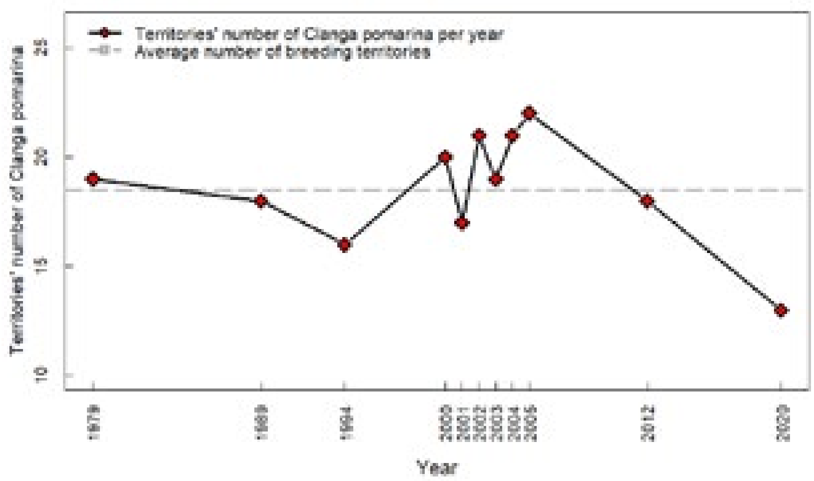


Figure 4. *Population changes of the active territories of the lesser spotted eagle in the Dadia NP.*

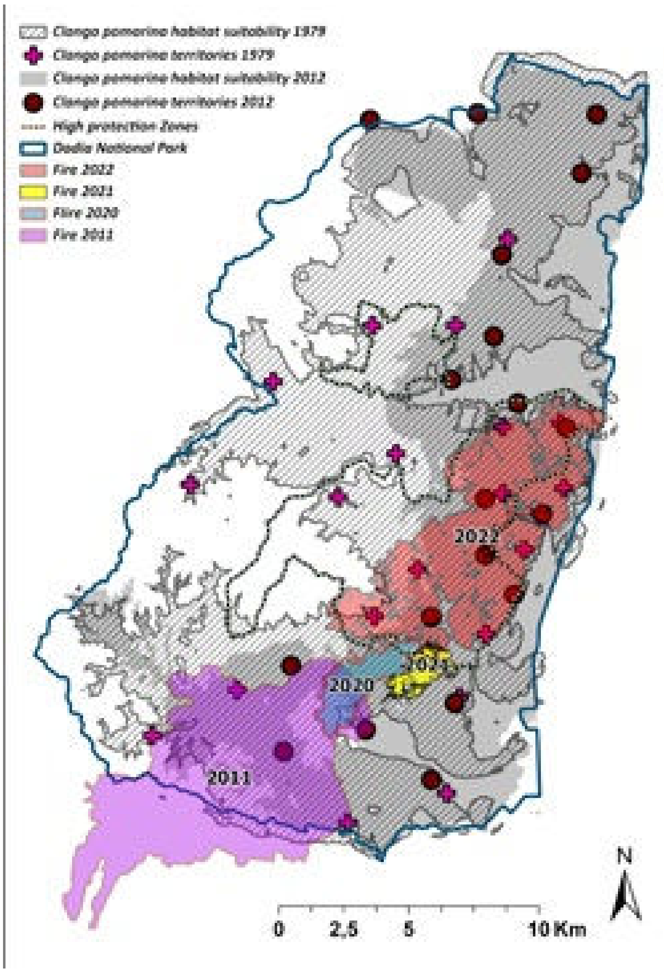


Figure 5. *Habitat-suitability map for the lesser spotted eagle, showing the spatial changes between the decades 1970-2000. © Kostas Poirazidis*

PRESERVING LANDSCAPE HETEROGENEITY IN THE MODERN ERA: IS IT POSSIBLE?

The abandonment of the countryside and traditional rural activities is now a reality due to changes in economic activity and the concentration of the human population in urban centers, a phenomenon that is occurring on an increasingly larger spatial scale in Greece, but also in many other countries of the world. The increase in biomass and the densification of vegetation in natural ecosystems, as a consequence of the above factors, combined with the worsening of climatic variables (decreasing rainfall and increasing average temperatures), is the main cause of the more frequent occurrence of large fires, even in more mountainous areas. Fire leads to regressive vegetation succession and the creation of temporary open areas with scattered forest islands. However, the frequent recurrence of these natural phenomena in a given area causes the degradation of ecosystems and an increase in secondary impacts (such as floods with soil erosion) with serious social and economic consequences, eventually leading to their gradual desertification. Although natural afforestation of open habitats increases the capacity of ecosystems to sequester carbon, contributing to mitigating the effects of climate change (Lorenz and Lal 2010) and maintaining landscape heterogeneity, the ecological integrity of ecosystems, through the preservation of traditional agricultural activities and maintaining landscape heterogeneity, should be a strategic objective in rural management decision-making, in order to provide multiple ecosystem services and goods to people. As simple as it sounds, this is one of the greatest challenges we have to deal with in modern times. The continuation of extensive livestock farming through special aids, but also as a tool and basis for cooperation between the authorities responsible for the management of protected areas and livestock breeders, could locally cure the problem of thickening forest areas, but the root cause of these problems will remain. To mitigate these impacts at the European level, efforts have been initiated to partially reverse this process, through rewilding of abandoned areas (Navarro and Pereira 2012), by reintroducing ungulates, such as the red deer (*Cervus elaphus*) or the fallow deer (*Dama dama*) in areas where they have disappeared or where there is a large decline in livestock numbers. This is one of the tools that can be relatively easy to implement, but it requires action on a large spatial and temporal scale, political will, and adoption by local communities. At the same time, a targeted European policy with a substantial strengthening of the restoration and preservation of traditional agricultural activities (in light of the new era and in the framework of the new Common Agricultural Policy and policies to mitigate climate change effects), such as the restoration and preservation of traditional dry stone walls and mosaic mountain farms as well as the maintenance or establishment of tree crops, will effectively help to preserve agroforestry landscapes and consequently protect biodiversity and ecosystem health.

Maintaining traditional agricultural activities and introduction of grazing of wild ungulates within forest areas are key management tools for the ecological integrity of ecosystems

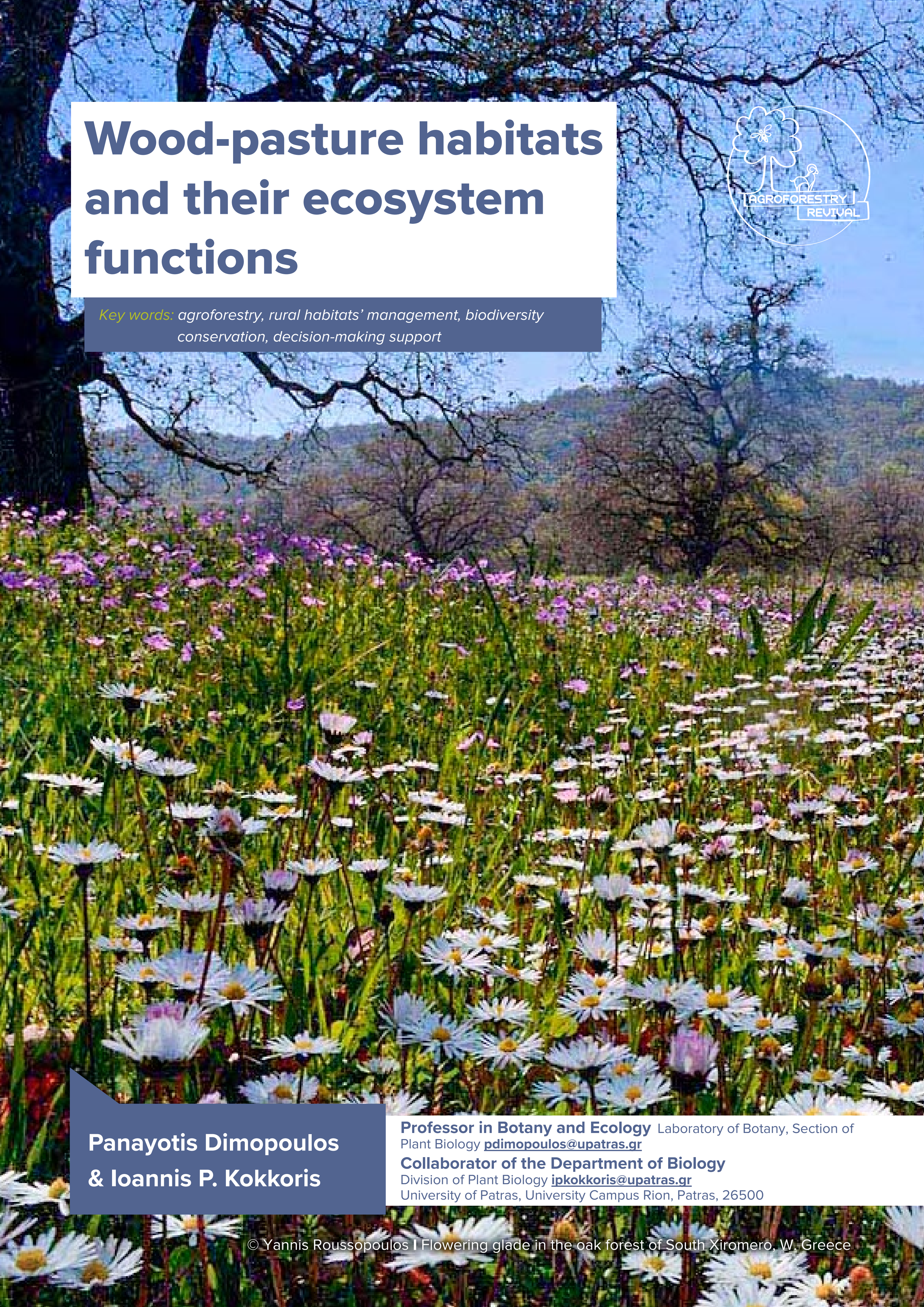
© Yannis Roussopoulos I Duet of male goats, Mount Arakynthos, Messolonghi area, W. Greece

Part B

Ecosystem functions of agroforestry landscapes and biodiversity

Wood-pasture habitats and their ecosystem functions

Key words: agroforestry, rural habitats' management, biodiversity conservation, decision-making support



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© Yannis Roussopoulos I Flowering glade in the oak forest of South Xiromero, W. Greece

INTRODUCTION

The Interpretation Manual for the Natura 2000 network and forests (European Commission 2003), also includes anthropogenic/transitional habitats (i.e. habitats evolving towards a potentially more mature vegetation state), such as heathlands, wooded peatlands, open/grazed forests, natural grasslands, or pastures. There are assigned to one of the three functional groups of the Annex I habitat types of Community importance (Directive 92/43/EEC).

Wood-pasture habitats have a high proportion of ecotone cover, supporting a wide variety of microhabitats, species, and ecosystem services.

Agro-forest habitat types occupy a spatial level between an ecosystem and a landscape, meaning they are in fact a complex of varying habitat types. These habitat/ecosystem complexes may be continuous because they refer to a series of plant communities/ecosystems along a successional gradient, or to a connected series of spatially adjacent plant communities. Agro-forest habitat types comprise elements of both ecosystem complexes, which can only be understood when the ecology and dynamics of the plants and their communities are known. This objective has not yet been achieved at European level.

In places where grassland and woodland are kept apart, their margins are well-defined and the ecotone is narrow, in contrast to the margins of wood-pasture which are wide, indistinct, and not always identifiable.

In patchy wood-pastures, the wood-pasture ecotone forms a major part of the entire wood-pasture area. A high ecotone proportion is the key factor for high species and niche densities of pastoral woodlands (Bergmeier 2010). Wood-pastures provide a wide range of local climate conditions, vegetation and soil types, thus creating a variety of microhabitats.

THREATS AND PROBLEMS

Threats to wood-pasture habitats result primarily from changes in traditional land-use practices caused by overall social and economic changes in rural activities. Such changes may follow two different paths:

(a) intensification of livestock farming that leads to overgrazing and hence to an increase in herds or grazing intensity, or

(b) abandonment of livestock farming followed by loss of small-scale habitat diversity.

As for other non-intensively used habitats, agricultural expansion and intensification, urbanization and road construction and other infrastructure lead to an increased fragmentation of wood-pasture habitats. More specific problems include:

Reduction in old-growth tree density

Much of the diversity of grazed forests and wood-pastures depends on the presence and abundance of old-growth, tall and broad-canopy trees, such as oaks, beeches, chestnuts, or other species. If the natural loss of old trees is not compensated by rejuvenation, the results are either open pastures or stone/rocky slopes, when overgrazing is practiced, or a more or less dense forest, through dynamic vegetation succession processes, when woodlands are not grazed.

Overgrazing

A main problem of existing wood-pastures in Greece and Spain is the lack of regeneration and woodland ageing (Dimopoulos and Bergmeier 2004; Plieninger et al. 2003). It is not yet known whether this is a problem associated with permanent, century-old wood-pastures, or a problem that has only arisen during the last decades of overgrazing. The lack of seedlings and juvenile trees is mainly observed in grazed forests, with sheep and goat grazing. Due to the high number of animals, the surface soil layer is affected by trampling, and young trees and shrubs are affected by selective browsing. Overgrazing also reduces the area of herbaceous vegetation under bushes. Otherwise, shrubby plants would serve as a shelter for the shade-demanding tree seedlings. In recent years an (ecologically) unacceptable replacement of sheep and goats by large beef cattle has been observed in Greece, which in many cases (especially in areas with friable soils and steep slopes) cause overgrazing and soil erosion.

Abandonment of livestock farming

While lowland wood-pastures in Western and Central Europe were primarily abandoned in the 19th century, rural abandonment and agricultural abandonment in the European Mediterranean mainly took place in the second half of the 20th century and is continuing to this day. The abandonment of livestock farming and the consequent absence of grazing in woodlands led to scrub penetration and expansion and to denser woodlands (Figure 1), with a corresponding increase in fire risks and loss of the patchiness that is characteristic of many types of wood-pastures.

Wood-pastures are under severe threat from crop intensification, abandonment of transhumance and replacement of sheep and goats by large cattle.

Removal of old olive groves

Groves with old olive trees are a characteristic feature of the Mediterranean cultural landscape, often used in many ways, including grazing. The vegetation underneath the ancient olive trees is often very rich in species, especially orchids and other bulbous plants. In the last two decades, large areas of old olive groves have been cut down and replaced by olive-plantations of high yielding varieties. In addition, when grazing is abandoned, these plantations are ploughed to prevent the establishment of shrubs and competing herbaceous vegetation, irrigated, and sometimes sprayed with pesticides, resulting in a reduction of plant diversity. Such plantations have been established in former fields and wood-pastures, especially in southern mainland and insular Greece, in Italy, and in Spain.

FUNCTIONS AND ECOSYSTEM SERVICES

The protection of wood-pastures requires management compatible with local, traditional land use and the establishment of a systematic long-term monitoring programme.

Ecosystem functions are defined as the capacity and/or potential to provide ecosystem services. Ecosystem services in turn derive from ecosystem functions and represent the existing flow of services for which there is a demand. For the purposes of this conceptual framework, ecosystem services additionally include ecosystem-derived goods. Unlike ecosystem functions, ecosystem services require human access and demand. Healthy or 'pristine ecosystems' and wilderness areas, which are in excellent (or near-excellent) ecological conservation status, are highly functional but may provide fewer ecosystem services than less 'pristine ecosystems' (such as pastures, scrubs, agro-forestry systems, etc.), simply because there is little demand for these

Figure 1. *High and relatively dense young scrubs growing above the woodland vegetation belt in the Vikos, Zagori, Region of Epirus NW. Greece, due to the abandonment of transhumant livestock farming. © Panayotis Dimopoulos*

services. An illustrative example would be a remote forest that may provide fewer recreational services than a green urban area, such as an urban park. It is therefore important to include a full set of functions and services, as well as the ecosystem value assessment, in ecosystem services assessments (European Commission, 2011).

The recording, mapping and assessment of wood-pasture habitats and their functions is a key strategic planning tool for integrated rural management.

Due to their multi-functionality and the wide range of ecosystem services they provide, wood-pasture systems are receiving increased attention by scientists and policy makers involved in agriculture and forestry, but also in the fields of rural development, tourism, and nature conservation (Mattison and Norris 2005; Rigueiro-Rodriguez et al. 2009; Terzi and Marvulli 2006).

DISCUSSION-CONCLUSIONS

In summary, agro-forestry systems, and specifically wood-pastures, include habitat types that are ecologically transitional between woodlands and meadows, but with structures and species composition not usually found in pure forests or meadows. Many wood-pastures have a long environmental history and special characteristics, such as old trees, dead wood (dead organic matter), periodic disturbance by large herbivores and/or light conditions in the understory, which bridge the historical pastoral use with primitive Holocene forests.

The specificities of wood-pastures cannot be maintained, either through forest management or through meadows management alone. The conservation of agro-forest habitats requires:

(a) long-term management comparable to or based on the relevant/local traditional land use, and in sufficiently large areas,
(b) systematic monitoring to avoid both overgrazing and undergrazing or full abandonment of grazing. In many cases, continued anthropogenic intervention is absolutely essential for habitat conservation.

To establish the clarity of future management and conservation objectives for grazed forests in Europe, it is necessary to define wood-pasture categories and assess their extent and conservation status in European countries (Bergmeier et al. 2010).

STRATEGIC PLANNING AND INTEGRATED MANAGEMENT OF WOOD-PASTURE HABITATS

The inventory, mapping and assessment of wood-pasture habitats and their functions is one of the main tools for drafting the strategic planning for an integrated area management. In the light of expected or estimated demographic, economic and social changes, as well as of the climate crisis, it is proposed to develop a roadmap with concrete steps to achieve the objective of integrated management, utilizing the best available data, resources, and practices (Figure 2).

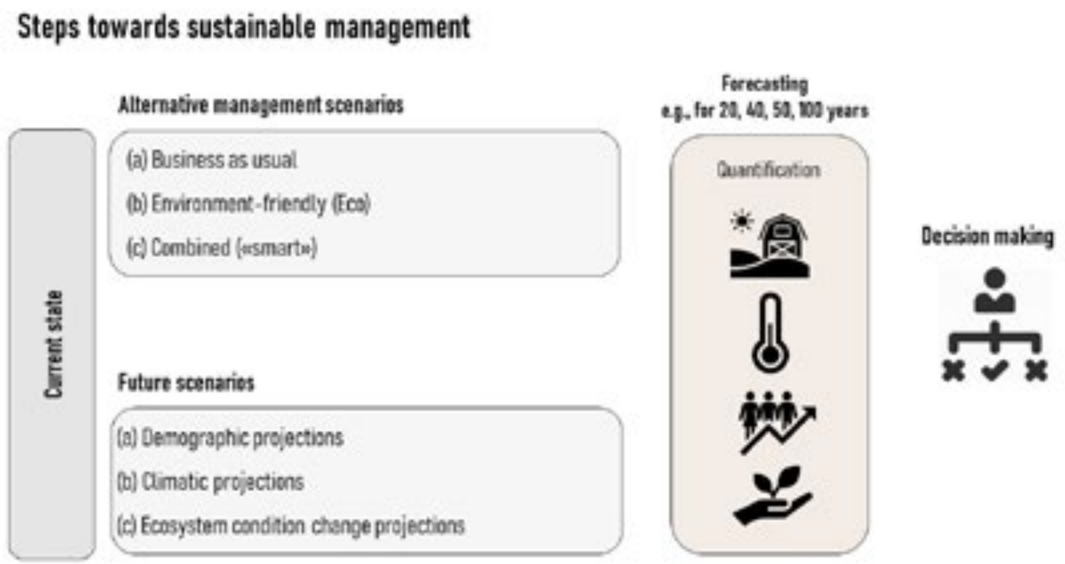

Figure 2. *Steps for integrated management (Kokkoris et al. 2019).*

For the project to be successful, the interaction and contribution of all stakeholders in the process of policy making and organizational and management decisions is needed. For this process to be effective, the available data, scenarios (models) and methodologies need to be fully comprehensible and adapted to both the profile of the stakeholders and the profile of the decision-makers.

© Yannis Roussopoulos I Terraces cultivations and valonia Oaks, Island Saint Efstratios, Northern Aegean sea

Vegetation, flora and threatened plant species in agroforestry systems

Key words: natural hedgerows, valonia oak forests, broadleaf evergreen shrubs

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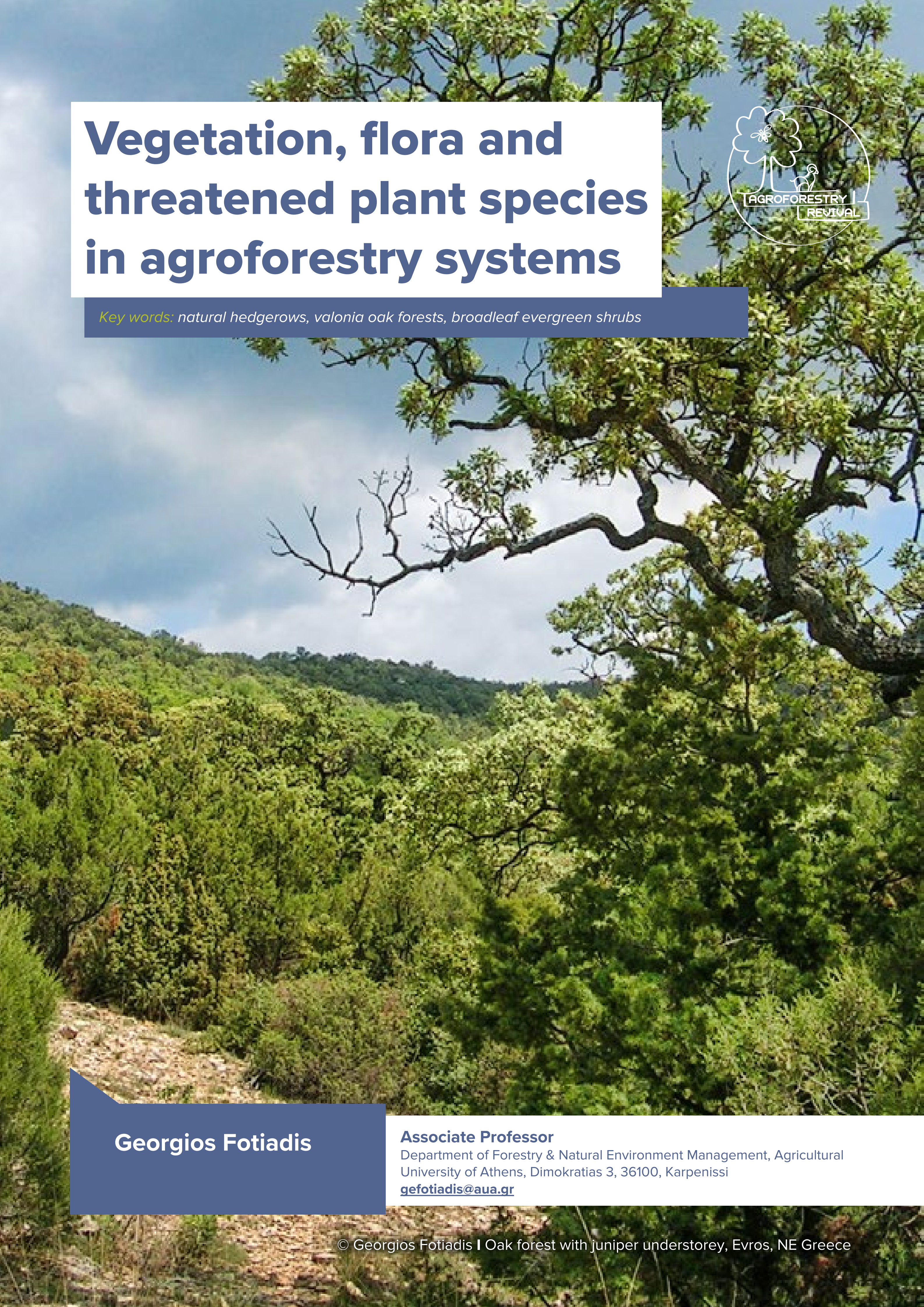

© Georgios Fotiadis I Oak forest with juniper understorey, Evros, NE Greece

INTRODUCTION

Vegetation in the Mediterranean basin has been formed for millennia alongside human activities, as a result of the same land surface being used for human needs and demands for multiple uses. Because vegetation and landscapes are part of the daily life of those exploiting them, they include special systems, called agroforestry systems that host many plant species, which are sometimes rare and important for the purposes of conservation and exploitation.

Semi-natural hedges usually they do not "constitute" agroforestry systems, but participate in combination with pastures and agricultural land

SHRUBLAND AGROFORESTRY SYSTEMS

Shrublands are perhaps the most interesting Mediterranean landscape to have been co-shaped by humans, directly related to grazing and firewood collection and constituting the most common agroforestry landscape in Greece.

Most of these shrublands are dominated by evergreen broad-leaved species, mainly by the kermes oak (*Quercus coccifera*), lentisc (*Pistacia lentiscus*) and strawberry tree (*Arbutus unedo*), spreading almost across the Mediterranean zone (Dafis et al. 2001).

The broad-leaved evergreen shrubs (Figure 1), especially the kermes oak stands, were the main areas for goat grazing. They also provided valuable firewood and due to their great resistance to grazing, managed to survive and reduce soil erosion in mountainous and semi-mountainous areas. In areas where they were converted to crops, parts of them remained at the edges of agricultural land, acting as conservation zones for important species of flora and fauna. Agroforestry systems can also include carob (*Ceratonia siliqua*) - olive (*Olea europaea*) shrublands; due to degradation from intense past management or recent abandonment, today these are mainly carob or olive grazing crops, where important plants adapted to highly xerothermic conditions survive (Caballero et al. 2009, Ispikoudis et al. 2021).

Figure 1. *Kermes oak shrublands and cypress forest in the background (Katharo Plateau, Crete) © Georgios Fotiadis*

In less dry areas in Central and Northern Greece, the semi-natural hedges (Figure 2) are composed of deciduous species (e.g. Jerusalem thorn – *Paliurus spina-christii*, European field elm – *Ulmus minor, U. procera*, bramble – *Rubus* spp.), constituting the “silbjak” or, as the locals call them, “tsalia” or “lumakia” formations. **Semi-natural hedgerows do not usually ‘constitute’ agroforestry systems, but participate in them in conjunction with pastures and agricultural crops.** “Tsakna”, meaning the thin wood for tinder, as well as larger firewood, were collected from the semi-natural hedges. At the same time, a large number of woody species of hedgerows were used for grafting, such as the almond-leaved pear (*Pyrus spinosa*) and for their edible fruits, such as the blackthorn (*Prunus spinosa*) and the Cornelian cherry (*Cornus mas*). Individual large trees were a resting place for farmers, herders and animals during the hot hours of the day (Ispikoudis et al. 2021). The flora composition of these systems mainly includes nitrophilous and synanthropic species that are favored by fertilizers and the presence of many farm animals in small or larger areas. Nevertheless, due to the strong heterogeneity in structure and the special conditions of the places where they grow (at the borders of agricultural land, in small spots where water is collected and nutrients are deposited), they have a particularly high plant diversity with many annual species (Fotiadis 2004).

The oak forests are the meeting place of wood and livestock products

Figure 2. *Semi-natural plant hedges between crops (Mt Helikon, wider area, Viotia, Central Greece) © Georgios Fotiadis*

CONIFEROUS FOREST AGROFORESTRY SYSTEMS

The pine forests spreading along the coastlines, specifically the Aleppo pine (*Pinus halepensis*), Calabrian pine (*P. brutia*) and stone pine (*P. pinea*) forests are among the most special agroforestry landscapes of the Mediterranean. They create forests either on stable soils (mainly *Pinus halepensis* and *P. brutia*), but also on sand dunes (mainly *P. pinea*, often mixed with other species). In fact, sand dunes with *P. pinea* forests are a priority habitat type under Directive 92/43/EEC, code 2270 (Dafis et al. 2001). The collection of resin and the production of edible pine nuts in the pine forests were a very important occupation of the forest-dwelling populations. Additionally, they required cleaning of the understory, which removed significant amounts of biomass and thus reduced the risk of catastrophic fires. The removal of the understory biomass and the maintenance of an open canopy in these forests also allowed their use as pastures for farm animals. Their floristic composition was influenced by many factors and mainly by the intensity of their use. In intensively grazed forests the understory consisted of phrygana (e.g. dominated by *Sarcopoterium spinosum*), in resin-extracted and intensively grazed forests it consisted of resistant herbaceous species (e.g. *Allium chamaemoly*), while in forests without such activities the understory was dense, with the participation of many evergreen broad-leaved shrubs (e.g. *Pistacia lentiscus, Erica arborea*). The abandonment of many agricultural activities has turned these forests into dense stands (due to rapid understory growth), making them impassable and at risk of devastating crown fires. On the other hand, the pine forests of the mountainous zone and especially those of the Scots pine (*Pinus sylvestris*) and the Bosnian pine (*Pinus heldreichii*) (Figure 3), which, in addition to their valuable wood, were also used as summer pastures or places for livestock sheds, host interesting plant species of central and northern European origin, such as e.g. *Avenella flexuosa* (Dafis et al. 2001, Caballero et al. 2009).

The mountain cypress forests of Crete and Symi represent a very special type of vegetation and agroforestry system for Europe. Their exploitation began in ancient times for their valuable wood, especially for shipbuilding, but they were also an important pasture for sheep and goats. In these forests, important endemic and rare plant species are often found, such as the endemic *Asperula pubescens* and *Silene sieberi* (Dafis et al. 2001).

Figure 3. *Bosnian pine meadow (Vasilitsa, Grevena, NW Greece) © Georgios Fotiadis*

Juniper forests and shrublands are found throughout Greece, from coastal sand dunes up to very high altitudes, dominated by different species depending on the substrate and the altitude zone (e.g. *Juniperus oxycedrus, J. phoenicea, J. macrocarpa, J. foetidissima, J. drupacea, J. excelsa*). Many of them are classified as priority habitat types under the codes 2250 (Coastal dunes with *Juniperus* spp.) and 9560 (Endemic forests with juniper species (*Juniperus* spp.)). Juniper species are mainly photophilous and very resistant to dry conditions and intense grazing. At the same time, however, they are among the slowest growing species, and for this reason they produce good quality wood, while the fruit of some species is used in cooking and for the production of beverages. Many important and rare plant species are found in these forests; they include species limited to the Balkan Peninsula with a small distribution, such as *Iris attica*, or Greek endemic species, such as *Cerastium candidissimum* and *Marrubium velutinum*. In fact, in the low canopy cover juniper forests of Prespa National Park (NW Greece), a very high plant diversity was observed, with up to more than 20 plant taxa per 0.25 square meters. However, the diversity of these ecosystems is threatened by the reduction or even abandonment of grazing, as they are gradually replaced by broadleaf or fir forests (Vrahnakis et al. 2011, Fotiadis et al. 2014). Moreover, tourism poses a significant threat to juniper formations on coastal sand dunes.

BROADLEAF AGROFORESTRY SYSTEMS

One of the peculiarities of Mediterranean forests is that apart from the familiar purposes they serve as forests, they are also used as important grazing sites.

Oak forests constitute the "meeting point" of timber production and livestock production: they include all types of oak forests that were preserved as grazing grounds (Pantera et al. 2009, Ispikoudis et al. 2021), such as Macedonian oak (*Quercus trojana*) and valonia oak (*Quercus ithaburensis* subsp. *macrolepis*) forests. The most well-known of these forests are those of Foloi in the Peloponnese and the "Kuri" forests of Almyros (Volos), Mouria (Kilkis) and Kozani, which they were specially managed: grazed during the summer and pruned before the winter to gather animal fodder and wood, the main source of energy for the forest-dwelling populations (Caballero et al. 2009, Ispikoudis et al. 2021). Their special management has resulted in the appearance of plant species that are usually found in forests (e.g. *Lathyrus laxiflorus*), as well as species that are adapted to grazing (e.g. *Phlomis fruticosa*). They additionally host other important species, while, according to Fotiadis et al. (2006), 35 endemic species and subspecies were recorded only in valonia oak forests in Greece, of which 30 are Balkan- and sub-Balkan endemics, and 5 are Greek endemics.

A special case of forest-meadow systems are the alpine beech forests (*Fagus sylvatica*) (Figure 4), which have a limited distribution in the high mountains of Northern Greece. They are important forests, with a protective role for downhill lands, but due to their development (in continuity with alpine meadows) they were either grazed or their trees were systematically pruned for livestock winter fodder. The understory of these forests features rare plant species for the Mediterranean region, which are usually found in Central Europe, such as *Lactuca alpina, Rumex arifolius*, but also Balkan endemics such as *Acer heldreichii* (Strid et al. 2020).

Alder (*Alnus glutinosa*), willow (*Salix* spp.) and plane (*Platanus orientalis*) wetland forests are among the most interesting forest-meadow systems, as they were used, mainly in the past, as a resting place for farm animals. Yet willows (*Salix* spp) were also for centuries a "medicine" for animals, as their bark contains large amounts of salicylic acid, while alders had a double pruning purpose, both for fodder and wood (Ispikoudis et al. 2021).

EPILOGUE

Vegetation is often co-shaped based on the needs and therefore the activities of the inhabitants of an area. In Mediterranean ecosystems, the strong relief and xerothermic conditions resulted in the creation of complex types of agroforestry systems. Gradually, however, the abandonment of activities and/or the change of traditional activities have led to the reduction of the mosaic-like structure of the vegetation and therefore its diversity. The lack of grazing and/or the abandonment of small crops and terraces leads to the gradual densification of forests and shrublands with a serious risk of biodiversity loss as well as an increased potential for large destructive fires.

The abandonment of activities and/or the change of traditional activities have led to the reduction of vegetation mosaics and therefore to their diversity

Figure 4. *Alpine beech forests (Varnoudas Mt, Prespa National Park, NW Greece) © Georgios Fotiadis*

Birds and agroforestry landscapes in Greece

Key words: landscape mosaic, spatial heterogeneity, endangered farmland birds, rural abandonment

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© Yannis Roussopoulos I Woodchat shrike *(Lanius senator)*

INTRODUCTION

Agroforestry landscapes are the result of centuries of mild disturbance on natural ecosystems, especially in the Mediterranean area, where people worked the land with the aim of autonomy and more efficient harvesting of limited lands in order to address their subsistence needs (Ispikoudis et al 2021). The main characteristic of agroforestry landscapes, one that determines their conservation value for birds, is their mosaic; that is the coexistence of various distinct ecotopes (pasture, field, shrubland, forest, water body) in a complex mix and in limited space, usually at a radious of 5-8 Klms around settlements (Poirazidis et al. 2021). Apart from the vegetation, additional but very important factors of heterogeneity are various anthropogenic microhabitats like stone walls, buildings, water reservoirs and others.

Farmland birds are the most threatened group of birds in Europe

Spatial heterogeneity and dynamic changes of these systems through human influence, in combination with a Mediterranean climate, contribute to the great conservation value of agroforestry landscapes for biodiversity and especially for bird species richness, since in relatively small spatial scales dense forest bird species coexist with species of open landscapes (Brotons et al. 2018).

The mix and alternation of habitats create a significant length of edge habitats, which favours all species of birds that benefit from the ecotone (i.e. *Laniidae*), while at the same time attracting species of open pasture areas (i.e. *Alaudidae*) and birds characterized as forest dwellers, like woodpeckers, as well as raptors, falcons, owls and also waterbirds, when circumstances allow (Tsiakiris et al. 2009).

The value of agroforestry landscapes for the conservation of birds lays in the fact that both at European and national level, farmland birds are **the most threatened category of birds**, while other categories of birds like “waterbirds” and “raptors” have restored their population levels and their range. This is because sweeping changes have resulted in the intensification of farming coupled with land abandonment, especially during the second half of the 20th century (EEA 2020).

BIRD FAUNA OF AGROFORESTRY SYSTEMS IN GREECE

One third of the 453 bird species that have been recorded in Greece, a total of 147 species, are characterized as **"species of agropasture systems"**, from which 95 species are breeders in Greece (Figure 1). This category features the highest number of species compared to other categories in Greece and contains species of open areas. Their basic habitats are: cultivated land, pastures (mesophile, dry, alpine), areas with scree and maquis, shrublands, rock faces, agroforestry areas and others. Most species nest on the ground or in bushes, and also this group includes martins and swifts that nest in buildings. Their diet includes insects, seeds, fruits and berries (Dimalexis et al. 2004).

This category primarily includes: Passerines, such as wheatears *Oenanthe sp.*, warblers *Sylvia sp.,* shrikes *Laniidae sp.* and buntings *Emberiza sp.*; species of open lands like pipits *Anthus sp.;* ground birds like larks *(Alauda arvensis, Lullula arborea, etc.*)*,* partridges *(*grey partridge *Perdix perdix* and rock partridge *Alectoris graeca);* the quail (*Coturnix coturnix)*, Coraciiformes (Bee-eater *Merops apiaster),* the hoopoe (*Upupa epops*), the roller (*Coracias garrulus*); cuckoos and other rare or threatened species, such as the thick-knee and the turtle dove, or even invasive species like the rose-ringed parakeet (*Psittacula krameri)* and the cattle egret (*Bubulcis ibis)*.

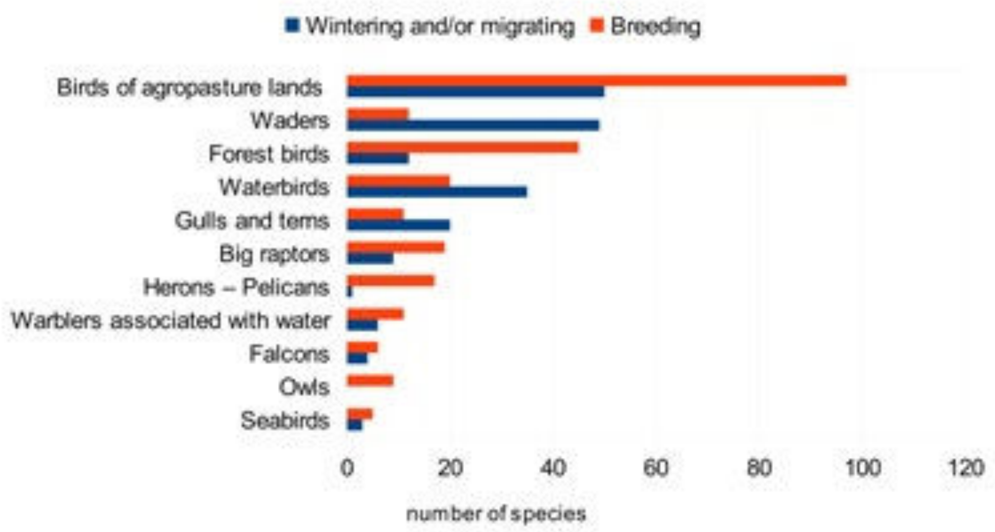

Figure 1: *Number of species per category of the birds of Greece (source Dimalexis et al. 2004)*

Associated with agroforestry landscapes are also species of other groups, mainly large raptors (Alivizatos et al. 2014), owls (little owl *Athene noctua*, scops owl *Otus scops*, barn owl *Tyto alba),* woodpeckers (balkan woodpecker *Dendrocopos syriacus*, little woodpecker *Dryobates minor*, wryneck *Jynx torquilla)* and forest birds (tits *Parus sp.,* flycatchers *Muscicapa sp.* and *Ficedula sp.* and thrushes *Turdus sp.)*

Sometimes and depending on local circumstances of landscape formation, the agroforestry landscapes are home to waterbirds like Herons (grey heron *Ardea cinerea*, little white egret *Egretta garzetta*, little bittern *Ixobrychus minutus*), ducks (mallard *Anas platyrhynchos*, ferruginus duck *Aythya nyroca*), coot *(Fulica atra)*, and moorhen *(Gallinula chloropus).* These birds can be observed in small artificial ponds or small natural wetlands which constitute spatial structural elements and are maintained and used by farmers and animal breeders for their water needs.

Agroforestry landscapes host a great variety of birds, because of their spatial heterogeneity

All the above species all the above species benefit from agroforestry landscapes during their breeding period, either because they nest or because they use the landscape for foraging. In fact, some, are typical "anthropophile species", like the white stork (*Ciconia ciconia)*, the lesser kestrel (*Falco naumanni)*, the little owl (*Athene noctua)* and the levant sparrowhawk (*Accipiter brevipes)*. Agroforestry landscapes are also very important for the migration and wintering of birds, because

there they find abundant food resources (Brotons et al. 2018).


© Yannis Roussopoulos I Rock partridge *(Alectoris graeca)*

CONSERVATION / THREAT STATUS

Agroforestry landscapes host the greatest part of rare and threatened species in the 27 member states of the E.U. (Birdlife International 2017, EEA 2020), which in the Mediterranean region are linked to agroforestry systems (like the *Alaudidae* species) and with areas of sparse vegetation or single trees (like the *Laniidae* species) (Bueno et al. 2019).

Short-term population trends for farmland birds reveal that 54% of species are declining, 21% are stable and only 18% are improving (Figure 2 / EEA 2020). The E.U. Environmental indicator for the common species of birds, shows a decline of nearly 35% within the last 30 years, for 39 species of common farmland birds (Figure 3 / Eurostat 2020).

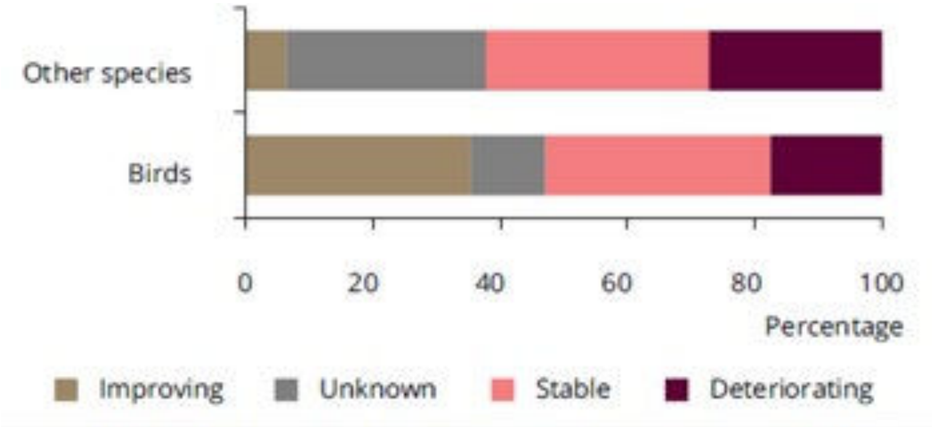

Figure 2: *Conservation status of farmland birds in the EU (EEA 2020)*

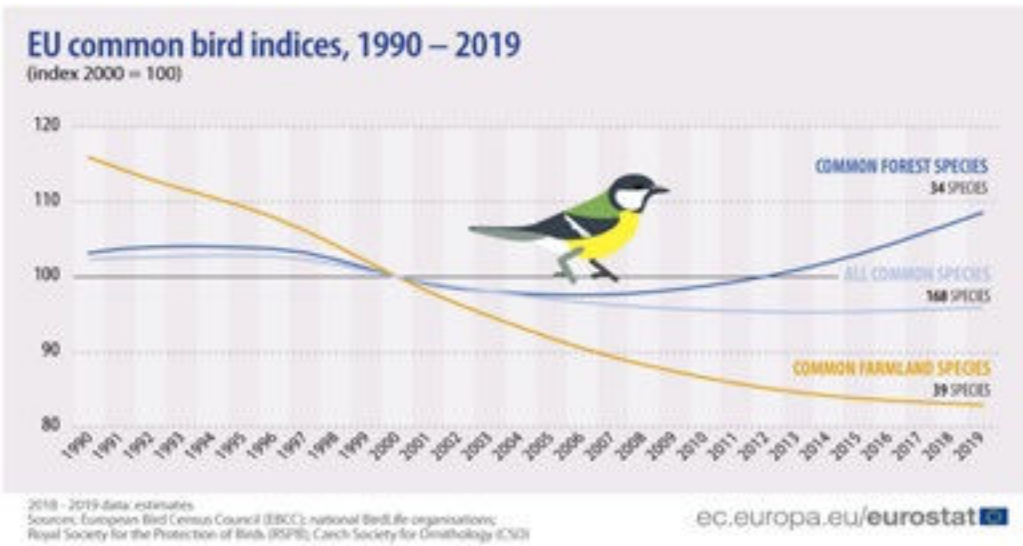

Figure 3: *Population trends of common birds in the EU (source: Eurostat 2020)*

In Greece, there are 147 species in the category "Species of Agropasture lands", of which 60 species are threatened or protected, with 39 breeders, while 21 species are now globally threatened (Table 1). In total, 8 species are included in IUCN's Red List, 18 species are referred in the Red Book of Threatened Animals in Greece and 20 species are mentioned in one of the three categories for Species of European Conservation Concern (SPEC).

Table 1: Conservation status of the most important breeding species of farmland birds in agroforestry systems.

Scientific name	Common name	Greek Red Data Book 2008	IUCN 2021	SPEC 2017	Annex I Directive 2009/147/EC	Marginal distribution in Europe
Hippolais olivetorum	Rock partridge	VU	NT	1	I	x
Sylvia rueppelli	Grey partridge	EN		2		
Sylvia nisoria	Quail		NT			
Lanius minor	Pheasant	CR				x
Lanius senator	Stone curlew	NT		3	I	
Lanius nubicus	Turtle dove		VU	1		
Pyrrhocorax pyrrhocorax	Great spotted cuckoo		VU			x
Corvus frugilegus	Swift		NT	3		
Emberiza cineracea	Roller	VU			I	
Melanocorypha calandra	Calandra lark	VU		3	I	
Alauda arvensis	Skylark	NT		3		
Oenanthe isabellina	Isabelline wheatear	NT				x
Hippolais olivetorum	Olive tree warbler	NT			I	x
Sylvia rueppelli	Rüpell's warbler	NT			I	x
Sylvia nisoria	Barred warbler	NT			I	x
Lanius minor	Lesser grey shrike	NT			I	
Lanius senator	Woodchat		NT	2		
Lanius nubicus	Masked shrike	NT			I	x
Pyrrhocorax pyrrhocorax	Red-billed chough	EN			I	x
Corvus frugilegus	Rook		VU			
Emberiza cineracea	Cinereous bunting	EN	NT		I	x

Legend: CR – Critically Endangered, EN – Endangered, NT – Nearly Threatened, VU – Vulnerable

SPEC Categories (Species of European Concern): 1- European species of global conservation concern, 2- Species whose global population is concentrated in Europe and are classified as endangered, 3- Species whose global population is not concentrated in Europe, but they are classified as endangered

To the above species must be added species that are inseparable from agroforestry systems and, even though they are not threatened, are considered vulnerable due to their very restricted range in Europe. Furthermore, the need to protect species with rapid decline, like the turtle dove and the rock partridge, or with limited global distribution, like the levant sparrowhawk and the sombre tit (Box 1, page 89), make it imperative to adopt measures for the protection and conservation of agroforestry landscapes, as part of the country's responsibility for biodiversity conservation in Europe and the planet. Finally, it is characteristic that Greece is the second most important country in Europe after Italy for the breeding populations of the rock partridge (near threatened species on a global level) and hosts more than 30% of the global population. Additionally, it is important for the levant sparrowhawk, a species characterized as rare in Europe (BirdLife International 2017). Other species of agroforestry systems, with a marginal distribution in Europe are the rock nuthatch, the rose-coloured starling, the barred warbler, the orphean warbler, and the olive-tree warbler.

Conserving agroforestry landscapes relies upon on the continuation of mild traditional land uses

© Maria Panagiotopoulou I Sisani, Kozani, Western Macedonia

PARTICULARITIES OF THE AGROFORESTRY HABITATS

All the above-mentioned species need specific structural characteristics of the agroforestry landscapes, such as single old trees and scattered bushes mixed with farmland, hedges, stone walls and creeks, or even some small burned areas. For example, the roller *(Coracias garrulus)*, which retains 40% of its global distribution in Europe, is gradually and slowly decreasing, to a rate of 5-20% during the last 30 years, because of the removal of old trees at large scales from farmland landscapes, where it nests (BirdLife International 2017).

Another threatened species that nests in single trees growing in Mediterranean agroforestry areas is the woodchat shrike *(Lanius senator)* which has a strong preference for locations with low vegetation that are grazed. Also, the woodlark (*Lullula arborea)* is a species which uses both forest and open habitats and benefits from the length of forest edge, which is particularly high in agroforestry landscapes (Zakkak et al. 2016, Panagiotopoulou et al. 2017).

Additionally, the red-backed shrike (*Lanius collurio*) is a species preferring the ecotone and is currently threatened either by land reclamation works that destroy hedges, by intensive agriculture and the use of agrochemicals, or by abandonment of periodic farming and animal raising at small scale, that leads to natural afforestation and eventually to the loss of open habitats such as nesting spots with sparse small trees and thorny bushes (Tsiakiris 2000, Zakkak et al. 2015).

Agroforestry landscapes include protective and/or sacred forests, which offer nesting spots for many species, as they preserve aged trees with many cavities (Avtzis et al. 2018). They are primeval forests which are managed locally and comprise valuable islets for many species, mainly for woodpeckers, like the balkan woodpecker (Stara et al. 2015).

In all cases the spatial heterogeneity in agroforestry systems is the fundamental characteristic for the conservation of farmland birds and biodiversity (Zakkak et al. 2016, Panagiotopoulou et al 2017). Since agricultural intensification or abandonment of marginally productive lands is the main threat for 21% of protected birds in the EU (EEA 2020), low recovering rates of farmland birds are possibly due to the fact that coverage of Special Protected Areas (SPA's) is inadequate for these species, or that their habitats within SPA's have not significantly improved (EEA 2020).

CONCLUSIONS

All the above result in a paradoxical contradiction between the conservation value and naturalness in Mediterranean agroforestry landscapes for birds. The most preserved open habitats, that could be characterized as less natural compared to original forests, have a greater conservation value, because they host more and rarer species, primarily species that prefer open habitats and low bushy vegetation. Consequently, for the conservation of these groups of species, there is a need for a socioeconomic approach aimed at preserving traditional land use in these landscapes through the continuation of low intensity farming activities (Brotons et al. 2004).

It is evident that common farmland birds are decreasing throughout Europe. However, there are hopes, stemming from the few agroforestry landscapes that "survive" and retain the variety of bird fauna as mentioned above. These are areas that escaped intensification and land use change and today constitute a paradise for farmland birds in many areas around the Mediterranean, including many areas in mainland and island Greece (Tsiakiris et al. 2009).

The dynamics of these ecosystems can be preserved only through traditional practices that can help bird species survive. Extensive grazing by sheep and goats, conservation of traditional cultivations, or even controlled burning and other tools must be implemented in order to preserve or restore a mosaic of open agroforestry habitats (Tsiakiris et al. 2009).

© Maria Panagiotopoulou **I** Little egrets *(Egretta garzetta)*, Nymphopetra, Central Macedonia, Greece

THE “BALKAN” SOMBRE TIT
(Parus lugubris, new name *Poecile lugubris)*

One of the most characteristic species of agroforestry landscapes in mainland Greece (Thessaly, Epirus, Macedonia, Thrace) is the sombre tit (*Poecile lugubris*, Figure/Illustration 4), a species related to the tits, as it belongs to the *Paridae* family. It has a very limited global distribution, in southeast Europe and mainly the Balkans, extending eastwards to Asia Minor (Turkey, Syria, Lebanon) and marginally to Georgia and the Middle East (Catsadorakis and Källander 1999). Despite its limited distribution the sombre tit is not included in any category of threatened or protected species.

In Greece it is found at altitudes up to 2000 m., in a variety of habitats, although in more open habitats compared to those of other related *Paridae* species, and almost always it seems to avoid dense forest. Typical habitat of the species are slopes with sparse tress (oaks, olive trees) and shrubs (e.g. *Juniperus)* that include terraces with cereals, non-intensively cultivated or abandoned fields, small openings and pastures in forests of Aleppo pine, grazed shrublands, maquis areas with sparse trees or bushes that include olive trees, fruit trees like prunes and almond trees, vines and sparse forests with oak, beech, willow and poplar or conifers, especially in stony areas with sparse vegetation, even in the sparse forest pastures of mountain forest boundaries, often with centuries old junipers (priority habitat 9560). In Prespa, a typical habitat of the species is the ecotone between broadleaved forest and farmland. It is a zone at altitudes between 850 and 1100 m., that contains grasslands, villages, small farms with natural hedges and stone walls (Catsadorakis and Källander 1999).

It breeds from March to early August and is monogamous. It feeds on seeds and is a hoarding species, caching and storing food for the winter (Panayotopoulou et al. 2006). In North Greece the sombre tit has sparse populations and a patchy distribution and it is one of the least known species.

Map: Global distribution of sombre tit (source: Birdlife International)

Iconic birds of prey in agroforestry systems

Key words: necrophagus birds, extensive pastoralism, habitat mosaic

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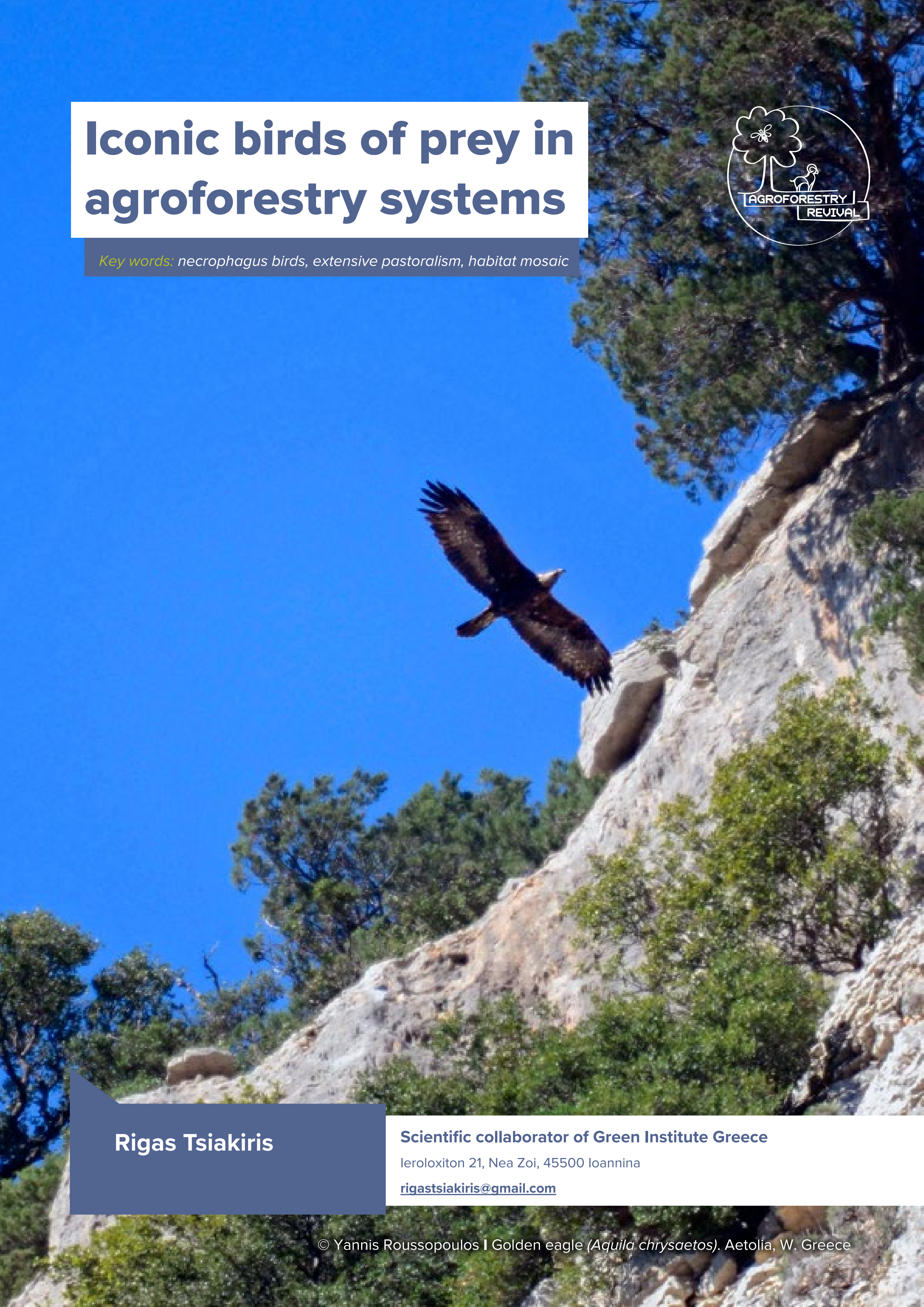


 I Golden eagle *(Aquila chrysaetos)*. Aetolia, W. Greece

INTRODUCTION

No other group of animals is as closely associated in our minds with agroforestry landscapes as birds of prey, particularly large vultures and iconic eagles. And this is no coincidence in evolutionary terms, since such landscapes (natural or man-made) in Europe attract the largest variety of raptor species on the planet, especially in spring and summer. Especially regarding vultures, which in the recent past were the most numerous group of birds of prey worldwide, Europe is currently considered as the region witnessing their fastest recovery, even though most vulture species around the world are still threatened with extinction.

European vultures, as they are inextricably linked to extensive livestock farming, are the most typical species of agroforestry landscapes

Moreover, although most large birds of prey nest in trees, they need a mosaic of "open" areas to locate their prey, in such variety and abundance as to be sufficient to maintain robust populations, either in the nesting or in the wintering area. This is also the reason why many European birds of prey from agroforestry landscapes migrate to the savannahs of Africa.

© Hristo Peshev **|** Griffon vultures Kresna Gorge Boulgaria

NECROPHAGUS BIRDS OF PREY AND TRANSHUMANCE

All European Vultures, namely the griffon vulture (*Gyps fulvus*), the black vulture (*Aegypius monachus*), the bearded vulture (*Gypaetus barbatus*) and the Egyptian vulture (*Neophron percnopterus*) are almost exclusively necrophagous species, so it is not surprising that they are associated with extensive livestock farming and agroforestry landscapes.

Humans have been associated with vultures from the dawn of civilization to the present day. Originally, humans followed vulture flocks to find and steal meat from the fresh carcasses that vultures had located and were feeding on. In modern times, by contrast, vultures follow humans and the herds of farm animals that have replaced those of ungulates or, more recently, gather in places were carcasses of intensive farming units are disposed of (Panagiotopoulou et al. 2018).

Figure 1: *The map (left) shows frequent vulture flights in summer in western Greece, as recently recorded by satellite telemetry. For example, the vulture coded H2 (right), started in the morning from the colony in Palairos, wandered across the southern Pindos mountain range, flew almost up to the city of Ioannina and returned to roost in the colony of Kleisoura in Messolonghi, travelling about 500 km in one day (map source: google earth) © Picture of griffon vulture: Yannis Roussopoulos.*

Particularly in the southern Balkans, characterized by an extremely varied relief, a sequence of agroforestry landscapes seems to have dominated the wider area until the pre-industrial period, starting from the coastal areas and reaching up to the high mountains.

These landscapes, carved by extensive livestock farming (either transhumant or around villages) and agriculture around scattered settlements, were also linked to the evolution of various cultural systems and the particular cultural identity of local societies that had been practicing agroforestry for centuries. In particular, the 'savannah-like' woodland landscapes and the wooded pastures are very similar to those created at the end of the glacial period. They were probably the continuation of the African savannah extending along the entire eastern Mediterranean, where herds of wild ungulates seasonally moved, followed naturally by scavenging vultures. Recently, the application of satellite telemetry to tagged griffon vultures born in their last colonies in the Balkans (and also to migrating Egyptian vultures) show that they still follow the same route, foraging in agroforestry landscapes in the Middle East, the Arabian Peninsula and East Africa, reaching as far as the Iran-Iraq border, in land-

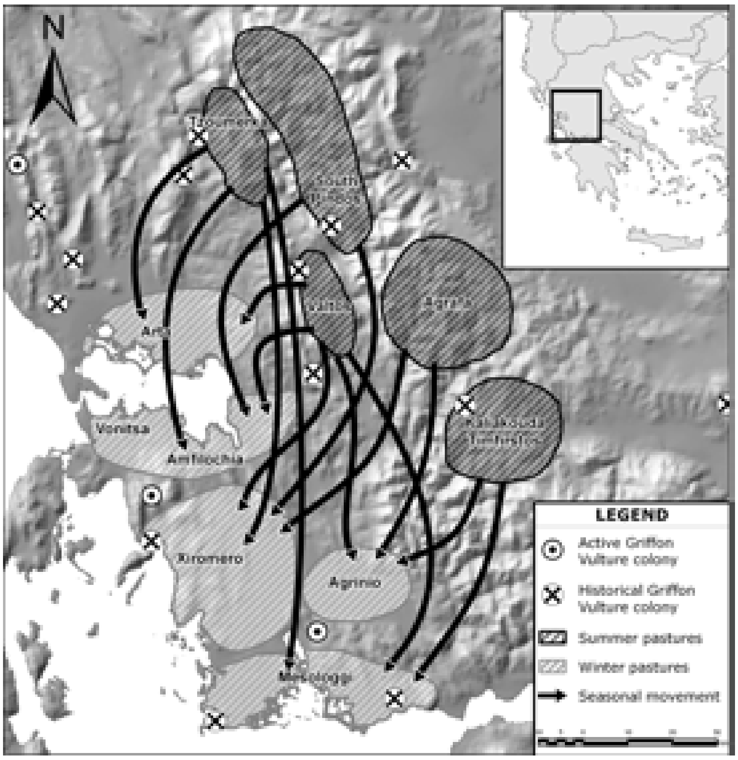


Figure 2. *Indicative map of transhumant herders' movements to the western wintering grounds (based on Psichogios et al. 1987) and vulture colony locations (Tsiakiris et al. 2014).*

scapes strongly reminiscent of semi-mountainous Greece and where extensive livestock farming and small-scale agriculture around villages is still the main force shaping the cultural landscapes (Tsiakiris et al. 2018).

Although the collapse of vulture populations worldwide has been mainly associated with the widespread use of poison baits, which is linked to the intensification of livestock production and the global effort to reduce losses by carnivorous mammals, the last seven continental nuclei of permanent vulture presence in the Balkans (Peshev et al. 2021) have largely maintained the agroforestry landscape that meets their needs. Typical areas like these in our country are found in Eastern Thrace, Western Macedonia, and especially in Aitoloakranania, where together with the mountains of southern Pindos they constitute the only and most extensive similar nuclei in the Balkans, where vultures still live without supporting conservation actions (e.g. artificial feeding places or "vulture restaurants"). It was recently found, again with the help of satellite telemetry, that they travel distances of up to 500 km per day (Figure 1), searching for dead animals in the extensive pastures (wood pastures, scrublands and mountainous upland grasslands) where extensive livestock farming has been practiced for centuries (Tsiakiris et al. 2014, see Figure 2).

Similar landscapes in Crete are home to the highest density and the largest number of vultures in the world, and the only, now partly safe, island population of bearded vulture on the planet. The same is true for the last three areas where black vultures have been breeding until recently, namely Aetoloakarnania, Olympus, and Eastern Thrace. The latter still maintains the only viable nuclei of the species in Eastern Europe, not only thanks to the conservation actions of their last colony in Evros' Dadia but also due to a large area in the eastern Rhodopes, where the local Pomak population continues to maintain the largest agroforestry landscape in the Balkans. Finally, a recent study on the breeding habitat of the globally threatened Egyptian Vulture (Oppel et al. 2017) showed that it prefers agroforestry mosaics, often around settlements and livestock facilities. Combining the current distribution maps of vultures in the continental Balkans, one would be surprised that these primarily occur in border areas, where often for political reasons agroforestry landscapes with a strong mosaic of land use still dominate, resembling the pre-industrial forest-pasture landscapes in the pastoral areas of the rest of central and northern Europe.

EAGLES AND SMALLER BIRDS OF PREY IN THE AGROFORESTRY MOSAIC

Starting from coastal areas and inland wetlands, ospreys (*Pandion haliaetus*) and sea eagles (*Haliaeetus albicilla*) nest in riparian forests and adjacent scattered trees, hunting fish and a variety of animals in the surrounding areas. These trees are also the roosting sites for the spotted eagle (*Clanga clanga*) in winter. Following the topography of the inland lowland and semi-mountainous areas with 'open' forests, which often include a mosaic of small wetlands - sometimes seasonal - we find the most iconic species of agroforestry landscapes, the imperial eagle (*Aquila heliaca*). Such areas still exist in North Macedonia and eastern Bulgaria, where the imperial eagle maintains its last viable populations. Similar landscapes in western Greece, Macedonia and Evros were until recently home to the last pairs of the species in our country, but also provide a habitat for the lesser spotted eagle (*Clanga pomarina*), the black kite (*Milvus migrans*) and formerly the red kite (*Milvus milvus*), the common buzzard (*Buteo buteo*) and the Levant sparrowhawk (*Accipiter brevipes*). All nest in trees but hunt small mammals, birds, reptiles and amphibians in open areas, often spotting their prey from scattered trees, as do most species of hawks (*Falco* spp.).

Most eagle species nest in trees, but need agroforestry mosaics to locate and catch their prey


© Yannis Roussopoulos **I** Honey buzzard *(Pernis apivorus)*

On partially forested slopes we also find the booted eagle (*Hieraaetus spennatus*) and the short-toed (or snake) eagle (*Ciraetus gallicus*), which are strongly linked to agroforestry mosaics (Sánchez-Zapata and Calvo 2001). In fact, the shrinking of open areas in the rainy western Pindos has so much reduced the habitats of the snake eagle that it is now observed hunting only in the high altitude forests surrounded by upland grasslands and on the periphery of settlements. Even typical "forest" species, such as the honey buzzard (*Pernis apivorus*) in summer and the goshawk (*Accipiter gentilis*) in winter, often prefer forest openings and clearings to hunt, a habitat mosaic kept open by livestock farming. Finally, the golden eagle (*Aquila chrysaetos*), a flexible species of open woodland and scrubland, prefers to feed on turtles in Greece, that it breaks by throwing them on sharp rocks. Complementing the above picture with island and Mediterranean areas, the habitat of the rock-nesting Bonelli's eagle (*Aquila fasciata*) and long-legged buzzard (*Buteo rufinus*) often, though not exclusively, consists of agro-pastoral areas where traditional agricultural activities are maintained. Finally, the most common birds of prey in Greece and Europe, namely the common buzzard (*Buteo buteo*) and the common kestrel (*Falco tinnunculus*), prefer agroforestry landscapes for nesting and searching for prey. This also includes endangered species such as the lesser kestrel (*Falco naumanii*), which occurs in more steppic habitats (grasslands), the Eleonora's falcon (*Falco eleonorea*) which hunts insects before the breeding season in cultivated agroforestry areas on the Aegean islands and the hobby falcon (*Falco subbuteo*) which nests in open, frequently pastoral woodlands in mainland Greece.

As 33 of Europe's 36 species of birds of prey occur in agroforestry landscapes, conservation, particularly of endangered species, is directly linked to the restoration and maintenance of agroforestry landscapes. Of these, 26 are under threat in Europe, 19 are included in the Greek and 9 in the global Red List [in the categories "critically endangered", "endangered", "vulnerable" or "near threatened" (CR, EN, VU, NT)]. For these species, immediate actions for the conservation and restoration of their populations are required, both by national and European legislation, which very often involve specific management actions in agroforestry landscapes. To date, 11 International Action Plans have been compiled for corresponding threatened species which need to be implemented immediately. All of them can be much more easily implemented if horizontal agroforestry policies are put in place, particularly within the EU member states.

CONSERVATION OF BIRDS OF PREY IN THE ERA OF CLIMATE CHANGE

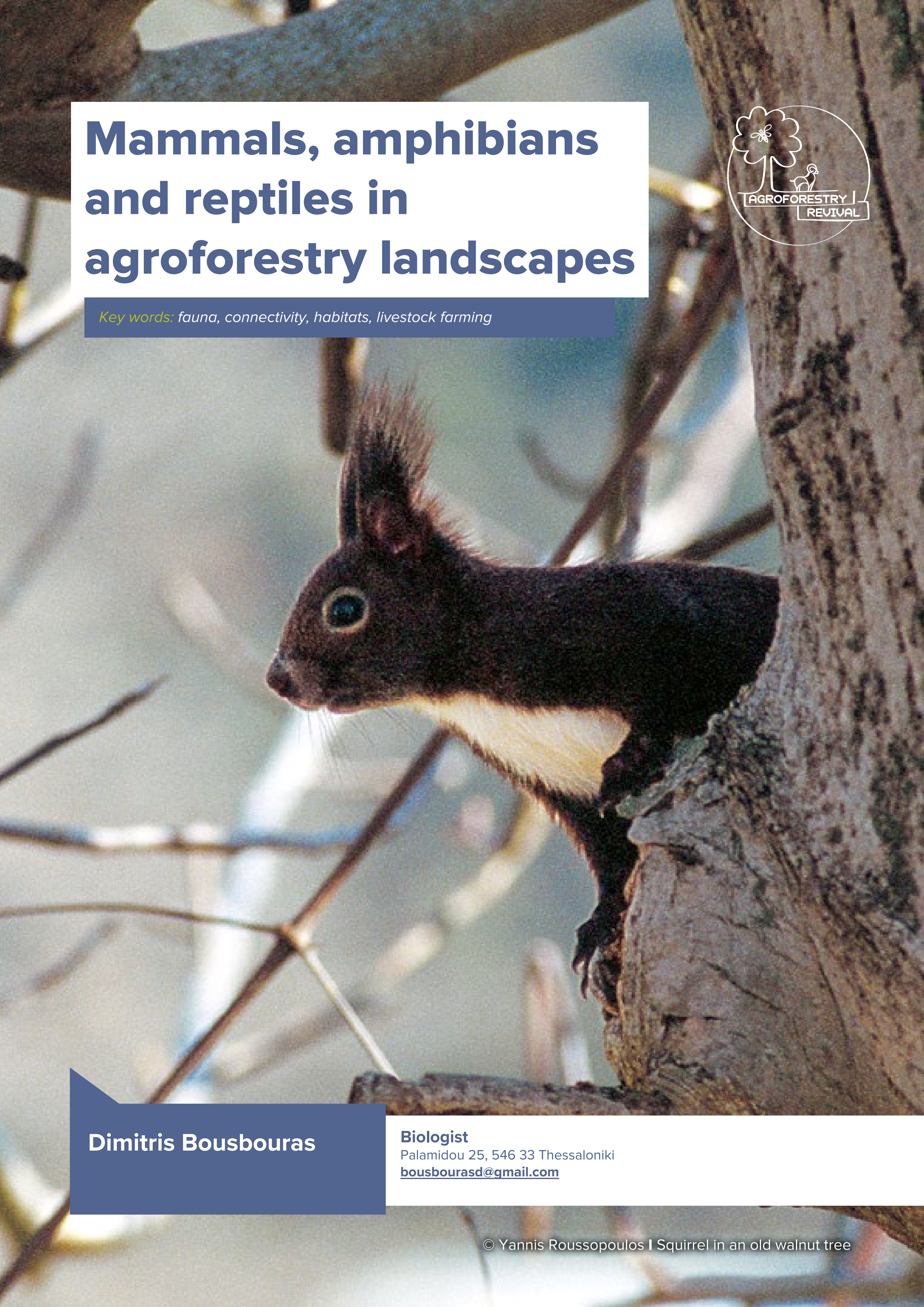
As climate change and socio-economic factors gradually lead to the abandonment of agroforestry landscapes and the activities that keep them alive, it seems that birds of prey ("species of conservation concern" for most Natura 2000 sites in Greece) will continue to decline following the trend of European farmland bird species. It is striking that most conservation actions to date have focused on individual measures within limited conservation areas, rather than on broader agriculture sectorial policies that will safeguard their populations in perpetuity. Such policies will increase the connectivity between current core ranges and the recovery of species and their habitats that are threatened with extinction or have already become extinct. The only realistic tool for maintaining robust populations for most species is the recognition of agroforestry as a wider viable solution for the conservation and restoration of landscapes that support the highest abundance and population density of raptors in Greece and Europe.

As 33 of Europe's 36 species of birds of prey occur in agroforestry landscapes, conservation, particularly of endangered species, is directly linked to the restoration and maintenance of agroforestry landscapes

© Yannis Roussopoulos I Hen harrier *(Circus cyaneus)* looking for prey. N. Greece.

Mammals, amphibians and reptiles in agroforestry landscapes

Key words: fauna, connectivity, habitats, livestock farming



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 I Squirrel in an old walnut tree

AGROFORESTRY LANDSCAPING AND WILDLIFE

Until the mechanization of agriculture, the struggle of farmers to keep their arable land productive was a continuous battle with water and wild vegetation. Let us bear in mind what the countryside was like all over the world until before the Second World War, and in many places, even until a few decades ago. Without heavy machinery, people would go into the field with a pack animal or cart and hang their bag and water container on the branch of a large tree, usually in the middle of the field. It was a tree left over from the native vegetation or one that had been allowed to grow from an acorn or seed that rolled down from the surrounding slopes to provide shade in the summer.

Agricultural land is the result of the modification of natural areas by humans: forests, scrublands, wetlands and steppes were transformed to farmland. Agriculture is in fact the extension of human activity into the habitat of other species. Until the total mechanization of agricultural land and the levelling and homogenization of large areas, wildlife could be found anywhere in traditional agricultural systems. Moreover, some species must have been favored, such as those which require large open spaces. Until the widespread use of firearms and the extensive use of pesticides, hares were almost everywhere, in meadows, in wheat fields, in vineyards, in olive groves. On the contrary, they are absent in large agricultural areas without hedgerows. Even such a highly adaptable animal cannot survive there.

Agroforestry landscapes, by contrast, offer opportunities for survival and well-being for many different species of terrestrial animals, except those that require a pure forest environment. These landscapes retain elements of their pre-human intervention state, allowing several species to use them as their primary habitat or as part of their range. These elements and species biology are keys to understand the value of agroforestry landscapes for biodiversity, but also to plan for an agriculture that is based on the principles of yield stability, safe food production and conservation of the species of each site.

AMPHIBIANS

Humans' fight against water in the countryside led to the draining of swampy land, or land whose soil was saturated with water during the growing season and places where there was shallow water throughout the year. This draining helped to reduce the incidence of malaria by reducing the number of mosquitoes, but at the expense of many other species of insects and other invertebrates. Among the species groups most affected are amphibians because both their food sources (insects) and their breeding sites, such as small pools of standing water or small ponds at the edges of fields, have decreased. This was the process occurring in the lowlands. In the semi-mountainous and mountainous areas with rugged terrain, the water running in streams and rivers is frequently captured for water supply and irrigation either at source or by dams. Thus, the narrow gullies and streams adjacent to the fields have water only during torrential rains. The places that used to hold water throughout the year or at least until mid-summer are now dry. Habitat loss is the main reason why amphibians have been among the world's most threatened vertebrates since the International Union for Conservation of Nature - IUCN first assessed the status of species on the planet (Stuart et al. 2004). Given the above, if we wish to preserve biodiversity, there is no choice but to follow the path of nature and resource conservation, as well as some of the practices traditionally used by farmers. In northern countries, ponds are formed for watering animals, irrigation and recreation. Where the water table is high, all a farmer has to do is dig, and the groundwater will flood


© Yannis Roussopoulos | Common European toad *(Bufo bufo)*

the pond. In the South, however, where the aquifer is usually low, the solution for watering livestock or for irrigation is to create a pond near springs or along a shallow gully. These techniques, now lost, are being rediscovered in inaccessible places such as in Titaros Mountain, for the cultivation of mountain potatoes. Exploiting the relief to have both deeper and shallower sites, with or without emergent vegetation, favours amphibians ranging from common pond frogs (*Pelophylax* sp.) to the rarer crested newts (*Triturus macedonicus* & *Triturus ivanbureschi*). There is no need to reinvent the wheel in the first place, as long as corresponding traditional techniques are applied (Bousbouras 2021).

The silvopastoral habitats have a high coverage rate of ecotones, supporting large variety of microhabitats, species and ecosystem services

Providing water for irrigation, by restoring the meandering of rivers, natural flow in streams or creating a pond by simply dredging one end of the field, where an uncultivated section is usually left, improves conditions for many species. Animals will come to drink water, including many predators of species that damage crops, thus controlling their populations. Even if the breeding site of the amphibians is not next to the field, but somewhere nearby, it will still be a positive intervention since species that move away from water, such as toads (*Bufo* sp.) and tree frogs (*Hyla arborea*), will come to the crops in search of insects and other invertebrates.

© Yannis Roussopoulos | Greek stream frog *(Rana graeca)*

REPTILES

Another struggle between humans and water is the fight against erosion. On sloping land, people formed terraces using the drystone walls technique. These drystones walls are very similar to natural rocks and areas of cobbles in dry landscapes, as the stones were not bonded together and had gaps between them. Lizards bask on them, thermoregulating, and hide in their holes when they perceive an enemy. It is possible to assume that such constructions have favoured certain species of lizards, and perhaps some species of snakes, which also hide in the drystone walls. These structures make it difficult for tortoises, which cannot pass through certain points. In general, it can be said that terraces, apart from holding the soil and improving the aesthetics of the landscape, considerably increase biodiversity and the populations of predators of insects and rodents that can cause damage to crops.

When humans managed to find a balance with the recolonisation dynamics of natural vegetation, the result is hedgerows and uncultivated areas between fields, where shrubs and trees grow in rows or clumps. These uncultivated parts are left either to protect the adjacent crop or simply because they are found on difficult terrain. In

© Yannis Roussopoulos I Dahl's whip snake *(Platyceps najadum)* warm climates this is where reptiles will find the space to escape the high temperatures in summer. They may also find winter shelter, deep in roots and stones, where they will hibernate. These thickets are of great value, perhaps higher than narrow linear hedgerows, where there is not enough space that can provide adequate security for some species.

The picture we usually have of rural areas is of extensive flat arable land separated by rows of trees and shrubs. In mountain areas, however, small areas of relatively flat land, with or without terraces and hedges, are flanked by rangelands. If there is no overgrazing and the tops of the trees or shrubs have an cushion-like shape, meaning they cover the ground with branches, conditions are excellent for reptiles and many small mammals (Catsadorakis and Bousbouras 2010). The diversity in landscape structure with open and closed microenvironments leads to an increase in the number of species, as there is sufficient shelter and adequate foraging areas. These environments are also responsible for the large tortoise populations in some areas, as these reptiles have a place to hide and sunny slopes without woody vegetation to lay their eggs.

© Yannis Roussopoulos I Greek rock lizard *(Hellenolacerta graeca)*, endemic species in Peloponnesus

MAMMALS

Similarly, open canopy grazed forests have a greater diversity than homogeneous dense forests managed exclusively for timber production, as light entering the openings allows the presence of reptiles, insects and mammals. The clearings that are created are similar to those in a mature forest, with many dead standing and overhanging trees. The formation of this landscape structure by grazing is positive for many species, but at the same time, the forest should be given the opportunity to expand into the most inaccessible places. In the inaccessible and denser stands, bears and deer will hide and breed, but in the forest openings they will find their food sources. In these clearings and in the contact zone between forest and meadows, most of the fruit trees are found and they provide their fruits at different times to both humans and wild animals.

Likewise, in agricultural land, larger mammals prefer places with a relatively high proportion of bushy and woody vegetation, as they find shelter and fruits to feed on. In contrast, large mammals do not occur in areas without concealment and food sources other than agricultural production. As a result, rodents, which can hide in holes in the ground, increase and damage crops. In Greece, some prefectures, in or-

© Yannis Roussopoulos | European fat dormouse *(Glis glis)*, in its nest, in a pubescent oak der to control large populations of rodents, use poisons, while the most sustainable treatment would be the re-establishment of hedgerows and the planting of large trees such as oaks, to favour the rodent predators.

Looking at the needs of species with a larger territory, such as the bear, it is found that a mosaic of forests, grasslands and farmland ensures easier movement between different areas. These corridors can be strips of forest, but also thickets or small woodland, as for animals that also move in open environments at night it is sufficient to ensure partial cover and basic food sources to move between mountain ranges and forests (Chouvardas et al. 2013).

If a new approach to farming is to be adopted, it must draw on practices from traditional management and data from species biology and ecology. Planning should be done at both the microhabitat and landscape level by considering wildlife species movement corridors between protected areas that can sustain permanent populations of species. But not just corridors, because the agroforestry landscape is both human habitat and wildlife habitat, and the main modes of recurrent management are crops and livestock breeding. Conservation biology must meet agronomy and rangeland science.


© Yannis Roussopoulos I Southern white-breasted hedgehog *(Erinaceus concolor)*

Bats in agroforestry systems

Key words: Chiroptera, hedgerows, clearings

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© Panayiotis Georgiakakis I *Pipistrellus hanaki*, Crete

INTRODUCTION

Greece hosts 36 out of the 46 bat species (Chiroptera) of Europe. All bat species are strictly protected under the Habitat Directive (92/43/EU, Annex IV), while 13 are also included in Annex II of the same directive. Two of those species, *Barbastella barbastellus* and *Myotis bechsteinii,* are also Special Areas of Conservation characterization species, due to their strong dependence on mature and dead trees, the loss of which is threatening their populations. Bats play a significant role in ecosystems as they are top night predators. The fact that they consume high numbers of insects, many of which are parasites for agriculture or an annoyance to humans, also makes them useful to us. Calculations in the USA estimate that the value of bats for agriculture ranges between 3.7 to 53 billion dollars per year, the equivalent amount that would have been spent on pesticides (Boyles et al. 2011). More than 1,400 bat species exist in the world, most of them being insectivores, while many feed on fruits, seeds, and nectar, thus playing a crucial role in plant pollination, agriculture and forest regeneration.

Agroforestry systems host a significant number of strictly protected bat species


© Panayiotis Georgiakakis I Silvopastoral landscapes in Crete

BATS AND AGROFORESTRY SYSTEMS

Agroforestry systems are used by the majority of bat species of Greece for food and possibly also for roosting and reproduction, when they include old and dead trees or other types of roosts (caves, mines, rock crevices) or simply for commuting to other roosting or feeding sites, as this kind of habitat improves landscape connectivity. Landscape elements, such as hedgerows, help bats in navigating from one habitat to another. The value of agroforestry systems increases when they include water bodies, such as creeks, permanent or temporary ponds as bats visit them for drinking water and preying on insects that emerge from water or live in the riparian zone. Even cattle troughs can be valuable for bats, especially in areas with limited water.

On islands, forests and agroforestry systems feature relatively high bat species diversity and are preferred by species that on the mainland depend on other habitat types, such as wetlands (Kafkaletou-Diez et al. 2022, Davy et al. 2007). Especially in areas like Crete, where undisturbed, especially wooded, surfaces are rare, the significance of agroforestry systems is even higher, as they support an important number of bats, not only of forest-dependent species but also more generalist ones. At least 14 of the 17 Cretan bat species occur in agroforestry systems with 13 species recorded in mixed forests (pine, cypress, prickly oak, etc) and 12 in prickly oak (*Quercus coccifera*) forests. Pine and cypress forests have fewer species (9 and 7 respectively) (Benda et al. 2019). Forested areas have a higher abundance of bats than shrublands, olive groves and settlements in Crete, and come second – in terms of bat abundance – after the wetlands with rich woodland vegetation (Georgiakakis 2009).

Pipistrellus hanaki is a unique species of forest-dwelling bats found in Crete, that also occurs only in Cyrenaica, Libya (Benda et al., 2004; Hulva et al, 2007). It uses a variety of roosting sites (rock crevices, buildings, tile roofs, electricity pillars, cracks, and tree hollows), but feeds almost exclusively around mature trees at 3 km radius from the roosts. The species is abundant in mature clumps of the species *Quercus coccifera*, *Q. ilex*, *Q. macrolepis*, *Q. pubescens,* and *Acer sempervirens*, but also in areas with mixed cultures of *Ceratonia siliqua*, *Olea europaea* and various *Prunus* species, like in creeks with *Platanus orientalis*, *Castanea sativa,* etc (Georgiakakis et al., 2018). It is worth mentioning that the occurrence of *Nyctalus leisleri* in Crete has been found only in two sites in the Chania Regional Unit, both in creeks with chestnut and plane trees. Other potentially suitable sites on the island for the species are mainly forested areas or/and wetlands (Benda et al., 2019).

Agroforestry systems are also important for *Rhinolophus hipposideros*, a species which uses mosaics of agroforestry and agrosylvopastoral areas. It is threatened in Mediterranean countries due to the abandonment of traditional agroforestry practices, pesticides, intensive agriculture and the destruction of old houses (Papadatou et al. 2011). In olive groves, not only species numbers but also bat activity is reduced with the increase of the intensity of cultivation processes. Large monocultures seem to be used by bats mainly for commuting rather than feeding (Herrera et al. 2015), which shows that bats need mosaic landscapes and traditional agricultural practices.

© Ioanna Salvarina I Agroforestry landscape in the area of Agiofillo, Trikala, Central Greece

BATS AND SPECIAL LANDSCAPE ELEMENTS

The value of agroforestry systems for bats also depends on the balance between open cultivated areas and green “arteries”, i.e. non-cultivated land with trees. The preservation and enrichment of landscape diversity with old and mature trees, but also with open spaces is important for bat species diversity in forested areas, as found by Kafkaletou-Diez et al. (2022) in Ionian island forests. Traditional orchards, olive groves and non-intensive crop cultures can also attract many bat species (Kyheröinen et al. 2019). At the same time, crops inside agroforestry systems benefit from the presence of bats, as the latter consume high numbers of insects-parasites and, in this way, contribute to a more sustainable agriculture and yield increase.

© Panayiotis Georgiakakis I Concrete water trough in agroforestry landscape in Crete

THREATS FOR BATS

Logging, especially of mature trees, monocultures, destruction or degradation of roosts, extensive use of fertilizers and pesticides, and extensive interventions such as road constructions and installation – operation of renewable energy sources infrastructure in agroforestry areas are the most important pressures and threats for bats. The installation of wind farms in forests is often followed by an important number of bat fatalities in Greece, as recorded by Georgiakakis et al. (2012). In this case, highest mortality is recorded for some bat species that feed close to trees or roost in them, possibly because bats perceive wind turbines as huge trees and try to explore them. Wildfires seem to impact more severely species that fly between trees, while species that fly higher occasionally increase their activity after a fire. Usually, after habitats' natural regeneration, restoration of the structure and functionality of bat fauna follows.

The preservation of mature trees, clearings and water bodies is necessary for bats

© Ioanna Salvarina **I** Individuals *Rhinolophus ferrumequinum* in an abandoned building near Axioupoli Kilkis, N.Greece

MANAGEMENT AND CONSERVATION SUGGESTIONS

The conservation of bats in agroforestry systems is mainly associated with the conservation of agroforestry systems' diversity and aims at the preservation of space mosaic and habitat connectivity. In that sense, linear elements of natural vegetation, such as tree lines and hedgerows, should be installed in cultivated lands and old and dead trees with many hollows should be preserved, along with the adoption of environmentally friendly cultivation practices.

It is also recommended to avoid monocultures that lead to the creation of large open areas (Kyheröinen et al. 2019). Water bodies and riparian vegetation should also be preserved as they are habitats of high significance for numerous bat species. It is also advisable, to create small ponds within agroforestry landscapes, especially in dry regions. The use of light should be used with caution and with suitable specifications so that it disturbs wildlife as less as possible. Concerning the installation of wind farms and solar parks, as well as any other large infrastructure, the degradation of suitable habitats for bats and their possible fatalities should be considered. Such constructions should be avoided in important areas for bat roosting, commuting, feeding or migration and if this cannot be avoided, then the necessary measures for the mitigation of impacts should be applied according to EUROBATS guidelines (Rodrigues 2017). The evaluation of the impacts of such large-scale projects on bats requires specialized knowledge and equipment and should be carried out by trained professionals. The conservation of roosting sites of bats (e.g. trees, caves, bridges, mines, buildings, bunkers) is also necessary for the preservation of their populations.

As bats are relatively misunderstood and unknown animals, actions to increase public awareness- in this case including farmers, stock breeders and loggers- will contribute to the success of any conservation measure.


© Ioanna Salvarina I A small church in an agroforestry landscape in Grevena, N. Greece

Threatened butterfly species in wood pastures

Key words: *lepidoptera, pasture, conservation, extensive livestock farming*

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© Olga Tzortzakaki I The Festoon, *Zerynthia polyxena*, a species protected by the Habitats Directive (92/43/EC), often occurs in wood pastures, © Olga Tzortzakaki.

INTRODUCTION

An increasing number of recent studies describe a large and alarming decline both in insect biomass and species richness (Warren et al. 2021). A similar decline in butterflies has also been observed at a European level and especially in Central and Western European countries (Table 1). As a result, many butterfly species are now included in the IUCN Red List of Threatened Species.

Land use changes and habitat degradation are the main drivers of butterfly population declines

Table 1. Examples of recorded declines in species richness and population size of butterflies in Europe (Warren et al. 2021).

	Extinct species	Population reduction	Study period
United Kingdom	8%	50%	1976-today
The Netherlands	20%	50%	1990-today
Belgium	29%	30%	1992-2007

Butterflies act as good bioindicators of the condition of the environment and the effects of human activities due to their quick response to environmental changes. In addition, it is a well-studied group of insects, as they are relatively easy for the general public to observe and identify. In many European countries, long-term monitoring schemes for butterflies take place with the participation of citizen volunteers (European Butterfly Monitoring Scheme), which provide valuable data on population changes and trends over time.

Butterflies have a complex life cycle; at each stage, which may last only a few weeks or months, they have different ecological requirements and rely on specific habitat characteristics for their survival. Their life cycle is separated into four distinct stages (holometabolous insects): egg - larva (caterpillar) - chrysalis (pupa) - imago (adult). Larvae have very high energy needs and feed on specific host-plants. When their development has been completed, they find a safe and protected spot where they attach and remain for a short period of time in the stage of a chrysalis. Then adult butterflies emerge, which need sunny, open areas with flowers full of nectar and suitable micro-habitats for the females to lay their eggs.

The main causes of the population decline of several butterfly species are: the degradation and loss of natural and semi-natural ecosystems due to land use changes, agricultural intensification with the prevalence of monocultures, and the widespread use of pesticides and insecticides, as well as pollution.

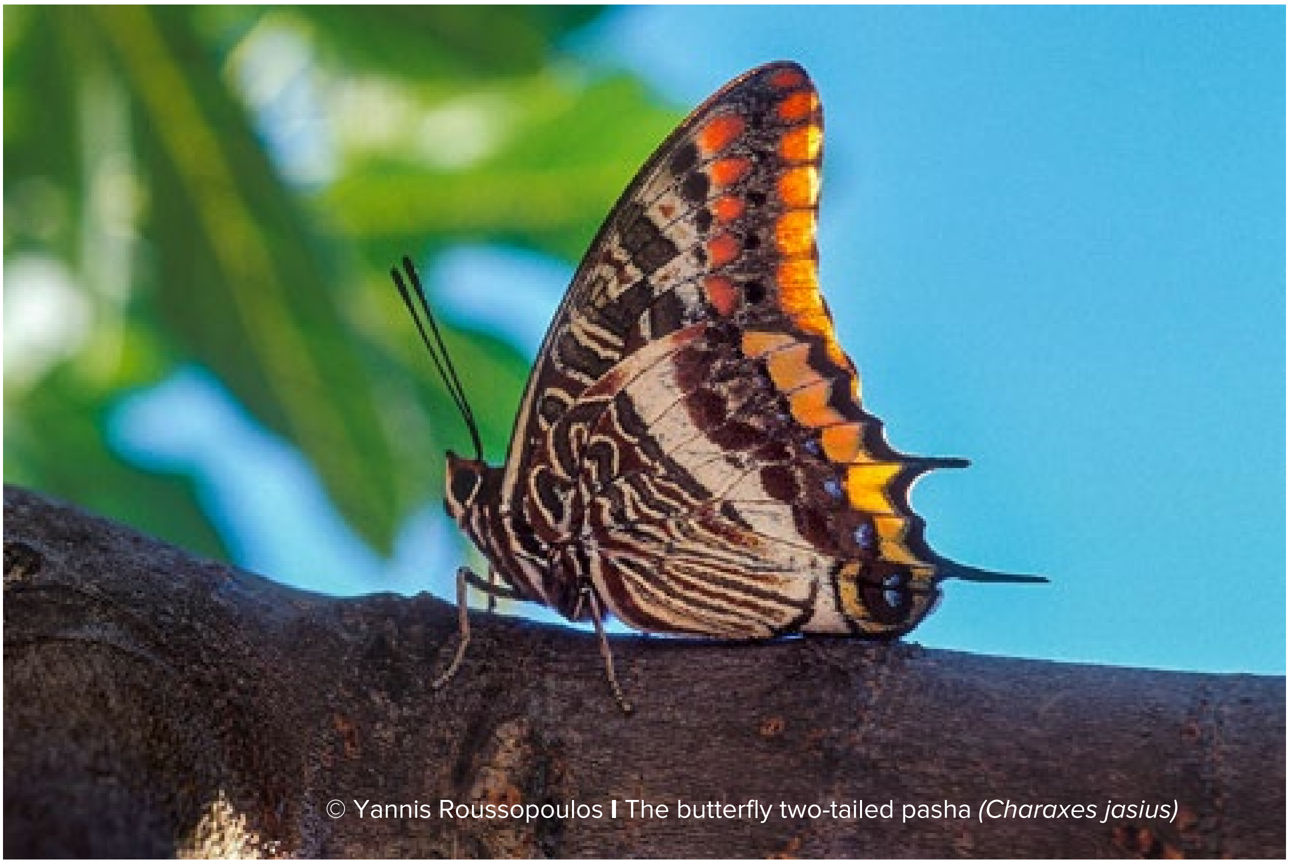
Besides, poor or inappropriate management of agroforestry systems and in particular wood pastures and grasslands, which constitute the main habitats for many butterfly species, can also lead to habitat degradation. This can often be the result of either intensive grazing or abandonment of agricultural land, mainly in mountainous and semi-mountainous areas. In many cases, land abandonment leads to shrub encroachment at the expense of open ecosystems and grasslands that sustain herbaceous plants valuable for butterflies.

Grasslands are ecosystems of high productivity and economic value, and rich in species of butterflies and other insects. In the Mediterranean Basin they have principally been developed by the long-term presence of livestock farming and other traditional activities, and the maintenance of the latter is intertwined with the evolution of grasslands and the agroforestry landscape. Adequate management regimes, such as the application of extensive grazing or controlled mowing, can ensure grasslands of adequate and sufficient extent and of high quality, with suitable habitat characteristics for the butterflies. Likewise, in wood pasture systems, extensive grazing and targeted coppicing contributes to maintaining forest clearings, which are essential for the survival of many butterfly populations.

THREATENED BUTTERFLY SPECIES

Wood pasture systems host a variety of threatened species, including species protected by the European and Greek legislation (Figure 1). A typical example is the Marsh Fritillary, *Euphydryas aurinia*, a species protected by the Habitats Directive 92/43/EC (Annex II), due to the severe decline of its populations in the past decades. It is predominantly found in wet meadows, calcareous grasslands and woodland clearings rich in herbs and flowers, and its survival and conservation largely depend on suitable grazing (Ellis et al. 2012). Similarly, the protected Apollo (92/43/EC, Annex IV), *Parnassius apollo*, became extinct in several regions of central Europe, as its habitats have been modified to cropland and artificial land or wooded and forested areas due to the abandonment of traditional livestock farming and changes in woodland management (Nakonieczny et al. 2007).

Landscape complexity and diversity at a large scale are vital for butterflies



© Yannis Roussopoulos I The butterfly two-tailed pasha *(Charaxes jasius)*

MANAGEMENT AND CONSERVATION RECOMMENDATIONS

All habitat characteristics that butterflies rely on, as well as landscape composition and diversity should be ensured at a large spatial scale and not only locally where butterfly populations occur (Ellis et al. 2012). This enables butterfly movements among patches of suitable habitat and thus the dispersal of reproductive individuals and gene flow among different subpopulations of a species. Corridors connecting patches of suitable habitats (connectivity) are crucial in order to facilitate the movements of adults, while they must also provide suitable habitat features such as nectar-rich flowers for the foraging adults.

Especially in Mediterranean ecosystems, it is very important to maintain traditional agricultural activities. Extensive livestock farming mainly of sheep, goats and small cattle is considered an agricultural activity of "High Nature Value", as it is vital both for the health and richness of the grassland and for the butterflies.

These practices ensure the mosaic-like nature and diversity of landscape which are necessary for an area to support a large number of species. Each species or species group has unique (often very specialized) ecological requirements as regards their larval host-plants, the presence or absence of shrubs and hedgerows, vegetation height, and the existence of adjacent woodland and openings among other landscape elements.

Furthermore, any other human activity (e.g. road construction, installation of Renewable Energy Sources, settlements) should not damage, degrade, shrink and fragment natural and semi-natural agroforestry ecosystems and grasslands, as the conservation of butterflies, insects and biodiversity in general is beneficial both for the species themselves and for human well-being.

All these must be taken into consideration in the agricultural, environmental and energy policies that are currently being implemented in Europe and those that will be implemented in the future. Inadequate agricultural and farming practices so far have caused the decline of several butterfly populations, like for example the notable butterfly declines in the UK due to the high loss of flower-rich meadows and calcareous grasslands (>80%) and poor management of the native woodland (Warren et al. 2021).

The large-scale conservation of suitable habitats is also a good “shield” against climate change, which leads to further alteration and loss of the species habitats. With proper management, it is possible that species can gradually adapt to the new and anticipated environmental conditions.

Traditional extensive livestock farming supports the conservation of several butterfly species

Finally, scientific research needs to continue, as it provides the evidence and data for understanding the species’ ecological requirements. In addition, long-term monitoring of species populations reveals their trends over time and their relationship to environmental changes and management practices. Cooperation between the scientific community, the authorities and the stake-holders involved in the management of the protected areas and agroforestry ecosystems and grasslands, such as farmers and citizens, is important for the success of any management plan.

© Yannis Roussopoulos I The butterfly green hairstreak *(Callophrys rubi)*

Agroforestry systems and pollinators

Key words: *ecosystem services, pollination services, bees, dehesa, arable wooded pastures*

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© Theodora Petanidou I Bumblebee *(Bombus terrestris)* in action, Mt Olympus, Lesvos

AGROFORESTRY AND ECOSYSTEM SERVICES

As a result of the ever-increasing demand for food production, natural areas around the world are gradually being transformed for agriculture, at the cost of biodiversity and local ecosystem services among others. A major loss through this process is pollination services, especially affecting crops that are pollinator-dependent. This is happening at an increasing rate in the tropics, where huge areas have been transformed into other land uses mainly for agriculture and livestock farming. Similarly, other large parts of the world that have been cultivated over long periods of time are now being abandoned as a result of improper land management, the effects of which are significantly enhanced by climate change (Talukder et al. 2021).

Worldwide experience: regarding pollination services, agroforestry systems are valued higher compared with simple annual crops

A nature-based solution to the above challenges is diversifying farming systems through agroforestry. In other words, this means intentionally integrating trees and shrubs into crop and animal farming systems, thus integrating biodiversity-based ecosystem services into agricultural production.

In this chapter I examine the role of pollination and pollinators in agroforestry systems not only for nature conservation and ecosystem health, but also for the sustainability of primary production in these systems. I explore examples stemming from research carried out in different agroforestry crops around the globe, focus on agroforestry traditional systems in the Mediterranean Basin, and finally propose solutions also based on the results and experience gained from related actions (viz. the project LIFE TERRACESCAPE).

POLLINATION AND POLLINATORS

Pollinators constitute a key component of global biodiversity, providing ecosystem services that are indispensable to crops and wild plants. There are many pollinator guilds worldwide, both vertebrates and invertebrates. The most important of these are insects and in particular wild and domesticated bees, which are vital to the maintenance of wild plant communities, ecosystem sustenance and, very importantly, agricultural production. The most important habitats for pollinators, especially bees, are open areas rich in flowering plants bearing conspicuous flowers with lush floral rewards, predominantly nectar and pollen. Such systems are low-nutrient grasslands, in particular calcareous ones, and wood openings, all hosting a high diversity of entomophilous plants.

As a result of different anthropogenic causes, the most important being agricultural intensification associated with habitat change or loss and increased exposure to agrochemicals, there has been a continuous decline of pollinators since the early 20th century (Biesmeijer et al. 2006, Potts et al. 2010, IPBES 2016). The decline is having serious consequences on ecosystem health and food security through the productivity of pollinator-dependent agricultural crops, especially the most nutritious food stuff (Klein et al. 2007, Potts et al. 2016). This is particularly evident in agricultural landscapes where semi-natural habitats have been intentionally converted into arable land.

Image 1. *A typical agroforestry system with oak trees on terraced land, western Lesvos, Greece. Although now abandoned, terraces used to be cultivated with cereals until the 1970s.*
© Anastasia Dalaka

POLLINATORS AND AGROFORESTRY: THE GLOBAL EXPERIENCE

In recent years, agroforestry systems have grown in number, area, and crop yield and have been acknowledged to promote socioeconomic sustainability vis-a-vis conservation of biodiversity and ecosystem services; among them, the promotion of pollination services, the evaluation of which is still scarce (Nicholls and Altieri 2012, Sabino et al. 2022).

All the existing studies on pollination services highlight the important role pollinators play in agroforestry systems, with some of them supporting valued crops at a global scale. Cacao and coffee are two of them; they are tropical understory plants in agroforestry systems, both highly dependent on pollinators for fruit set (Arnold et al. 2018, Klein et al. 2003, Vansynghel 2022). Like in other tropical crops, the pollination services they receive depend on the local agroforestry systems and the natural habitats in surrounding landscapes (Klein et al. 2008).

The pollinator-rich "savanna-type" natural systems occur regularly in the Aegean and the Mediterranean, also as part of the ecological succession

In general, studies focusing on pollination services in agroforestry systems are limited. The existing ones, however, converge on the importance of these systems for pollination services and pollinator conservation in different biogeographical regions (Sabino et al. 2022 for Brazilian Legal Amazon; Image et al. 2023 and Staton et al. 2022 for silvoarable agroforestry systems comprising fruit trees in England). Using paired landscapes (agroforestry vs agricultural/non-agroforestry), Kay et al. (2018) have demonstrated the positive influence of agroforestry systems in supplying pollination services in three European biogeographical regions: Mediterranean (montados and dehesas), Continental (orchards and wooded pastures), and Atlantic agroforestry systems (chestnut soutos and hedgerow systems).

THE MEDITERRANEAN AGROFORESTRY SYSTEMS

Dehesas and montados are the most well-known traditional agroforestry systems in the Mediterranean *(Iberian Peninsula)*: they are open wood pastures, occasionally also cultivated with annual crops, dominated by sparse oak trees. For their high biological diversity, these systems are protected by the European Habitats Directive. Indeed, Moreno et al. (2016) found dehesa wood pastures hosting more species of vascular plants compared with open pastures, which also applied to bees (although not significantly more).

'Dehesa type' systems also exist in the eastern part of the Basin: they are savanna-like structures similar to the Iberian ones, dominated by different tree species including oak, terebinth, sweet chestnut and even particular species, like mastic trees. Olive and carob groves, traditional almond and fig orchards, as well as combinations with other fruit trees (pear, apple, pomegranate etc.), can be also added to the list. Most of these systems originated from natural scrub communities or from sparsely occurring trees, which were gradually transformed through management.

Traditional management (occasional and light ploughing, organic manuring, conserved field margins, sheep grazing) allow a diversity of wild annual plants to sustain pollinator resources, in favor of both the cultivated trees and the combined annual crops, if any. This is also the case of Lesvos, Greece, where traditionally cultivated olive groves proved to be richer in annual plants (Dalaka and Petanidou unpublished data) and in wild bee species (Potts et al. 2006) compared with abandoned olive groves. Yet, on the same island, considered as one of the world hot spots for bees (Nielsen et al. 2011, Petanidou, unpublished data), bee diversity maximized in traditionally managed agroforestry systems dominated by oak (Potts et al. 2006) and chestnut (Petanidou, unpublished data). In fact, induced wild bee diversity in agroforestry systems benefits cultivated fruit trees which may not need honeybee pollination at all, as evidenced for almond trees cultivated in southern Sinai, Egypt (Norfolk et al. 2016).

Carob groves, densely or sparsely planted, constitute a Mediterranean uniqueness. Carob tree *(Ceratonia siliqua)* is native to the Mediterranean where it has been cultivated historically for its pods used as foodstuff for domesticated animals and as supplement to human diet (gum extracted from endosperm, carob powder and syrup). Carob is a dioecious and, more rarely, gynodioecious plant, implying that pollination is important for its fruit set. Even though it is characterized by ambophily (it is both insect- and wind-pollinated), the plant requires insect pollination. Indeed, in the Mediterranean, the carob tree is serviced by a high variety of flower visiting insects, both diurnal (mainly bees, flies, wasps) and nocturnal (mainly settling moths) (Dafni et al. 2012). Because it flowers late in the year and has a prolonged flowering period (September – December), carob is a highly valued provider of floral rewards (nectar and pollen); this makes the plant indispensable not only for late pollinator flyers when floral resources are scarce, but also for co-flowering plant species with minor floral display. Overall, it is an important species contributing to the system's conservation of pollination resources.

Image 2. *The most widespread agroforestry system traditionally cultivated in Nisyros, Dodecanese, consisted of a mixture of terebinth, olive, and oak trees –all for their edible fruits and the acorns, and to a lesser extent of other fruit trees. © Theodora Petanidou.*

CONCLUSIONS: LEARNED LESSONS FOR A SUSTAINABLE AGRICULTURE

Agroforestry is about diversified farming systems that represent an important pollinator-friendly alternative to industrial agriculture (IPBES 2016). It is linked to indigenous and local knowledge, and at the same time supported by hard scientific evidence on its potential to increase or maintain system productivity while protecting natural resources and providing ecological services, including pollination, pest control or prevention, carbon sequestration, and the conservation of soil health, water quality, and biodiversity (Muschler 2016).

Driven by the Basin's meagre nature potential (water scarcity, poor soil) coupled with a highly variable ragged landscape with diversified microclimates, the Mediterranean peoples often adopted mixed-crop agroecosystems blending low vegetation (low scrub or grassland) with shrubs and trees of different stature. In fact, such traditional farming systems simply followed a natural doctrine, combining plants of variable forms, cycles and functional traits, not to mention requirements and benefits. It is not sure whether the traditional farming systems considered pollination requirements

Image 3. *Detail of a typical agroforestry system with sparse olive trees, northeastern Lesvos. © Theodora Petanidou.*

and benefits in the frame of setting an effectively productive system. It is only a posteriori that we know that by promoting a mixed cultivation system and employing different types of plants, the resulting pollination system has always been to the benefit of the entire system. And maybe this has been one of the most important cues explaining the high bee and other pollinator diversity in the Mediterranean we enjoy today (Nielsen et al. 2011, Petanidou, unpublished data, Reverté et al. in review).

Conclusion: mimicking nature, mixed-crop agroecosystems by blending low vegetation they sustain high pollinator diversity and promote sustainable agriculture

Currently, vast areas in the entire Mediterranean have been abandoned, as their cultivation was estimated to be non-profitable in the frame of modern agriculture (Petanidou 2021). This applies especially to the intensely terraced islands of the Aegean, which used to bear agroforestry systems to some extent (Images 1-4). Efforts to re-cultivate such areas not only aim at producing quality products of high added value, but also at recuperating the green infrastructure these systems once used to function, for the benefit of biodiversity and to combat the impacts of climate change. Wrapping up my 5-year coordinating experience of the project LIFE TERRACESCAPE, where the re-cultivation effort based on annual crops had very limited success, I conclude that for such a purpose, agroforestry systems should be the top choice.

Image 4. *Valonia oak-dominated agroforestry systems are widespread in the island of Kea, Cyclades; although the arable land is abandoned nowadays, collection of acorns resumed a few years ago mainly for export. © Theodora Petanidou.*

Biodiversity in the agro-forest soil

Key words: soil quality, soil microbial diversity, climate change, nutrient recycling

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© Yannis Roussopoulos I Valonia oak *(Quercus ithaburensis subsp. macrolepis)*, Xiromero, W. Greece

THE IMPORTANCE OF THE SOIL SYSTEM

Soil is a complex mixture of minerals, organic matter, water, air, and living organisms. The characteristics of agroforestry soils vary greatly, depending on a variety of factors influencing soil formation, such as topsoil nature, climate, topography, and the dominant plant species in the system. The age of soils also varies widely, ranging from a few years to millions of years. Although soil depth can differ significantly, with some soils extending several meters deep, most soil processes take place in the top 10 cm of soil, which usually corresponds to the organic A' horizon. Some critical physical and mechanical properties of soils such as water retention capacity, the ease of movement of soil water and air and thermal stability, depend on soil mechanical composition and porosity (Schaetzl & Thompson 2015). The interaction between soil properties and processes largely determines the health and productivity of an agroforestry system. Soil plays a crucial role in supporting the growth and development of plant species, providing the root system with essential nutrients (such as nitrogen, phosphorus, magnesium, potassium, etc.), oxygen, and water, which are necessary for the survival of all living organisms.

Agroforestry systems are known to be a natural reservoir of CO_2, contributing significantly to the absorption of carbon dioxide from the soil

Odum (1971) defined soil as an ecosystem because it is a unit comprising all the organisms in a given area (bio community) which interact with each other and with abiotic factors in a way that leads to a flow of energy, a well-defined food structure, biological diversity, and the recycling of matter. Soil, as an ecosystem, is self-regulating through nutrient recycling, but it is not energy self-sufficient since it relies on the photosynthetic activity of plants.

The aboveground vegetation continuously supplies the soil system with plant debris and dead organic matter. In an agroforestry system, the presence of trees ensures that these contributions are recurring and seasonal, thereby ensuring a constant supply of dead organic matter for nutrient recycling. However, in cultivated lands, the soil is often left bare, and most plant residues are removed after harvest. Consequently, the soil quality of cultivated land tends to deteriorate over time (Wall et al 2012).

Agroforestry systems offer several advantages to the soil system by incorporating trees, which enhance many of the soil's plant, chemical, and biological properties. For example, trees contribute dead plant material to the soil system, increase nutrient availability, improve soil structure by increasing porosity, protect soil from erosion, remove excess nitrates from over-fertilized land, promote organic carbon fixation in the soil, and create conditions conducive to increasing soil biodiversity. Such measures significantly enhance the health and productivity of managed systems and help mitigate several environmental problems. In addition, the soil provides a favorable environment for the growth of various organisms, which together form the bio community of the soil system. These organisms interact with each other and plant species, forming an integrated system (Wall et al 2012).


© Yannis Roussopoulos I Field margins and hedges in the Evinos river delta, W. Greece

SOIL BIODIVERSITY AND BIOLOGICAL ACTIVITY

Soil organisms have a crucial role in the decomposition of organic matter and the recycling of nutrients. The mesofauna (size 0.1-2 mm) mainly comprises nematodes, microarthropods, and collembola, while the macrofauna (size greater than 2 mm) consists of insects, earthworms, and even small mammals. These organisms decompose dead organic matter by crushing plant debris and mixing it with the inorganic soil. They are often referred to as the engineers of soil systems (Hurst 2019).

> ***Compared to a field under pure agricultural cultivation, an agroforestry field can store up to 4 tonnes of carbon per hectare per year, which is ten times more***

However, microorganisms (microflora) play the main role in decomposing dead organic matter and releasing nutrients. It is important to note that one gram of soil can harbor up to 10 billion microorganisms from thousands of different species. The soil microflora consists of three main groups: bacteria, fungi, and actinomycetes. These microorganisms break down complex organic compounds into simpler ones and ultimately into inorganic compounds that plants can assimilate. Bacteria are the smallest single-celled organisms living in the soil. Because the growth rate of bacteria is faster than that of fungi, bacteria dominate the degradation of low molecular weight substrates. Bacteria are active in all kinds of organic substances except for lignin. Nitrogen-fixing bacteria are a particularly interesting class of organisms capable of fixing atmospheric nitrogen and converting it into inorganic nitrogen. Such bacteria can either live freely in the soil or form a symbiotic relationship with the roots of certain plant species (Hurst 2019).

Fungi are mainly heterotrophic and have a range of enzymes that enable them to break down dead organic matter in the soil. In soils with adequate aeration, fungi constitute a significant part of the microbial mass due to the extensive growth of their fungal hyphae. Fungi play an important biological role in the soil ecosystem because they can immobilize large quantities of nitrogen, owing to their large biomass and resistance to degradation. Some fungal species can form symbiotic relationships with the roots of certain plant species, a combination known as mycorrhizae. This relationship is critical for the survival and growth of plants, especially in phosphorus-poor soils. The mycorrhizal system allows roots to exploit soil depths that would otherwise be impossible for plants since roots have a much larger surface area and length. This symbiosis benefits both the plant and the fungus, as the plant supplies carbohydrates to the fungus, and the fungus provides nutrients to the plant (Hurst 2019).

Finally, actinomycetes are aerobic Gram-positive bacteria that are particularly vulnerable to low soil acidity but remain active even in highly arid soil conditions. Their significance lies in their capacity to decompose challenging-to-degrade organic compounds such as lignin (Hurst 2019).


© Yannis Roussopoulos **I** Short-toed lark *(Calandrella brachydactyla)*

AGROFORESTRY SOILS AND CLIMATE CHANGE

Forest soils house the most extensive storage of organic carbon in terrestrial ecosystems. Soil carbon comprises 80% of the overall carbon (stored in biomass and soil) in northern forests, 60% in temperate forests, and 50% in tropical forests. In contrast, in arable areas with no trees, the concentration of soil organic carbon is steadily declining due to the increased rate of organic matter decomposition and the release of large amounts of carbon dioxide into the atmosphere, thereby exacerbating the greenhouse effect. Furthermore, climate change scenarios predict a rise in temperature and hence greater microbial activity, raising the question of how to limit carbon loss from cultivated land to the atmosphere. Given this, in recent years there has been a constant call from the scientific community for the "protection, restoration, and reforestation of forests" to allow nature to remove carbon dioxide from the atmosphere and store it in the soil, thus making a decisive contribution to reducing the greenhouse effect. However, such a solution is not feasible as human nutritional needs increase. In the near future, agroforestry systems appear to be the most viable solution and are included as a strategy in the Kyoto Protocol. An agroforestry field can store up to 4 tonnes of carbon per hectare per year, ten times more than a field under pure agricultural cultivation. Therefore, forestry systems that involve intercropping crops with trees, forestry or fruit treesand in some cases animal grazing, therefore becoming agroforestry systems, should be the primary objective for addressing the consequences of climate change in the years ahead (Jhariva et al. 2019).

Agroforestry systems are vital in improving soil health by significantly increasing microbial biodiversity

Small wetlands in silvopastoral landscapes

Key words: *water reservoirs, extensive livestock breeding, abandonment of countryside, agro-environmental policies*

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© Yannis Kazoglou | Dragonfly just after metamorphosis from larva to adult

Water, whether stagnant or flowing, abundant or limited, is a landscape element that always attracts the attention of most living organisms. It is one of the three essential features of wetlands and essentially defines the other two, which are wetland vegetation and hydromorphic soils (Fitoka et al. 2020). But what exactly are wetlands? According to article 1 of the Ramsar Convention on Wetlands of International Importance, especially as Waterfowl Habitat, *"wetlands are areas of marsh, fen, peatland or water, whether natural, permanent or temporary, with water that is static or flowing, fresh, brackish or salt, including areas of marine waters the depth of which at low tide does not exceed six meters"*. Despite its weaknesses, this is a broad, commonly accepted definition of wetlands, among many scientific and legal definitions found in the international literature. Keddy (2002) suggests a shorter definition which also manages to describe the majority of the planet's wetlands: "*A wetland is an ecosystem that arises when inundation by water produces soils dominated by anaerobic processes and forces the biota, particularly rooted plants, to exhibit adaptations to tolerate flooding*". The diversity of wetland definitions appears to follow the diversity of wetlands themselves in terms of types, sizes, conditions, locations, and characteristics, a fact that according to Mitsch and Gosselink (1986) leads to an unsurprising lack of a single, universally recognized definition of what a wetland is.

Natural or artificial wetlands found in silvopastoral landscapes affect grazing dispersal and constitute small biodiversity oases

Wetlands may cover areas of thousands of square kilometers or be much smaller. For the purposes of the present article, we will limit the subject to small or even very small wetlands. The upper limit for "small wetlands" in Greek legislation and recent literature (Fitoka et al. 2020) is set to eight (8) hectares; however, in the case of wetlands in silvopastoral landscapes, they may even cover areas of a few square meters, as they include small natural or artificial water bodies (ponds) and even completely artificial structures, such as water troughs for farm animals. The role of these small wetlands in silvopastoral landscapes is manifold. In ideal conditions, natural small wetlands with stagnant or low-flowing water have smooth banks with low emergent vegetation and, possibly, visible color signs of fluctuating water levels, as well as a zone of relatively deeper water. Possible “residents” or users of these habitats, depending on the season, may be invertebrates such as dragonflies and other insects, tadpoles and mature frogs and toads, newts, small fish or larger animals that leave their tracks in the mud of the bank, probably because at some point they passed through the wetland to drink or feed. In streams and small rivers, the zonation includes the active bed (covered by running water at low and high flows), the banks, ponds or troughs in or near the active bed, which are refuges for fish fauna, and the riparian zone with the always interesting forest vegetation and flora. In this case, wildlife species (invertebrates, amphibians, reptiles and fish) are usually less numerous and more specialized compared to those dwelling in small wetlands with stagnant waters, a fact determined by the almost permanent shading and water flow, as well as the lower air and water temperatures (Zogaris et al. 2007).

Moving on to aesthetically less ideal conditions and images, the importance of artificial water bodies that are often found in silvopastoral or silvoarable landscapes should not be overlooked. These include either older soil structures or more modern ones with a concrete or plastic waterproof substrate and/or surrounding walls to retain and collect water, such as (a) small lakes created by excavations, fed by adjacent streams, often made in order to irrigate cultivated fields, (b) long and narrow concrete, wooden or metal water troughs fed by springs or surface waters, and

© Costas Zissis | Alpine Newt, Mt.Tymphe, Ioannina

(c) ponds, small pools and reservoirs for watering livestock, supplying other water storage infrastructure or for other uses (Papanastasis et al. 2021). In practice, all these constructions resemble natural wetlands and apart from farm animals, they are also used by wildlife. Roe deer (*Capreolus capreolus*), brown bears (*Ursus arctos*), wild boars (*Sus scrofa*, which often use the mud as well as the meadows below or around the water sources in their characteristic way) and many birds including large raptors such as the lesser spotted eagle (*Clanga pomarina*), very specialized species like the black stork (*Ciconia nigra*) and dozens of passerines especially in dry islands and Mediterranean habitats, all utilize these constructions in different ways. Such artificial wetlands also attract bats, which fly over water troughs and ponds to catch insects on their nocturnal hunts. Amphibians also use such structures either within them or where water overflows and soaks the ground outside them. These muddy surfaces often provide the right conditions to some orchid species and concentrate groups of small butterflies (puddling areas), bees and various other wild pollinators and their predators.

In order to preserve the valuable silvopastoral landscapes of Greece, it is necessary to manage the infrastructures serving extensive livestock farming, including small natural and artificial water reservoirs

© Yannis Roussopoulos I Yellow-bellied toad *(Bombina variegata)*

The aesthetic, environmental and economic value of these small natural or artificial wetlands, which are found in silvopastoral landscapes and are critical elements for the preservation of extensive livestock farming, highlights the need for the integrated management of this special category of rural landscapes. At the same time, it points out the important role of extensive animal husbandry for the preservation of such landscapes. Extensive livestock breeding is, however, declining or gradually abandoned, which results in the degradation of traditional agroforestry systems. Specific, well-targeted and implementable national and European policies are needed for the maintenance of existing traditional silvopastoral and silvoarable systems and the creation of new such systems, in combination with proper management of natural wetlands and artificial water reservoirs at areas that can still support extensive animal farms. Only through the implementation of such policies will active human populations be maintained and, possibly, revived in mountainous, semi-mountainous, insular and generally disadvantaged areas which usually host the magnificent cultural landscapes of Greece.


© Costas Zissis I Concrete artificial water pont for grazing animals Mt Stouros, Ioannina, Epirus NW Greece

© Yannis Roussopoulos I Grey wagtail *(Motacilla cinerea)*

© Yannis Roussopoulos I In the area between Andritsaina and the ancient temple of Epicurean Apoll o, Peloponnese

Part C

Management, restoration and creation of agroforestry landscapes

Classification of silvoarable systems in Greece

Key words: traditional systems, new silvoarable systems, overstory, understory

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© Konstantinos Mantzanas I Olive trees in combination with barley. Kassandra peninsula, Chalkidiki, N. Greece.

INTRODUCTION

Silvoarable agroforestry systems, which combine the presence of trees and agricultural crops on the same land, are one of the three types of agroforestry systems found in Greece, the other two being silvopastoral and agrosilvopastoral systems. The vegetation of these systems is very rich and consists of various species and functional types. Overstory trees exist in dynamic equilibrium with understory shrubs and herbaceous plants (Papanastasis, 2004). There are several types of agroforestry systems characterized by the trees of the overstory. Depending on the management practice they can be distinguished into traditional and new silvoarable systems. In traditional systems, the trees of the overstory are native, remnants of older forest areas, and past management lasting until last few years has not caused any disturbance to the individual parts of the system. The new ones include systems where the trees were specifically planted for their fruits or for their timber, while at the same time the understory is used to produce agricultural crops in order to achieve a better use of the space.

The «forest» tree species that form traditional silvoarable systems are the various species of oak, cypress and poplar

The ecological value of traditional agroforestry systems refers to the preservation of its mosaic landscape and biodiversity, as they include a large number of species and individuals of both plants and animals. These systems are more stable than any form of conventional agriculture in terms of protecting the soil, improving the environment, habitats and wildlife, ensuring the stability and functionality of ecosystems, but also preserving or improving the country's landscapes (Ispikoudis et al. 1996). Economically, agroforestry systems provide a wide variety of products and services. The various trees of the overstory produce timber, firewood, stakes and fruits. Wood of various species, such as walnut, is valuable for furniture, while poplar is used for paper production. The foliage and acorns of oaks are used as food for animals, while the fruits of walnut, chestnut, and various other fruit trees (apples, pears, almonds, olives, etc.) are used as food for humans. Along with trees, understory agricultural crops provide a steady annual income to farmers.

SILVOARABLE SYSTEMS

The tree species that form traditional agroforestry systems are the various species of oak, cypress and poplar. Of the various oak species, the valonia oak (*Quercus ithaburensis* subsp. *macrolepis*) stands out; it is found in various regions of mainland Greece as well as in many islands with a typical Mediterranean or sub-Mediterranean climate. In various areas of its range, the valonia oak grows in or on the borders of fields usually cultivated with cereals, and forms silvoarable systems or agrosilvopastoral systems, if the fields are also grazed by livestock after the grain harvest (Papanastasis 2015). Also, the Macedonian oak (*Quercus macedonica* or *trojana*), which is mainly founds in the Region of Western Macedonia, occurs in agricultural crops, in or on the borders of fields planted mainly with cereals and forms the same systems as the valonia oak (Mantzanas et al. 2006). Other oak species such

© Konstantinos Mantzanas I Walnut trees with dry beans, Sisani Kozani, NW. Greece.

as *Quercus pubescens*, *Quercus frainetto* and *Quercus petraea*, form silvoarable and agrosilvopastoral systems in extensive areas in the semi-mountainous and mountainous zone of the mainland. Among the coniferous tree species, the cypress (*Cupressus sempervirens*) is planted on the borders of cultivated fields with cereals or other agricultural crops for the natural marking of fields or for wind protection of crops, forming silvoarable and agrosilvopastoral systems (Papanastasis 2015).

Various productive clones of poplar trees (*Populus sp.*) are cultivated or planted within arable lands that have relatively deep and fertile soils, are irrigated or have good water conditions near canals and riverbanks. The most common system, however, is around arable land with vegetables or other summer crops. This planting scheme results in the creation of silvoarable systems, which are traditional in several parts of the country, particularly in Northern Greece. Poplars are used for timber production but also serve other purposes such as boundary marking or as windbreaks (Papanastasis 2015). The most important among the evergreen fruit trees, is the olive tree (*Olea europea*), which is found almost all over Greece and especially in the plains and coastal areas. According to Papanastasis (2015), the olive tree has been one of the most widely cultivated species in the Mediterranean zone of Greece already since the 1st century BC. The area covered by olive groves in our country amounts to 700,000 hectares, of which approximately 125,000 hectares are agroforestry systems, either silvopastoral or silvoarable (Papanastasis et al. 2009). In olive agroforestry systems the trees are usually old and come from wild olives grafted to produce edible olives and olive oil. The characteristic of these trees is that they branch at a remarkable height above the ground (1.5-2 m.) and this is due to the fact that the grafting was done at this height to avoid the eating of the new shoots by goats. Under the trees, various crops can be found such as cereals, maize, alfalfa, vineyards, or vegetables such as potatoes, onions, tomatoes and beans. Another type of tree in this category is the carob tree (*Ceratonia siliqua*), which occurs in very limited areas in the Southern Peloponnese and Crete. Its fruits were used in the past as fodder for livestock, while some crops can be found in the understory (Schultz et al. 1987). In recent years there has been a strong interest in carob honey and carob flour and products derived from them such as nuts (rusks).

The most important among the evergreen fruit trees, which form traditional silvoarable systems, is the olive

Walnut tree (*Juglans regia*) and almond tree (*Amygdalus communis*) belong to the broad-leaved fruiting species that form extensive silvoarable systems. Walnut systems are found throughout the country, mainly in the semi-mountainous zone, but also in the mountainous. Trees may be scattered or in rows within agricultural plots. They are used for walnut production as well as for high-quality timber, while in the understory there may be cereals, alfalfa, vineyards, cotton, tobacco, etc. Walnut silvoarable systems combining walnuts with vines, cereals, alfalfa, vegetables or dry beans have been recorded in the Municipality of Voio, in the Regional Unit (RU) of Kozani, Greece (Mantzanas et al. 2006). Silvoarable systems with almond trees are found mainly in the dry areas of the country and on the islands. The almond tree grows alone or in a mixture with other species such as olive, fig, walnut and pistachio (Papanastasis 2015). Traditionally, almond is intercropped with various agricultural crops such as cereals, tomato, legumes, and hay crops. Almond tree silvoarable systems have been recorded in the Voio Municipality of Kozani RU, where almond trees are co-cultivated with vineyards, tobacco and alfalfa in addition to cereals (Mantzanas et al. 2006). Other planted broadleaf tree species that form silvoarable systems on a smaller scale are the chestnut (*Castanea sativa*), the mulberry (*Morus alba*), the fig (*Ficus carica*), the pseudoacacia (*Robinia pseudoacacia*), the cherry (*Prunus avium*), the apple (*Malus domestica*) and the pear tree (*Pyrus communis*).

Of the broad-leaved fruit tree species, the most extensive silvoarable systems are made up of walnut and almond trees

CONCLUSIONS

Silvoarable systems are formed by a wide variety of trees (forest or fruit bearing) and with various combinations of agricultural plants both in mainland and insular Greece. Among them, the silvoarable systems of olive, walnut and the various species of oak, which are traditional forms of land use, cover the largest areas.

 I Walnut trees and cereals. Argiroupoli, Drama, N. Greece.

Agroforestry systems in arable land

Key words: monoculture, environment, trees, establishment, CAP

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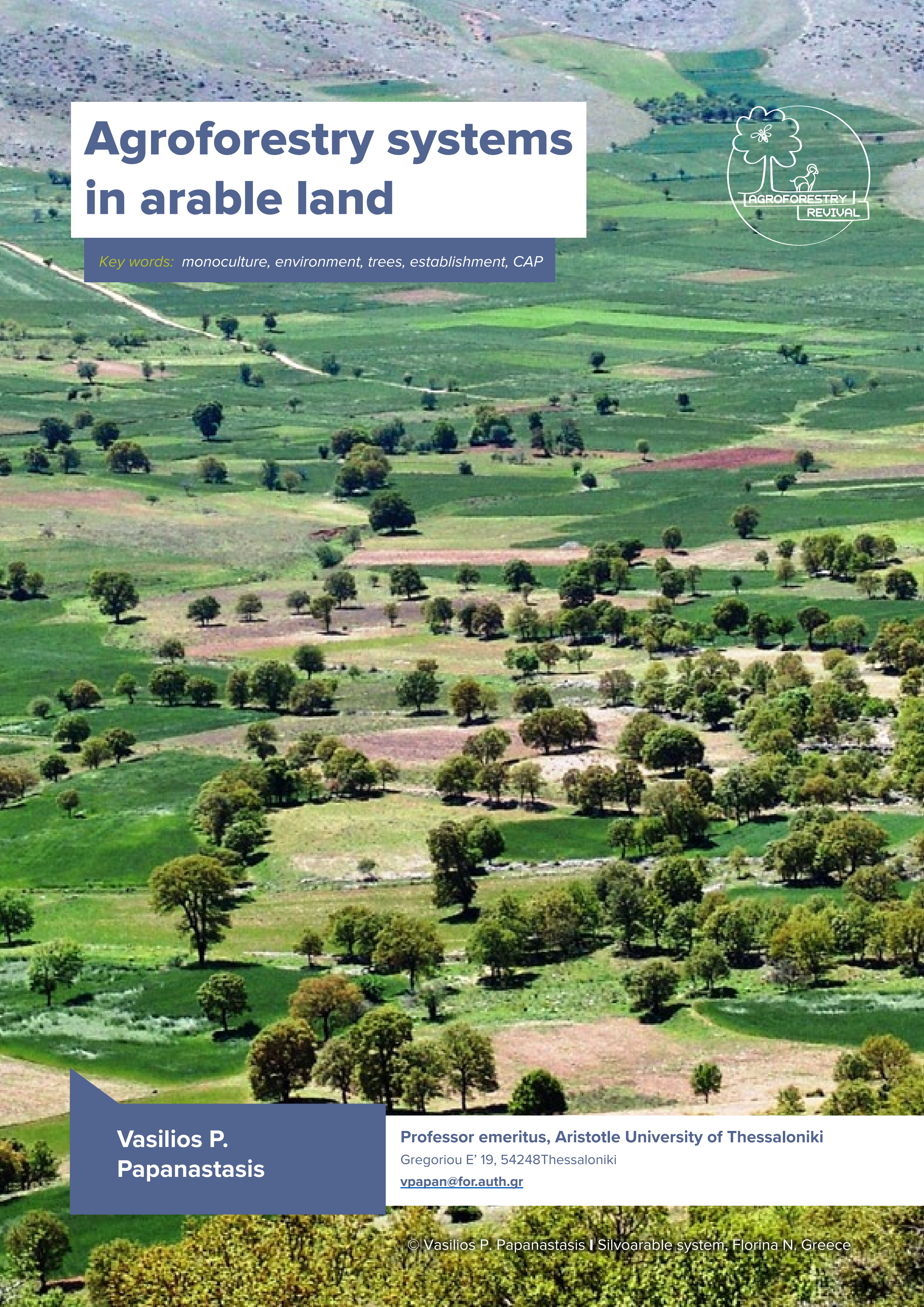

© Vasilios P. Papanastasis | Silvoarable system, Florina N. Greece

INTRODUCTION

Before World War II almost all arable tracts of land in Greece featured some trees, either planted or indigenous, the latter being remnants of the ancient forests that had been cleared for cultivation. These trees were preserved in order to guarantee the provision of firewood and fruit for the farmer's household needs, shade for relaxing during lunch in the hot summer days, fruit and foliage for animal feed, and crop protection from adverse weather conditions. The intercropping of trees with agriculture yielded multiple products and services. Although it was more laborious and provided a relatively low income, it required limited energy use, therefore constituting a sustainable production system for arable agriculture..

Agroforestry systems improve the soil in arable land and mitigate the adverse effects of climate change

ENVIRONMENTAL PROBLEMS OF ARABLE LAND

Post-war labour mechanization, as well as the use of chemical fertilizers and pesticides, resulted in the intensification of agricultural activities, transforming traditional polycultural systems into monocultures. The main victims of this intensification were trees, which were uprooted because they obstructed agricultural machinery but also in order to increase the "productive" area of farms, a practice also dictated by the Common Agricultural Policy (CAP) of the '80s and early '90s. Consequently, several arable farms were deprived of their trees, leading to serious environmental problems, especially in the large plains, most of which having been rendered treeless (Figure 1).

Some of the most serious environmental problems that arable land tracts currently face are:

- soil erosion by water and wind, mainly in the hilly and steep tracts cultivated with annual crops, especially where inappropriate cultural methods (e.g. ploughing down slope/ vertically to the contour lines) are also applied,

- salinization caused by irrigation with brackish water resulting in the accumulation of salts in the soil,

- nitrate pollution due to the excessive use of fertilizers, particularly nitrogenous ones, leading to the accumulation of large quantities of nitrogen oxides in the water, soil and plants, and

- loss of biodiversity due to monoculture and the use of pesticides.

All these problems led to a significant reduction in productivity, desertification and farm abandonment. For example, 120 thousand hectares of annual crops were abandoned in Thessaly from 2000 to 2018 due to the continuous soil degradation and reduction of crop yields below profitable levels (Danalatos et al. 2022).

Fugure 1. *Extract from a farm registry map in the Almyros area of Thessaly showing the presence of many trees in 1945 (left), which had disappeared by 2007 (right) (photo adaption: C. Evangelou).*

AGROFORESTRY SYSTEMS

Meaning of agroforestry systems

According to the European Commission Regulation 1305/2013, agroforestry is defined as that system of land use in which trees are combined with agriculture on the same tract of land. This combination leads to the creation of agroforestry systems, which involve the mixture of trees and crops, trees and pasture for livestock, and trees, crops and pasture for livestock, known as silvoarable, silvopastoral and agrosilvopastoral systems respectively. In these systems, trees are deliberately combined with crops and pasture for livestock without the intention of creating a forest. As a result, agricultural activity is not suspended.

Environmental benefits

Agroforestry systems can effectively contribute to the solution of environmental problems in arable tracts of land due to the multiple benefits derived from the synergies from the co-cultivation of trees and crops. The most important benefits are as follows (Papanastasis 2015, Dupraz et Liagre 2008):

Soil

Trees within agroforestry systems provide organic matter through their roots and foliage, resulting in the improvement of the physical and chemical properties of the soil. Specifically, soil porosity is improved and fertility is increased. Also, they affect microorganisms and favour the establishment of symbiotic mycoflora. However, their most important function is soil protection from erosion thanks to their deep root system, especially in steep areas of land (Figure 2).

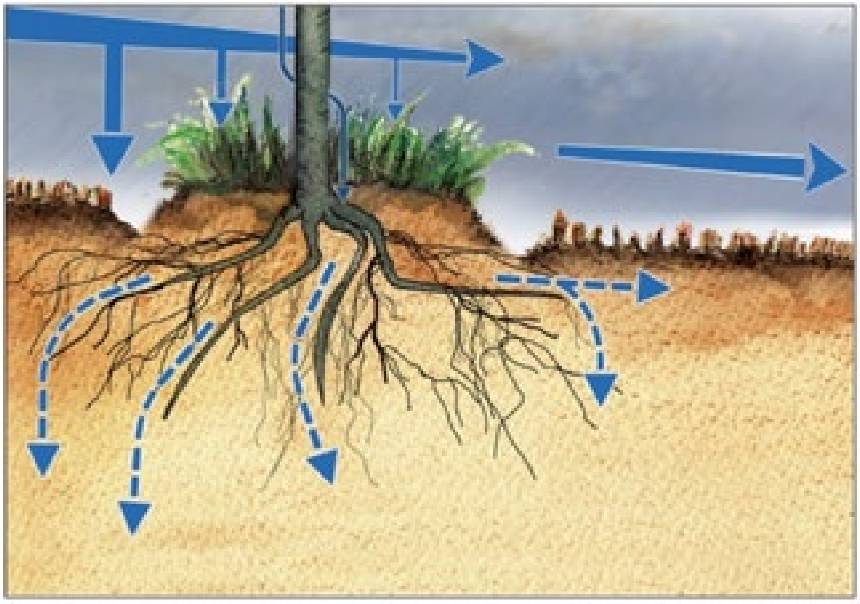

Figure 2. *Schematic representation of tree root capacity to combat soil erosion in steep arable land (illustration C. Dupraz).*

Water and nutrients

Trees intercept the surface runoff of nutrients added through fertilizers and channel these into the soil, as its permeability increases at the same time. In this way, the pollution of neighboring sensitive ecosystems (e.g. wetlands, lakes, rivers) is avoided. In addition, they create a “safety net” with their deep root system, which traps nitrates leached from the root zone of crop plants and absorbs them, thus preventing groundwater pollution. Finally, trees prevent soil salinization and increase crop yield.

Biodiversity

Trees create a multitude of habitats for various species of flora and fauna, both above and below ground. When planted in rows, the zone they take up within the field becomes a refuge for many species because it is not cultivated. On the other hand, the complexity of agroforestry habitats creates conditions of competition between harmful and non-harmful organisms, resulting in the reduction of insects and diseases affecting agricultural crops.

Climate change

Trees improve air quality and the microclimate, thus enhancing agricultural production in the farms where they are established. However, their decisive contribution is carbon storage and mitigation of the effects of climate change. This is done through their significant contribution to the reduction of carbon dioxide in the atmosphere by photosynthesis, with which they release oxygen and trap carbon in their trunk, branches, roots and soil. Agroforestry has been credited as a carbon sequestration strategy since the Kyoto Protocol in 1997, because it is considered as having greater potential than other land uses, especially agriculture. According to research conducted in France, an agroforestry field can sequester and store from 1.4 to 4 tons of carbon per hectare per year with a density of 50-100 trees per hectare, an amount that is 5-10 times greater than in a field with herbaceous agricultural crop (Dupraz et Liagre 2008). This means that agroforestry systems can contribute to an increased rate of carbon sequestration thus resulting in the decrease of the carbon footprint of agriculture.

The plantation of forest or fruit trees in arable land increases their overall productivity

Establishment of agroforestry systems

Agroforestry systems can act as a solution to environmental problems faced by treeless arable lands. Their establishment should take a scientific approach, so that they are compatible with the equipment and cultivation practices already applied in these tracts of land. Establishing modern agroforestry systems requires the following steps (Papanastasis 2015):

Selection of suitable tree species

Trees to be chosen should be able to adapt to the climatic conditions of the area where they will be established and serve the intended purpose. These could be forest trees that produce timber (e.g. poplar, hackberry, lime tree), timber and fruits (e.g. walnut, chestnut), timber and fodder (e.g. carob tree) as well as timber and wind protection (e.g. cypress) or simply fruit trees, especially local varieties. It is imperative that seedlings to be planted should, as much as possible, be healthy and originating from domestic genetic material.

Choosing the right agricultural crop

Agricultural crops can be perennial or annual, as long as their biological cycles are combined with trees. For example, winter grains and legumes are grown when trees are still leafless, so competition is limited. In contrast, industrial plants growing in the summer period compete with trees for light and water unless they are irrigated (Figure 3).

Density and arrangement of trees

When trees are mature, they should not exceed 100 individuals per hectare, but it is recommended to plant more at the beginning, so that they can later be reduced by thinning. In large farms, the trees should be established in parallel lines, 25-35m apart, depending on the tree species and the machinery used by the farmer, while along the line the distances can vary from 4-10 m. In small farms, however, it is preferable to plant trees on their borders.

Figure 3. *Combination of walnut with irrigated cotton in the area of Drama, N. Greece (© M. Lazaridou).*

Tree care

Trees should be cared for regularly with proper pruning so that they form a bare trunk of 2-3 m, a height that will have high commercial value when the tree is felled. Also, the crown must also be regularly pruned so as not to overshadow the agricultural crop. In a rationally managed agroforestry system, trees cover an area equal to 15-20% of the farm's surface, depriving it of agricultural production. Its overall productivity however is higher than when the agricultural crop is grown as a monoculture.

Trees in arable land ensure an additional bonus to direct payments of Pillar I of the CAP

COMMON AGRICULTURAL POLICY (CAP)

Farmers are wary of planting trees in fields because they deprive them of productive surface. The "greening" of the new CAP means that trees are now "welcome" elements in the rural landscape, so they could be established if financial incentives are given. Such an incentive was the agroforestry measure of Pillar II of the previous CAP periods, which financed the establishment of new agroforestry systems on arable land. Unfortunately, this measure was not implemented in Greece, and the new CAP 2023-27 does not provide for a similar measure. However, trees are included for the first time in the "landscape characteristics" of Pillar I in the enhanced conditionality and there is a specific ecological scheme entitled "Improvement of agroforestry systems rich in landscape elements". These provisions constitute important incentives for the maintenance of already existing trees, particularly in the arable land of hilly and mountainous areas. In parallel, the establishment of new agroforestry systems should be brought back in Pillar Ii in the next programming period of the CAP.

The value of silvopastoral agroforestry systems and challenges for their future

Key words: traditional practices, ecosystem services, tree and animal component, climate challenges

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© Yannis Roussopoulos I Fruit of valonia oak, Akarnania, West Greece

SILVOPASTORAL SYSTEMS IN BRIEF

Silvopastoral are those land-use systems in which trees (or other woody perennials) are combined with pasture and livestock on the same unit of land (Mosquera et al. 2018). Grazed open forests can be characterized as silvopastoral systems since their relatively open crowns permit the growth of a lush understory of herbaceous and woody species, mostly evergreen, which means that green leaves and twigs are available as forage throughout the year.

Silvopastoral systems are inextricably linked with the Greek natural environment and traditions and should be protected and preserved as part of our heritage for future generations

Silvopastoralism can be considered one of the oldest land use systems and represents an exceptional example of harmonious co-existence of humans, livestock and nature. Since the early days of humankind, humans raised flocks to ensure animal products for their survival. Based on Le Houerou (1981), raising livestock in the eastern Mediterranean began as early as 10,000 BC whereas by 3000 BC this practice had already been spread to the western part of the region. Mobile pastoral communities have been, and still are in many parts of the world, moving their herds through rangelands, in search of fresh forage and water, making the most out of scarce resources.

Silvopastoral are complex agroforestry systems and can be characterized based on their components which are trees (species composition), grazing animals and the presence of man (ownership-management). Based on the woody component, silvopastoral systems can be distinguished into coniferous and broadleaved systems (Papanastasis 1996). These systems differ according to the prevailing climatic conditions, their structure and management in the past. Thus, the analysis of each of these components, independently of their past and present management, contributes to their better understanding, forming a useful basis for their preservation and future management.

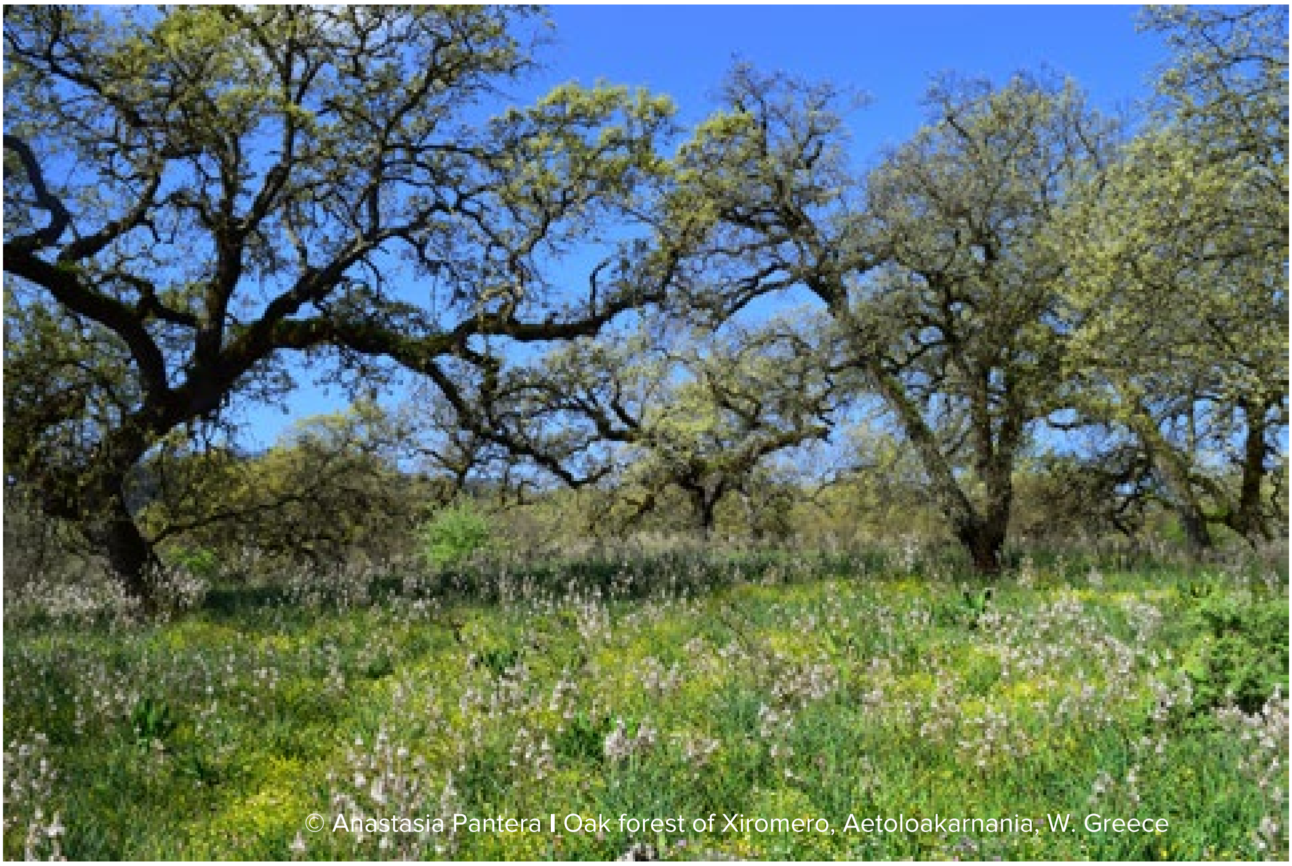
VALUE OF SILVOPASTORAL SYSTEMS

Silvopastoral systems provide numerous ecosystem services depending on their components, ranging from provisional (timber, dairy products, etc.), regulatory (water purification, carbon sequestration, etc.), cultural (recreation, traditional pastoral systems such as transhumance, etc.) and supporting (nutrient cycling, habitat provision, etc., see Papanastasis 2015). Trees in silvopastoral systems provide numerous products such as timber, fuel wood, fence posts, charcoal, fodder, nuts, etc., serving multiple purposes (e.g. water and nutrient absorption, nitrogen fixation, shade, protection from windbreaks and hedgerows, erosion control); trees are managed based on specific needs of the local population and on the availability of natural resources in each area. These two parameters (local population & site) influence the availability of resources, thus forming a variety of systems depending on the specific area, diversified by the traditions of local populations.

One of the most common coniferous silvopastoral systems (Shultz 1986), is that formed by pine trees. Several pine species form silvopastoral systems providing a variety of products. For example, Aleppo pine (*Pinus halepensis* subsp. *halepensis*) silvopastoral systems provide fodder for bees, sheep and goats. This system type evolved in time mostly for its resin production and for livestock grazing. Resin collection is an old practice; resin is used as a basic component in many ways and in very different products, one of which is “retsina”, a Greek white wine. Recreation is another popular use for these systems as well as honey production. Similarly, brutia pine (*Pinus halepensis* subsp. *brutia)* forms similar silvopastoral systems used for grazing by goats and sheep, timber production, fuel wood, honey, resin, wildlife, meat, and recreation. Other popular conifer silvopastoral systems include those formed by black pine, junipers, cypresses and fir species with their more common products derived from livestock and timber products.

Oak, as the dominant species, prevails in broadleaved or semi-broadleaved silvopastoral systems (Shultz et al. 1986). The shape of the tree as well as its solid wood structure, have for centuries greatly influenced the economy, artworks and civilization of the areas where it grows , providing a variety of goods ranging from meat and dairy products to charcoal and acorn-derived products. Other broadleaved tree systems are those of chestnut (*Castanea sativa*) and walnut ((*Juglans regia)*. They greatly support livestock and wild animals contributing to the conservation of biodiversity. They offer multiple products such as nuts, high quality timber, fruits, honey, fuel wood, wildlife, meat, recreation etc. The olive tree also forms traditional silvopastoral systems. Olive orchards are frequently described in the Bible as the grazing land of thousands of sheep. Its silvopastoral systems also include orange, almond, walnut, apricot, fig trees and poplars, as well as various grazing animals. Two systems with increasing interest and value are the ones formed by the carob (*Ceratonia siliqua*) and the mastic tree (*Pistacia lentiscus*), providing a variety of products including dairy, fruits, chocolate substitutes (from the pods) and mastic by-products (gum, oil, lotions etc.). Other broadleaved- ree silvopastoral systems include those formed by the heather tree (*Erica arborea,* whose root wood is used for the construction of smoking pipes) and white mulberry (*Morus alba*, for silk production, a very old practice going back to the Byzantine times), fig (*Ficus carica*, for fruits production) and the poplar-sheep silvopastoral systems. It should be noted that the fig silvopastoral system is a very old one, well adapted to the dry and poor areas, providing fodder for sheep and goats, rendering it an interesting choice under the challenging environmental conditions of climate change.

The silvopastoral systems with their multiple products supported and contributed to the survival of people in rural areas through the centuries


© Anastasia Pantera I Oak forest of Xiromero, Aetoloakarnania, W. Greece

The grazing animal species component of silvopastoral systems (Papanastasis 2015) depends on local environmental conditions (and, therefore available fodder) and traditions, ranging from sheep and goats, dominating in Mediterranean countries, to cattle and reindeer in northern countries. Goats have been blamed many times as the main cause for the destruction of the natural environment, neglecting its key cause which is overgrazing and mismanagement in general. On occasions when resources shrank considerably, people living in mountainous regions over- or misused the ecosystems. Grazing animals represents a cash income to the farmer through selling meat and milk products, nutrient transfer from forage to soil through their droppings, a successful way for sprout removal, and contribute to soil organic matter cycling. Another important contribution of grazing animals to ecosystems is that of reducing understory biomass and, subsequently, reduce forest fire risk. This raises a very important issue, especially after the devastating forest fires in recent years and deserves to be further investigated.

© Anastasia Pantera **I** Silvopastoral areas are characterized by high plant diversity

PRESENT AND FUTURE CHALLENGES

Silvopastoral systems have supported local economies in many poor mountainous regions where available resources are limited during the winter period. However, the lack of holistic management in many regions has resulted in the gradual degradation of many traditional silvopastoral systems. Glorious past oak silvopastoral systems are nowadays only used for grazing, especially by sheep, and are also declining due to overgrazing, abandonment and land-use changes. The present unwillingness of farmers to practice silvopastoralism or pass on their knowledge to their successors, poses a major threat that may lead to their disappearance. Young people seem to be averse to pastoralism. In many areas the price value of land has increased in favor of other uses which, in combination with the high labor costs, has driven many locals to other occupations (mostly within the tourism industry), or to more intensive agricultural practices rather than farming and pastoralism. Additionally, overgrazing in combination with frequent forest fires or illegal logging has seriously degraded the environment in certain areas prohibiting any further agricultural or pastoral use. Cheap chemical substitutes have decreased or even diminished the economic value of natural products such as pine resin or acorn-cups derived tannins. Decreased grazing of silvopastoral systems favors the development of a dense, flammable understory biomass partly responsible for the frequent forest fires and the subsequent change in land uses (Mosquera-Losada et al. 2018). These systems are directly related to biodiversity and their degradation may lead to the disappearance of many valuable species.

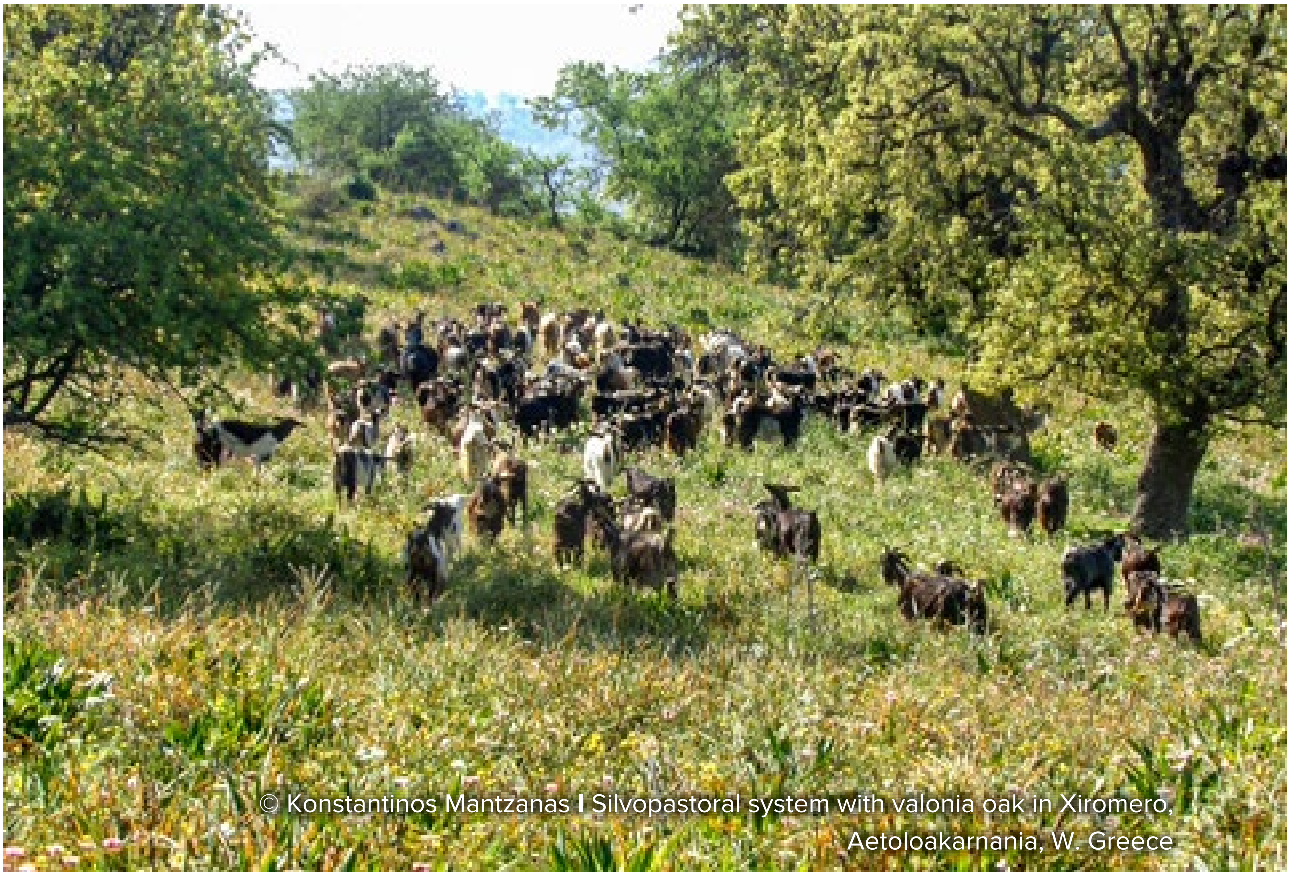
Silvopastoral systems are of great importance not only for their environmental value, but also for their value as traditional land-use systems (Papanastasis 2015). Most of these systems have supported the local economy of many rural areas providing inhabitants with the means to survive through eras of famine and wars. So, even in the lowlands, silvopastoral systems were, are and must continue to be used for their multiple products and services.

CONCLUSIONS AND SUGGESTIONS

Silvopastoral systems are very rich and viable systems with great ecological, economic and environmental importance. Their sound management is a prerequisite for their conservation, protection, and improvement.

Silvopastoral systems are characteristic examples of circular economy in practice and can contribute to mitigating climate change effects

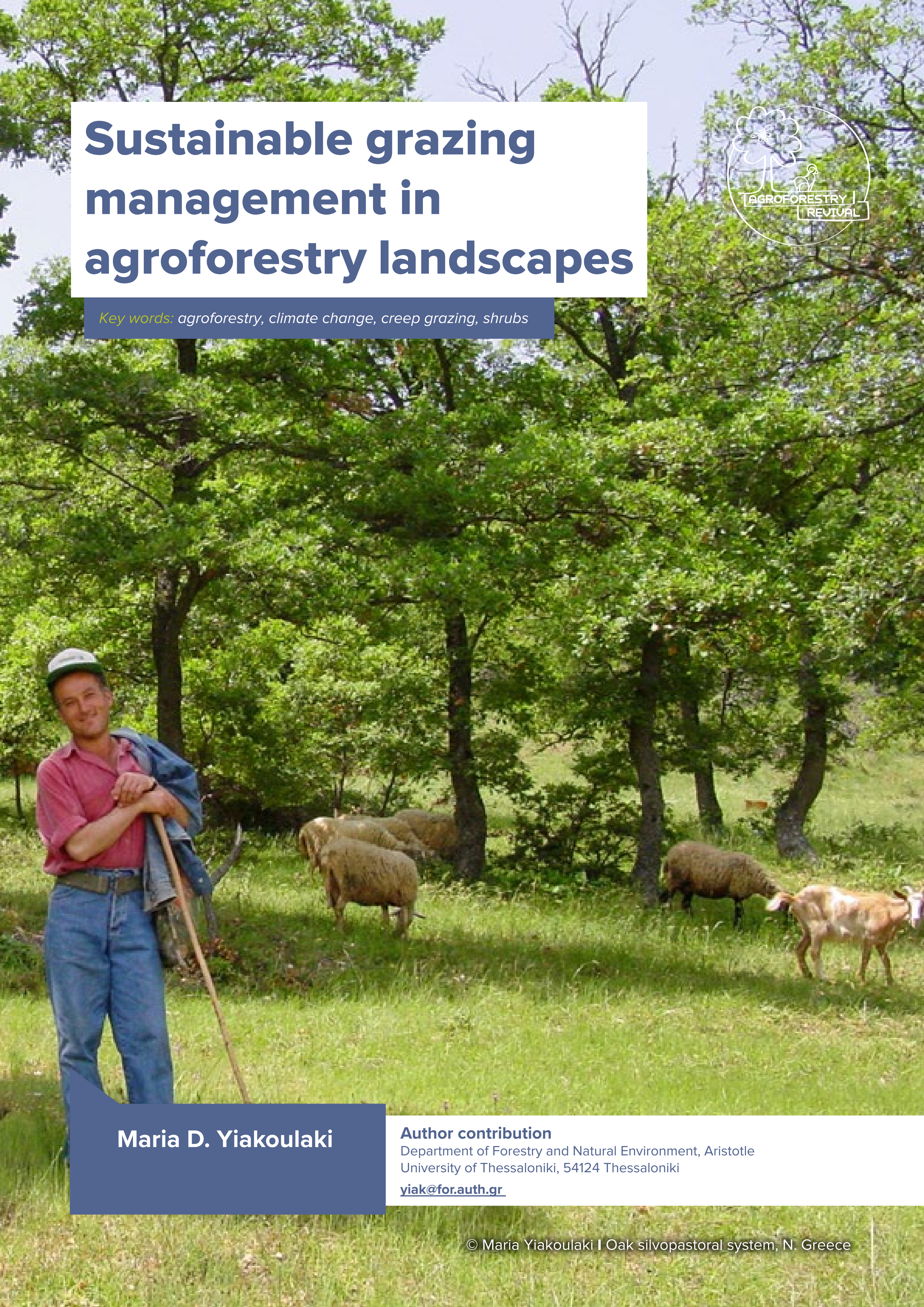
Farmers, especially livestock breeders, are an integral part of these systems, and they must understand the ecological, economic and traditional role of these systems. Special incentives must be given to farmers to preserve the existing form of their farms and even establish new silvopastoral systems. At present, there is a broad palette of modern communication tools to support public awareness, stressing that these systems are not only a part of the local economy and environment, but also a part of local history and tradition.


© Konstantinos Mantzanas | Silvopastoral system with valonia oak in Xiromero, Aetoloakarnania, W. Greece

© Anastasia Pantera I The contribution of oak forests to biodiversity is high, especially in silvopastoral system with oaks in Xiromero, Aetoloakarnania, W. Greece

Sustainable grazing management in agroforestry landscapes

Key words: *agroforestry, climate change, creep grazing, shrubs*



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© Maria Yiakoulaki I Oak silvopastoral system, N. Greece

GRAZING IN AGROFORESTRY SYSTEMS

Livestock grazing is an integral part of silvopastoral and agrosilvopastoral agroforestry systems. It is important from an ecological, economic, and environmental point of view, and it plays a significant role in the formation of agroforestry landscapes due to the relationship and interaction between livestock and natural resources. Agroforestry systems and the landscapes they produce constitute a part of a location's identity; they are connected to the areas in which they are found and are considered valuable local resources. These systems are traditionally used by farmers to provide shade and feed for their animals throughout the year.

Rational grazing can contribute to the sustainable management of silvopastoral and agrosilvopastoral systems

Sustainable management of agroforestry systems focuses on maintaining and restoring biodiversity, producing products, and protecting critical ecosystem services as well as farmers' livelihoods, all of which are mutually-beneficial goals for humans and nature, rather than isolated efforts or aims in direct confrontation with each other (Tanentzap et al. 2015). Grazing is a tool for vegetation management and its rational use can contribute to the sustainable management of agroforestry systems and the fight against their degradation (Röhrig et al. 2020). Controlled grazing reduces the competition between understorey and overstorey vegetation, increases tree productivity, facilitates the cultivation and harvesting of products (wood, resin, fruits, etc.), and provides additional income from animal products. Grazing also contributes to the reduction of dry biomass accumulation and wildfire risk (Yiakoulaki et al. 1999, Mancilla and Vicente 2012) as well as the invasion of woody species (Zarovali et al. 2007). It also promotes the conservation of diversity and endangered bird species (Papoulia et al. 2002, Tsiakiris and Stara 2004).

THE STRUCTURE AND ROLE OF GRAZED AGROFORESTRY SYSTEMS

The structural components of agroforestry systems and the landscapes they create are: trees, which form the overstorey; grasslands or agricultural residues after the harvesting of cereals (Figure 1) that form the understorey; livestock using the understorey or the overstorey; and humans who manage the systems (Papanastasis 2015). In some environments, there may be a midstorey of shrubby vegetation, which also contributes to animal nutrition with its foliage or fruits. Constructions for livestock (e.g. barns and shelters), watering troughs, salt places, paths, fences and barriers, dry stones, and terraces constitute the functional and visual features of

Figure 1. *Agrosilvopastoral system with almond trees, cereals, goats and sheep that graze the cereal stubble after crop harvesting. Kolchiko, Lagadas Thessaloniki © Maria Yiakoulaki*

agroforestry systems, which demarcate them, separating them from the rest of the landscape, and facilitating their management and environmental protection while improve the living conditions of animals and their grazing distribution patterns (Melvin et al. 2007, Kizos and Plieninger 2008).

Trees can be natural or cultivated, evergreen or deciduous. They can be placed within the pastures, at their edges, or both, either in lines, in groups, or scattered without a specific pattern. The animals that utilize the agroforestry systems are ruminants (cattle, sheep, goats and buffaloes), horses, poultry, pigs, and donkeys. The rational management of agroforestry systems requires that animal species (grazers) be suitable for the system's vegetation and that they graze in the proper season and period. Trees are the dominant structural components, because in addition to feeding the animals, they contribute to their welfare by providing protection from the sun, rain, wind, and birds of prey. In particular, the shading they provide mitigates extreme climatic conditions by affecting the growth, morphology, and chemical composition of the understorey vegetation and, consequently, the quality of the forage (Lin et al. 1999). In addition, due to the shade in the understorey, the animals' grazing period is extended and the increased inclusion of green vegetation in their diet leads to an improvement in the nutritional characteristics of milk and meat (Mele et al. 2019). At the same time, trees' shade help reduce the energy required by animals to regulate their body temperature (Smith et al. 2012) and improve their feed efficiency (Sullivan et al. 2011). It is often observed that livestock gather under trees at midday to protect against high summer temperatures (Figure 2).

Cultivation practices combined with designed grazing systems can mitigate the effects of climate change

In agroforestry systems, grazing animals move freely and are able to feed on a wide variety of plant biomass and produce livestock products. Through their traveling, trampling, and selective grazing, they affect the structure and composition of the vegetation, while heavy grazing reduces the participation of palatable species and increases the less desirable plants. Furthermore, mixed grazing contributes to a better utilization of vegetation, as the different animal species, apart from their different dietary preferences, graze at different heights (e.g. goats browse from higher vegetation strata than sheep, which graze at a height of 3-5 cm).

GRAZED AGROFORESTRY SYSTEMS AND CLIMATE CHANGE

Climate change has a negative impact on livestock production systems (Tubiello et al. 2007); however, livestock farming (extensive and intensive) is also a large contributor to climate change, causing 18% of global anthropogenic greenhouse gas emissions (Steinfeld et al. 2006). The main greenhouse gases from livestock production systems are carbon dioxide (CO_2), nitrous oxide (N_2O), and methane (CH_4). CO_2 derives from land use and its changes and accounts for 32% of atmospheric emissions. N_2O comes from manure and slurry management and represents 31% of emissions, while CH_4 originates from the fermentation of cellulosic feeds in the ruminant digestive system and represents 25%.

Figure 2. *Gathering of sheep under the oaks. Ossa, Lagadas, Thessaloniki © Maria Yiakoulaki*

Sintori et al. (2019) reported that extensive goat farms cause higher emissions/kg of milk produced in comparison with semi-intensive and intensive farms. However, extensive farming is associated with other environmental advantages. Agroforestry and its practices can mitigate the effects of climate change (Montagnini and Nair 2004) by reducing atmospheric concentrations of greenhouse gases through carbon sequestration in woody plant tissues and in surrounding soils. Tree species, used in agroforestry, are generally of high nutritional value and digestibility and can improve ruminant productivity, while at the same time they can increase the rate of CO_2 sequestration and reduce methane emissions (Thornton et al. 2009). The increased cover with leguminous trees in the overstorey and the enhanced participation of cool-season forages and legumes in the understorey can simultaneously reduce CH_4 and CO_2 emissions. Furthermore, the inclusion of forages containing secondary compounds at low or moderate concentrations, such as condensed tannins, saponins, and essential oils has shown potential for improving animal productivity, health, and mitigation of enteric CH_4 production. Along with improving the qualitative characteristics of forage, the application of designed grazing management systems (e.g. rotational system) could potentially lead to further reductions of CH_4 emissions to the atmosphere (Hristov et al. 2013, Savian et al. 2018).

Artificial shrub plantations in grasslands will have clear economic and environmental advantages

Planting highly nutritious and productive shrubs on natural grasslands can contribute to meeting the nutritional needs of animals in critical times of the year. These shrubs can be used either directly for grazing by the animals, or their foliage can be harvested as a supplementary feed. Experiments in the United States (Yiakoulaki et al. 2007, 2009), have shown that the combination of Albizia julibrissin (Figure 3) with naturally occurring grasses and forbs with the creep grazing system (a new designed grazing system for goats) contributes to increased pasture productivity, improving their quality and meeting the nutritional needs of kids (young goats) without the provision of supplementary feeds. At the same time, when shrubs were introduced in the diet of kids (as a percentage of 53%), their weight doubled (81 g/day) and the animals reached weaning earlier without the stress of weaning (Yiakoulaki et al. 2014).

In Greece, shrubs are not yet cultivated in pastures and designed grazing systems are not applied for their management. The creep grazing system, as described in the Technical Guidelines for the improvement of vegetation, within the context of the implementation of the Grazing Management Plans (Common Ministerial Decision

1058/71977/07.07.2017, Government Gazette issue B' 2331) on the grazing lands of Greece (Law 4351/2015, Gazette A' 164), could be potentially implemented by planting shrubs of indigenous flora. Tree medic *(Medicago arborea)* and Mediterranean saltbush *(Atriplex halimus)* can be used in arid areas (islands), while white mulberry *(Morus alba)*, coronilla *(Coronilla emeroides)*, common fraxinus *(Fraxinus ornus)*, etc. in wetter areas. In addition, the creep grazing system is flexible and with minor modifications can be applied to other kinds of animals (sheep and cattle).

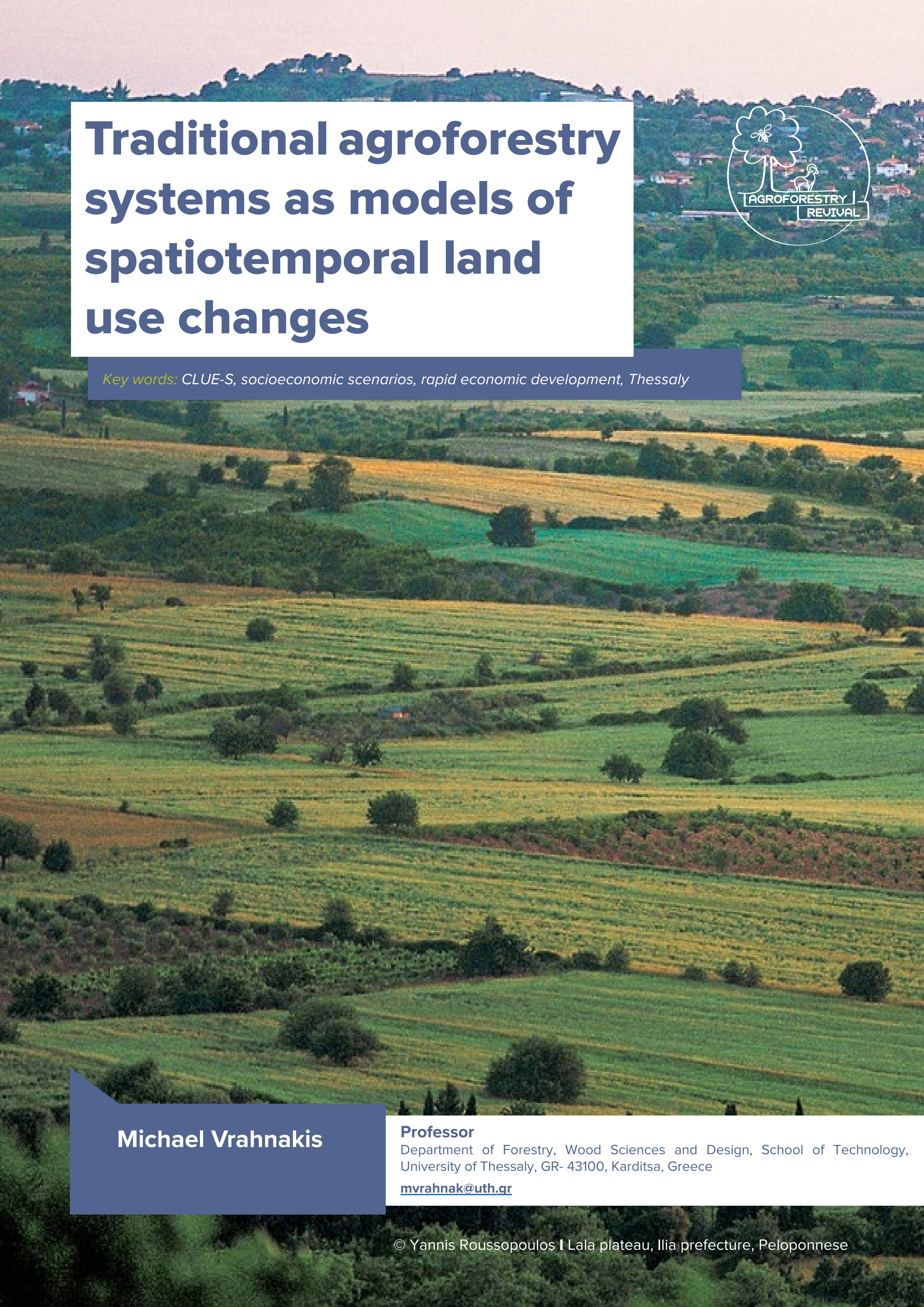
The encouragement and financial support of breeders to adopt the aforementioned practices in the rearing of their animals will have not only financial, but also clear environmental benefits.

Figure 3. *Creep grazing system with plantation of Albizia julibrisin shrubs in a natural mixed grass/forb pasture. The shrubs were planted in rows with intervals of 2-3 m between the rows and 0.5-0.6 m between the shrubs (on the same row). The shrubs were pruned to a height of 0.5-0.6 m to ensure kids' access to leaves. Experimental pastures of Langston University, Oklahoma, USA, © Maria Yiakoulaki*

© Yannis Roussopoulos I Mantilo stream valley, Efpalio area, Fokida, C. Greece

Traditional agroforestry systems as models of spatiotemporal land use changes

Key words: *CLUE-S, socioeconomic scenarios, rapid economic development, Thessaly*



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© Yannis Roussopoulos I Lala plateau, Ilia prefecture, Peloponnese

TRADITIONAL AGROFORESTRY SYSTEMS IN GREECE

Traditional agroforestry systems (TAFs) are important landmarks of rural areas, of extremely significant cultural and scientific value. According to Papanastasis (2015), these systems „reflect the ways in which humans of the past treated and utilized available natural resources, interacted with their environment, incorporated natural elements -especially trees- into their lives and were close to nature“. In addition, they have significant scientific value due to the possibilities they provide to modern humans for establishing alternative techniques of management, use and modification of the rural landscape. By retaining these two qualities, TAFs further contribute to enhancing the ecosystem services offered by typical agroforestry systems (Castle et al. 2022).

What do the modeling tools tell us about the prospects of traditional agroforestry systems in the current socio-economic environment and in the medium term?

Greece holds a prominent place in Europe in terms of the presence of TAFs. It is estimated that they occupy an area of about 3 million Ha or 23% of the country's territory (Papanastasis et al. 2009). Agroforestry is present in all types of its possible systems (silvoarable, silvopastoral, agrosilvopastoral). Typical density varies from 10 - 100 trees/Ha (as in Italy), compared to Spain and Portugal where the density is 10 - 40 trees/Ha (Eichhorn et al. 2006). The existing systems are considered degraded and largely abandoned, bearing the negative consequences of the abandonment of agricultural, pastoral and forestry activities in Greece's rural areas (Papanastasis 2004).

TAFs can be found all over the country, however they occur more often in Northern (Macedonia, Thrace) and Central (Thessaly, Sterea Ellada) Greece, Crete and the Aegean islands. In the region of Thessaly, which is environmentally strained due to intensive and one-dimensional agriculture, TAFs are located mainly in semi-mountainous areas, near rural settlements. The TAFs of semi-mountainous Thessaly were the object of the AGROTHES research project «Prospects of agroforestry in the Thessaly Region: A research study with a social, environmental and economic dimension aiming to strengthen the participation of farmers» (2018-2022) (General Secretariat for Research and Innovation, Hellenic Research and Innovation Foundation, University of Thessaly). The project investigated the prospects for the implementation of agroforestry in Thessaly in order to strengthen farmers' participation. A special environmental research methodology was developed in the context of the project, which included the mapping and modeling of land uses to predict future developments based on socio-economic scenarios under the CLUE-S spatiotemporal model (Mamanis et al. 2021, Nasiakou et al. 2022). The Municipality of Mouzaki, in Western Thessaly, was chosen as the research area.

Figure 1. *Geophysical map of the Municipality of Mouzaki. The altitudinal division of the area is evident from the east (lowlands) to the central-west (semi-mountainous areas), and to the west (mountainous areas). (Source: http://opencyclemap.org/). Bottom right: Orientation map of the Municipality of Mouzaki (in red) in the Region of Thessaly.*

THE TRADITIONAL AGROFORESTRY SYSTEMS OF THE MUNICIPALITY OF MOUZAKI

The Municipality of Mouzaki, located in the western part of the Regional Unit of Karditsa (Figure 1), is considered as representative of the Region of Thessaly, occupying plain, semi-mountainous and mountainous areas. In addition, residual agroforestry systems are mainly found in the mountainous and semi-mountainous areas, but also in the lowlands.

The Municipality of Mouzaki occupies an area of 31,326.97 Ha and includes 27 Local Communities (LCs) with a total population of 13,768 permanent residents (census 2011). Silvoarable lands occupy 556.38 Ha (1.78%), silvopastoral systems (tree cover 10-40%) 3815.39 Ha (12.18%), agricultural crops 35.57%, grasslands 7.68%, forests (tree cover >40%) 33.75%, sparse shrublands (shrub cover 10-40%) 1.61%, dense shrublands (shrub cover >40%) 2.51%, urban areas 4.65% and bare lands 0.27% (Figures 2-3).

Figure 2. *Wider area of the L.C. of Vatsounia (Municipality of Mouzaki). Residual silvoarable systems in the form of hedgerows are visible to the east of the settlement (Source: GoogleEarth).*

Figure 3. *Agroforestry systems in the modeling area (Municipality of Mouzaki). Top left: Active silvopastoral system of Quercus pubescens at the entrance to the semi-mountainous settlement of Vatsounia. Top right: Semi-active silvoarable system of vine and wild pear trees at Vatsounia. Bottom left: Silvopastoral landscape with wild pear trees near the lowland settlement of Loxada. Bottom right: Active silvoarable system with vines and mulberry trees at the entrance to the lowland town of Mouzaki (Photos: M. Vrahnakis).*

Within these areas, mainly of the LCs of Vatsounia and Ellinopyrgos-Agios Akakios, extensive but abandoned silvoarable systems are found, which were gradually installed from 1960 onwards as hedgerows, as attested by oral testimonies from local residents. The trees featured in these systems were walnuts (for fruit and wood), mulberries (for berries, leaves for fodder and stakes to support local varieties of climbing beans), cherries, apples and local varieties like “firiki” (small apples), figs, cranberries, hazelnuts, pears and oaks. Trees were combined with crops such as cereals, a local variety of dry maize, chickpeas, lentils, Vicia varieties, potatoes, clover for seed production and grapevines usually combined with pear and oak trees.

An application of the CLUE-S spatiotemporal tool shows that rapid economic growth favors the expansion of agroforestry systems over a 20-year time frame, a fact that helps decisively the maintenance of today's traditional systems

As part of the AGROTHES research project (2018-2022), the residents of the LC of Vatsounia reported that in the 1970s, an attempt at establishing poplar plantations was made, but these did not thrive and were consequently abandoned. These agroforestry systems housed a considerable number of species of fauna, most of which are no longer found, such as common quails (Coturnix coturnix) in the cereals (which after the appearance of baling machines disappeared), common wood pigeons (Columba palumbus spp. palumbus), northern lapwings (Vanellus vanellus), Eurasian woodcocks (Scolopax rusticola), common blackbirds (Turdus merula), Eurasian skylarks (Alauda arvensis), hares (Lepus europaeus), roe deer (Capreolus capreolus) and wild boar (Sus scrofa). Unfortunately, these traditional systems are in danger of collapsing due to the expected natural afforestation, leading to the reduction of agricultural crops; for this reason, it was deemed necessary to study the changes over time in the agricultural landscape of the territory of Mouzaki.

LAND USE CHANGE PREDICTIONS BY THE CLUE-S SPATIOTEMPORAL MODEL

The modeling of land use changes in Mouzaki used cartographic material such as land use maps, aerial photographs and satellite images. This material was first processed with GIS technology in order to study the evolution of the landscape and subsequently with the CLUE-S spatiotemporal model which outlined the future landscape in the reference year 2040. Three socio-economic scenarios were used: (a) business-as-usual (BAU), (b) rapid economic development (RED), and (c) ecological land protection (ELP) (Mamanis et al. 2021). At the same time, demographic and socio-economic data were collected. A digitized photomosaic of aerial photographs (1960), as well as recent satellite images (2014, 2016, 2017, 2019), diagrams and maps of landscape transformation (1960-2020) were also produced.

The analysis showed that the changes of the land cover/ land use units (1960-2020) are mainly located in the mountainous part (Central and Southeast Mouzaki). The most important change is the expansion of woody vegetation and the densification of forests, especially in the southern and eastern parts, at the expense of open grasslands and agricultural crops (Nasiakou 2022). Silvopastoral systems expanded, while silvoarable systems remained limited throughout the studied period. Demographic changes and the abandonment of land and traditional practices (agroforestry) were identified as the main causes of landscape change.

In relation to the predicted changes in the landscape of the Municipality of Mouzaki, the results from the CLUE-S model appear to be that silvoarable land expands in all three scenarios. The scenario that favors it the most is that of rapid economic development (Nasiakou 2022). In contrast, upland silvopastoral systems appear to remain stable, with only a small increase under the business-as-usual scenario.

From the spatial analysis of land use changes for 2040 it emerged that:

- Silvoarable land increases significantly (+57%) under the rapid economic development scenario.
- These changes are found in all semi-mountainous localities with abandoned silvoarable systems (LCs of Vatsounia, Drakotrypa, Porpi) (Figure 4).
- An appearance of new silvoarable systems in lowland areas bordering higher elevations (LCs of Mavromati, Lazarina, Magoula, Fanari).

- No changes are expected to the silvopastoral systems under the three scenarios.
- In any case, the traditional silvopastoral systems should be revitalized with cultivation and addition of trees.

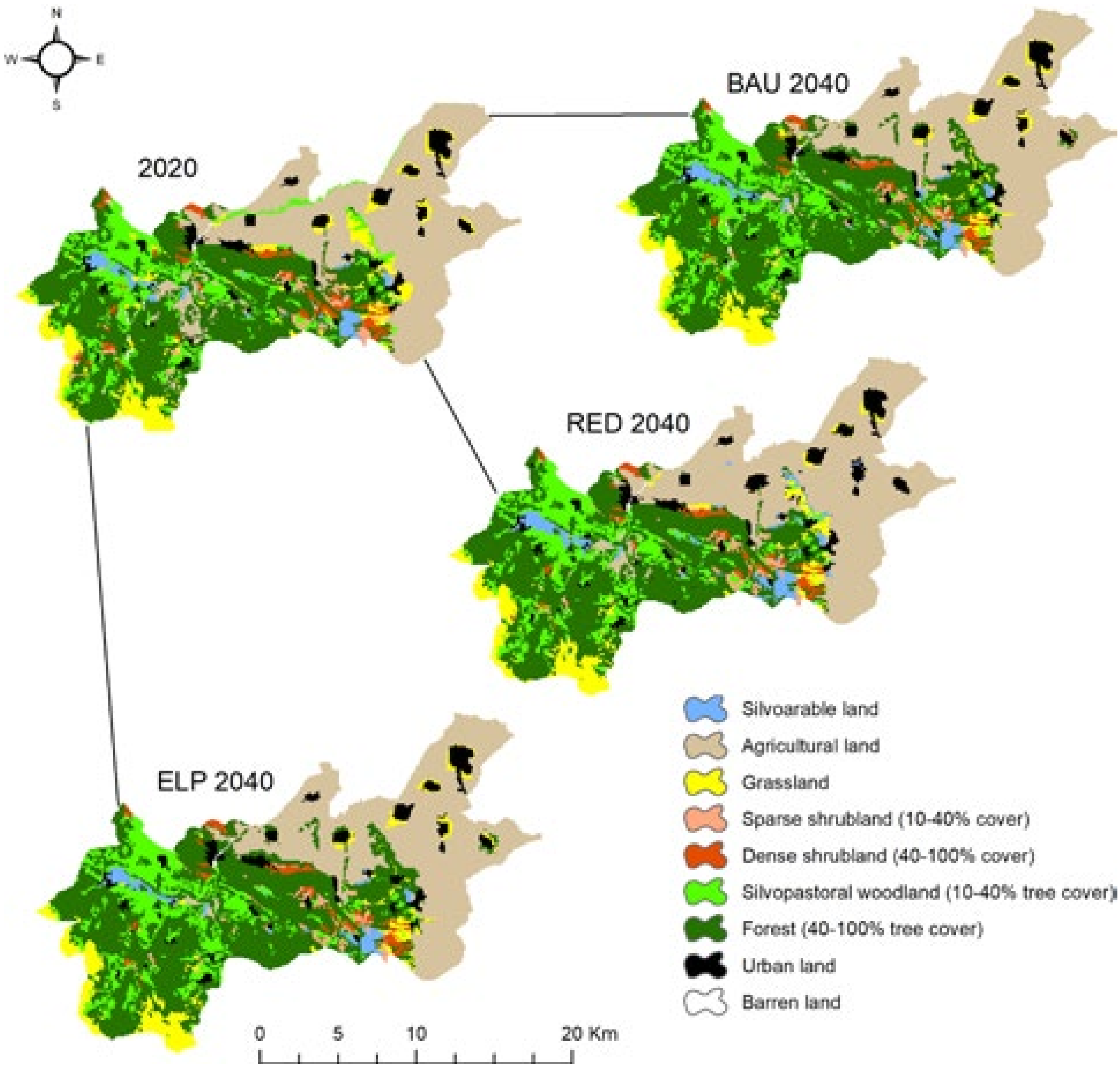

Figure 4. *Land use changes in 2040 under the three scenarios for the Municipality of Mouzaki (Mamanis et al. 2021).*

Mountain pastures: the case of the ForOpenForests project

Key words: Mt Oiti, Mt Kallidromo, mountain pastures

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© Yannis Roussopoulos I Valtos district, small plateau in the fir forests

INTRODUCTION

The project entitled “Conservation of priority forests and forest openings in “Ethnikos Drymos OOitis” and “Oros Kallidromo” of Sterea Ellada - LIFE11 NAT/GR/1014”, abbreviated to “ForOpenForests”, was carried out in the period 2012-2017 and lasted for 63 months (more info at https://foropenforests.org). Its main objective was the implementation of appropriate management measures for the conservation of biodiversity at the species, habitats and landscape levels in these two areas of the NATURA 2000 Network. It had been preceded by a strong concern resulting from the realisation that these two mountainous areas showed clear signs of a gradual spread of fir forests (*Abies cephalonica* Loudon) at the expense of clearings and openings which had been created in the past by intensive grazing. Shepherds have been burning forests for centuries to secure pastures for livestock (Karetsos 2002). By analogy, the same practices (clearing, fires and grazing) were applied in all the mountainous regions of Greece, as in other Mediterranean regions (Papanastasis 1986, Papanastasis 2004).

Extensive livestock farming could be included as a management tool for the preservation of forest openings

These tradOitional activOities created the so-called “pseudo-alpine” landscapes, which in turn preserved the outstanding biodiversity of the aforementioned areas. During the 1970s and 1980s, when an environmental awareness was cultivated, it was seen that some areas of special interest had to be protected, and indeed with the logic of absolute protection. Directives 99/409 EEC and 92/43 EEC laid the foundations of protection, with the corresponding institutional arrangements and the integration of the directives into the national legislation of the member states.

There had of course also been previous attempts at national protection policies in our country through the establishment of National Forests (Parks). The concept of absolute protection, at least in the cores of these areas, prevailed and the tradOitional activOities that had shaped the landscapes and the special elements of the protected areas were definOitively prohibited.

The long-term prohibOition and at the same time the actual reduction of the grazing pressure and forest exploitation for lumber production, resulted in the gradual return of the forests to their past limits and density, before humans appeared. The re-dominance of forests is accompanied by at least the reduction of plant diversity and the limitation of different elements of the landscape and the habitats of other life forms.

Researchers and relevant authorities should propose new management measures, including grazing, for biodiversity conservation

Figure 1. *Estimation of biomass production inside and outside of fenced plot © George Karetsos*

PECULIAROITIES OF THE OOITI AND KALLIDROMO REGIONS

In the two mountainous regions of Oiti and Kallidromo, we encountered different practices of tradOitional livestock farming activOities. In Oiti, the prohibOitions in the core area of the mountain have been in force since its designation as a National Forest (1966), and the Protection Regulation has been in force with specific condOitions. On the contrary, Kallidromo mountain has been continuously grazed and joined the “NATURA 2000” Network relatively recently (2001); until then, there was no institutional protection framework, which is currently expected to be completed. Oiti is a higher mountain with larger openings at high altitudes. On the contrary, Kallidromo features smaller gaps but richer biomass production. Oiti, outside the core, is grazed by all types of animals, while Kallidromo is grazed by goats and cattle but sheep are absent.

The juniper stands of Mt. Oiti seems to have shrunk due to the abandonment of grazing, which favored their preservation

Oiti mountain

In the case of Oiti, we faced two risks. The first referred to the “closure” (densification) of mountain grasslands characterized as priority habitat types: semi-natural dry grasslands on calcareous substrates (*Festuco Brometalia*) (6210*) and grassy beds with *Nardus*, of various species, on siliceous substrates in mountainous areas (6230 *). Also, in the corresponding areas of the above habitats and within them, we also studied the potential risks of Mediterranean temporary ponds (3170*), which are also linked to grazing. The area of the above habitat types was under a strict regime of protection and prohibOition of grazing. The serious danger they faced was the relatively quick resettlement of the spruce fir forest, with the following mechanisms: at first, with the rapid appearance and inOitial establishment of individuals of *Juniperus communis* L. subsp. *nana* (Wild.) Syme, in the form of patches (islands), and, afterwards, in the favourable environment of these islets, with the establishment of fir itself, timidly at first and then with growing intensity.

Because of this, and under a prohibOition regime, we implemented pilot applications of management practices consisting of cutting the excess biomass to a sufficient area, as a measure to substitute grazing; we also installed a network of fenced plots, where we estimated the amount of biomass produced inside and outside them in the same area, and assessed the grazing capacity and grazing pressure in the area. The composOition of the herbaceous vegetation was estimated through the method of transects cuts and needles and above-ground rangeland production with clipping in quadrats quantity with boxes (Figure 1). With special permission, we also applied tradOitional patch (island) burning of *Juniperus communis* subsp. *nana* to a sufficient extent and assessed the production and biomass composOition of the burned patches after burning. In essence, we tried to replace the tradOitional techniques of securing pastures, which shepherds would use at the end of the summer season. For habitat type 3170* (Mediterranean temporary ponds), we found that it is not yet endangered, but it may be threatened in the future with the encroachment of the forest. Its survival is also linked to other serious climatic factors and mainly to ensuring that the water remains for a sufficient time, in order to ensure the particular type of vegetation composOition and less the practice of grazing, which may have a posOitive effect. Of course, we are concerned about the change of grazing animals from sheep to beef cattle, a recent widespread habit, which must be studied over time. All measurements were under the close supervision of the Laboratory of Rangeland Ecology Chair of Grassland (Grassland Ecology), Department of Forestry and Natural Environment of the Aristotle University of Thessaloniki (Papanastasis et al. 2013).

The second risk is related to the decline of the stands of the priority habitat type Endemic Mediterranean forests with *Juniperus foetidissima* (9560*). In Mt Oiti it appears fragmented in small clusters always mixed with fir or as individual trees in upland areas. These stands appear to be remnants of older and more flourishing forests that shrunk due to the abandonment of grazing. Today they occupy the most extreme xerothermical limestone areas of the mountain with essentially no soils and are in danger of further limitation due to the expansion of fir forests within their areas/range. They also show extraordinary inherent difficulties in their natural regeneration (Proutsos et al. 2021). The measures we implemented correspond to practices of shepherds who burned fir forests to ensure grazing, but created favorable condOitions for the establishment of *Juniperus* spp as pre-forest plant communOities. Of course, we did not apply burning, but in pilot experimental plots, we removed young fir individuals and killed older ones that were suppressing *Juniperus foetidissima* individuals and stands. At the same time, we tried to strengthen environmental awareness regarding the illegal logging of the juniper trees that are preferred by local residents for their raw wood, which is intended for various constructions.

Kallidromo mountain

At Mount Kallidromo we encountered two types of priority habitats related to grazing. Semi-natural dry meadows on calcareous substrates (Festuco Brometalia) (6210*) and Mediterranean temporary ponds (3170*). The openings covered by these two habitat types on the mountain are smaller than in Mt Oiti, while Mt Kallidromo does not have a pseudo-alpine zone, possibly due to its lower altitude. Sheep breeding is practically absent. Livestock farming in Kallidromo has lately been turning towards beef cattle and goat farming is constantly being limited. LimOiting the intensity of goat grazing in Kallidromo also clearly showed tendencies to "close" the forest openings. The practice of nomadic cattle breeding also extended to the Mediterranean temporary ponds (3170*), because cattle preferred the edges and to some extent the interior of the shallow waters of the ponds.

The ForOpenForests project was testing conservation practices in mountain grasslands, used historically by the shepherds at the end of the summer

For the above reasons, we also installed fenced plots in the openings of the forests, where the biomass produced inside and outside them and the assessment of the grazing capacity and grazing pressure of the area were estimated. Correspondingly, the composOition of the vegetation was recorded with transects. It was found that the ratio of grasses to broad-leaved herbs is more balanced compared to Oiti. It was also credited that the grazing pressure by cattle is exerted more towards the seasonal ponds, while that by goats more towards the forest. The pilot measures were mainly directed towards habitat type 3170*. Parts of the ponds were fenced off to prevent cattle from grazing, while in the remaining area grazing continued to be practiced freely. The aim was to assess whether in the fenced off sections the composOition of their particular flora was maintained in a better condOition than the unfenced ones, because the characteristic species of the habitat showed a very low presence in the latter (Figure 2).

In Kallidromo, we also installed special collars on 30 cattle, equipped with transmitters to record the animals' course and posOitions, which were recorded via satellite on a digital map (Figure 3). The aim was to study the grazers' preference habits of the different habitats and to reinterpret the attitudes and frequency of watering.

Figure 2. *Seasonal pond fencing to prevent grazing in Kallidromo mountain. © George Karetsos*

Figure 3. *Placement of collar with GPRS transmitter © George Karetsos*

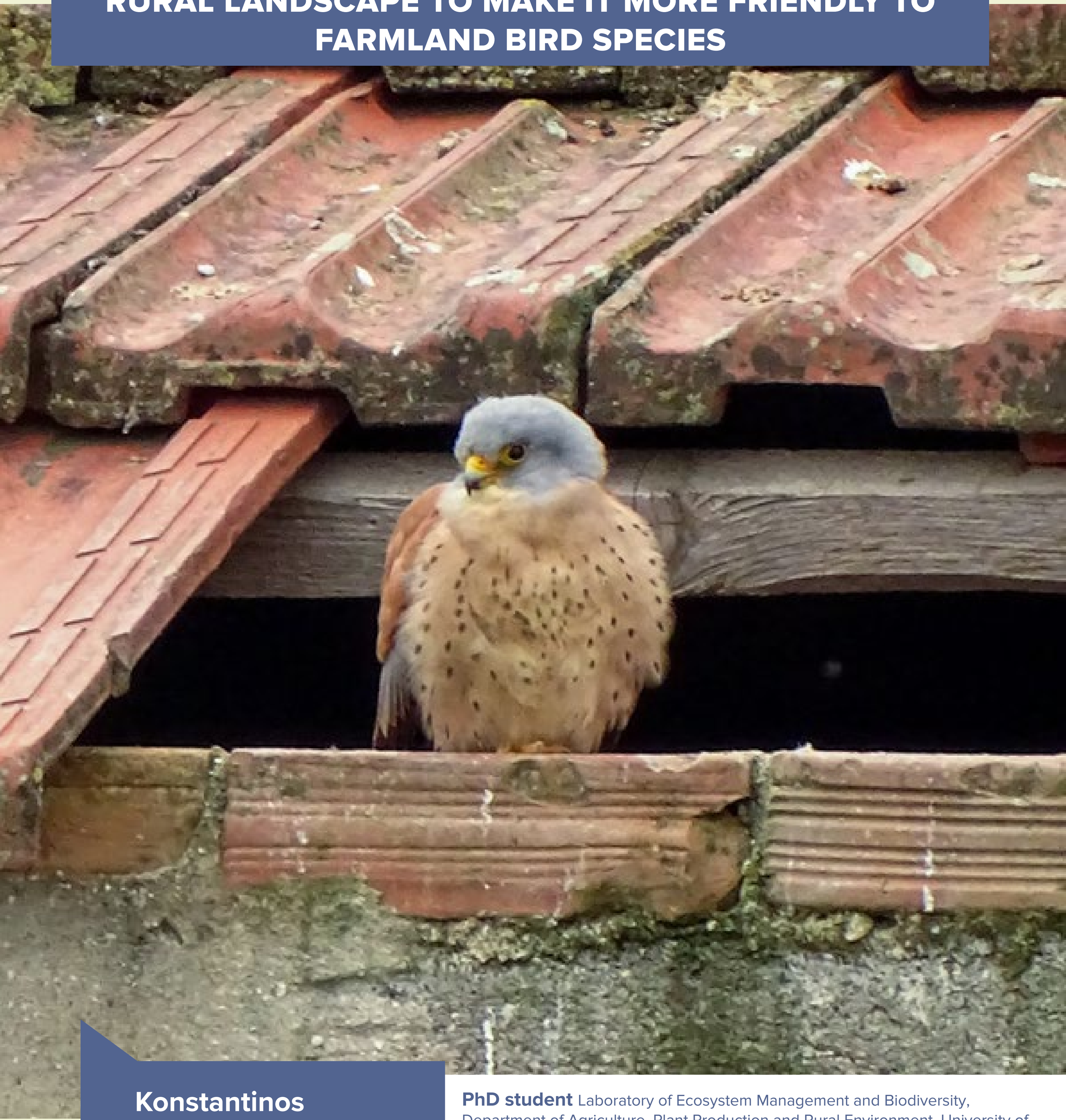
CONCLUSIONS

The two mountains present several differences. Kallidromo is more wooded and its openings are three times smaller in area compared to Oiti. Moreover, Oiti shows less biomass productivity but maintains animal populations of all categories and in greater numbers. The preference in recent years towards beef cattle (at the expense of sheep) has not been studied over time and we do not know the consequences. The maintenance of openings in both mountains is required. Extensive animal husbandry could be practiced in a more correct way and could be included as an important practice and management measure for biodiversity conservation. This means that the competent state and regional services should introduce new management measures and include grazing in the practices of controlling openings and biodiversity in balance.

Worrying is the recent change in the grazing animals from sheep to cattle, which should be studied in depth time

© Yannis Roussopoulos I Cereal cultivations on a mountain plateau, Valtos Mts C. Greece

INTERVENTIONS IN THE STRUCTURE OF THESSALY'S RURAL LANDSCAPE TO MAKE IT MORE FRIENDLY TO FARMLAND BIRD SPECIES



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© Konstantinos Vlachopoulos I A male lesser kestrel is about to leave its nest after offering food to the incubating female.

Human activities, particularly agriculture and animal husbandry, have had a significant impact on the evolution of the Mediterranean rural environment. More than 50% of the surface of the European Union is covered by agricultural land. Since its widespread adoption in 1960, the high-yield model of agriculture has increased the amount of intensively farmed land, fragmenting the landscape and converting complex natural ecosystems with high species richness into monocultures. Animal species diversity in agricultural ecosystems is declining, and this relationship is strongly influenced by changes in land use and landscape fragmentation. Numerous scientific studies have shown that intensive agricultural practices such as clearing natural vegetation, excessive use of agrochemicals, and tillage with heavy machinery have had a negative impact on the presence of vegetation elements such as hedgerows, individual trees, and uncultivated strips of land between fields. These landscape components carry out a variety of functions and provide ecosystem services such as pollination and CO_2 sequestration. Among the major taxonomic groups of creatures that inhabit agricultural areas, birds exhibit the most significant decreases in species diversity and population abundance. In particular, a study which investigated the population trends of 148 European common birds over a 30-year time series, revealed that the overall decline in abundance for 57 species was 39%.

The use of a "umbrella species", such as the lesser kestrel, can benefit both taxonomic groups by mitigating the effects of intensive agriculture on the biodiversity of agroforestry landscapes

The Thessalian plain is one of Greece's most intensively cultivated areas. Thessaly has a cultivated area of approximately 5,000,000 hectares, with arable crops accounting for 80% of this total (ELSTAT, 2018). Thessaly's agricultural landscape is a vast monoculture of hundreds of thousands of acres, with only a few "islands" of natural vegetation. With over 5000 breeding pairs, this area also features the largest population of kestrels (*Falco naumannni*). The lesser kestrel is a small falcon that feeds on orthopterans (grasshoppers, crickets, and other insects) and coleopterans (various species of beetles) as revealed by a pellet analysis that was conducted in

2016 (Makri et al. 2016). This species prefers to forage at *steppe*-like grasslands and extensive crops, particularly grazed ones, because it prefers short grass to locate its prey. The average distances that the lesser kestrels travel in search of their prey are differentiated according to sex (Vlachopoulos et al. 2016). The population of lesser kestrels declined dramatically in the mid-1970s, which was attributed to crop changes and agricultural mechanization. Since 2013, population growth has been on the rise. In the framework of the LIFE-Nature project “Conservation and management of *Falco naumanni* in three Special Protection Areas (SPAs) of Greece” (LIFE11NAT/GR/001011), agroforestry pilot actions were carried out, among other targets, to enrich the agricultural landscape with vegetation elements, primarily through the creation of hedgerows, the maintenance of uncultivated strips of land, and the planting of solitary trees on field margins.

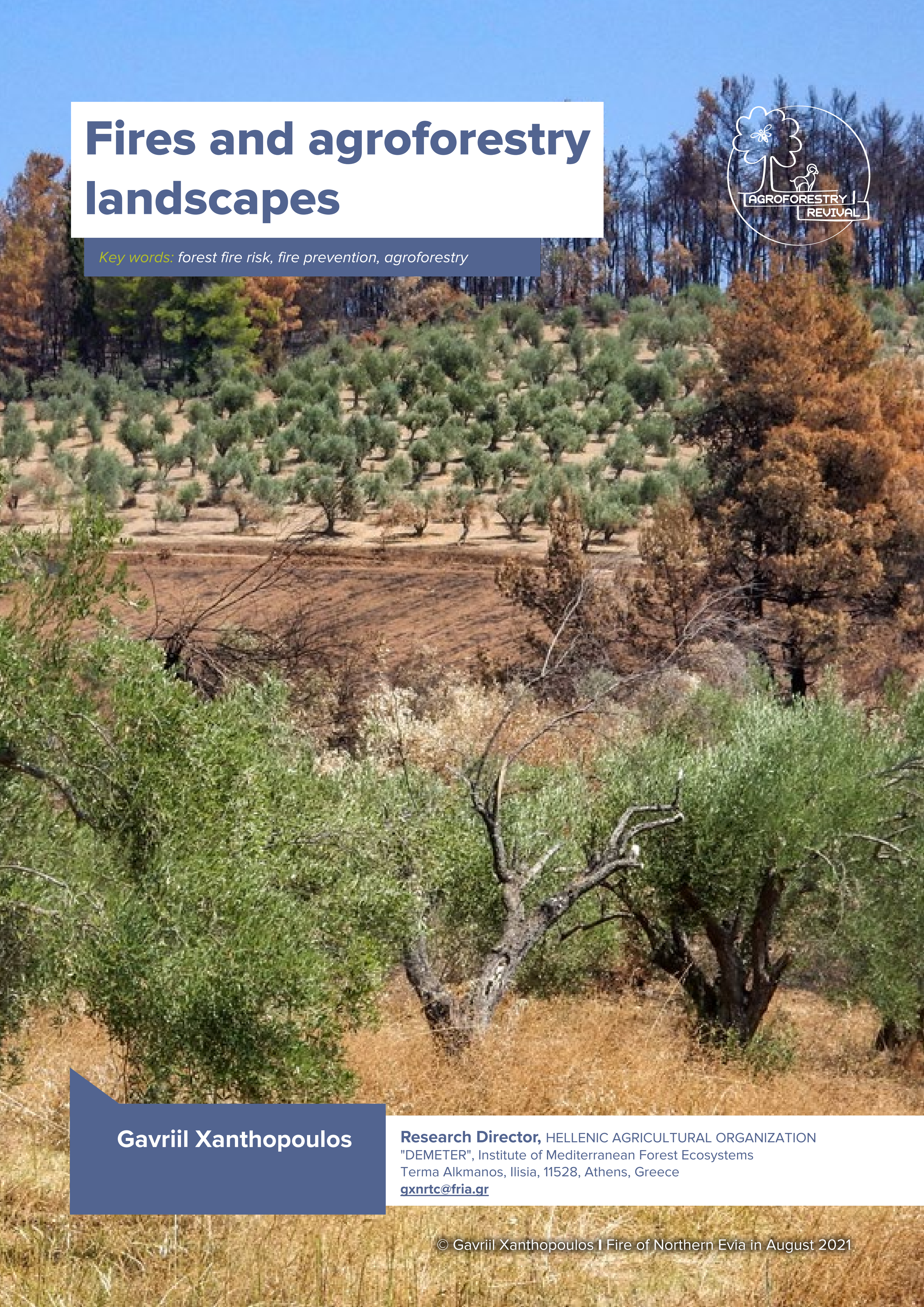
These interventions are expected to improve the habitat of the Orthoptera, small mammals and Coleoptera, the species’ main prey. The use of an “umbrella species”, such as the lesser kestrel, can benefit other taxonomic groups that are expected to colonize and use these rural landscape structural elements. This project can serve as a springboard for larger-scale action and the overall transformation of the rural Thessalian plain into a more biodiversity-friendly landscape. International experience has shown that combining proper agricultural methods with agroforestry can reverse the effects of intensive agriculture. Furthermore, it is widely shown in literature that agroforestry systems help not only biodiversity but also the local population, because the producer can benefit from tree products in addition to the crop that he harvests, ensuring an additional income.

© Konstantinos Vlachopoulos I Planting of narrow-leaved ash *(Fraxinus oxycarpa)*, Elm *(Ulmus campestris)*, and Mulberry (*Morus* sp.) to improve landscape heterogeneity, primarily for the benefit of lesser kestrels' prey species.

AGROFORESTRY REVIVAL

Fires and agroforestry landscapes

Key words: *forest fire risk, fire prevention, agroforestry*



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THE EVOLUTION OF FOREST FIRES

In recent decades, forest fires have become increasingly difficult to control and the destruction they cause is also intensifying, despite the significant strengthening of forest firefighting mechanisms globally. Greece, as well as other neighbouring countries, is no exception (Xanthopoulos and Nikolov 2019). It is predicted by the entire research community studying the phenomenon that the problem will worsen due to climate change, fuel accumulation caused by rural abandonment and reduced forest management, as well as residential establishment within or near forests (Rego et al. 2019). In fact, the temporary avoidance of fires thanks to strengthened suppression forces causes further biomass accumulation, a fact that will certainly lead to more destructive fires in the near future. This phenomenon, called the "fire paradox" has been experienced by many countries around the world, including Greece (Arévalo and Naranjo-Cigala 2018). Strengthening forest fire prevention is proposed as an essential pillar to reduce the incidence of disasters and limit costs, as its efficiency is much higher than the cost of fire suppression.

Agroforestry, in addition to its many economic and environmental benefits, can play an important multifaceted role in forest fire prevention

FOREST FIRE PREVENTION

Forest fire prevention is defined as the set of actions taken before a fire starts aiming to:

- Reduce or eliminate the likelihood of fires
- Reduce the possibility of unhindered spread of any fire that occurs
- Reduce the damages in the event of a fire
- Ensure the existence of a mechanism capable and ready to rapidly detect new fire outbreaks and to respond without delay with the necessary forces to immediately put it under control.

Forest fire prevention is a multidimensional activity which includes a technical/technological part (risk forecasting, fire planning, roads, reservoirs, hydrants and other technical works) and a social dimension (information, awareness and organisation of citizens, policy, legislation). However, none of these can ultimately prevent disasters if the forest area is not properly prepared, keeping the risk from flammable material at a manageable level. The statistics on forest fires in Greece offer tangible evidence: during the decade 1960-1969, when fires were under the responsibility of the Forest Service, which had neither aerial resources nor forest fire-fighting vehicles but had on its side the contribution of human populations living near the forests, the average annual burnt area was 123,770 hectares. In the period after the transfer of fire suppression responsibility to the Fire Service (1998-2022), the annual average was 437,460 hectares, despite the availability of many hundreds of fire engines and dozens of aerial firefighting resources. The increase in the amount of living and dead biomass in the countryside, but also the creation of horizontal and vertical fuel continuity, due to abandonment of activities by the continuously declining population (Xanthopoulos and Nikolov 2019), are the main reasons for this change; they are probably more important than the adverse meteorological conditions favoring wildfires and occurring with higher frequency due to climate change. In that sense, it is important to note that the proportion of the rural population within the total population of Greece decreased from 44.06% in 1960 to 20.61% in 2019. This has reduced the use of wood for heating and cooking, while many agricultural cultivations that in the past acted as breaks of the continuity of fuel were abandoned, and extensive livestock grazing, that helped to control the quantity of fuel, declined.

The state's response to this major problem, especially after the disastrous fire season of 2021, is to increase funds for fire suppression and prevention. Prevention funds are largely allocated for fuel reduction works, primarily by removing the understory of tall forests, but also by creating new firebreaks. However, at an annual cost of more than €70 million, this high expenditure is difficult to maintain in perpetuity, while the treated vegetation will recover in a few years. It is clear that a policy change with a focus on 'smart' prevention is needed (Moreira et al. 2020).

When applied to large areas, agroforestry gives a real opportunity to firefighting operations to stop large fires

Returning the population to the countryside is a reasonable goal that would help rebuild fire and climate change resilient landscapes, but is generally difficult to achieve. A more realistic objective, however, may be to retain the population already there and attract younger residents as far as possible. This requires policies for their economic viability and ensuring some minimum living standards. Local conditions (climate, soil type and condition, size of plots, production and marketing conditions, etc.), together with the existence of modern knowledge and the ability to organise production and marketing, play an important role in achieving this sustainability. One of the promising options in this direction is agroforestry.

AGROFORESTRY AND FOREST FIRES

The term agroforestry describes land management systems where forest or agricultural trees are intercropped with herbaceous species on the same piece of land. In scientific terms, these systems are divided into silvo-agricultural, silvo-pastoral, or agro-silvo-pastoral systems. In any case, they are a practice that has been applied since ancient times in Greece and in many other countries of the world, as it has many economic and environmental advantages. Among the advantages offered by agroforestry is the role it can play in preventing forest fires. This role is multifaceted. Firstly, agroforestry can help to keep human populations in the countryside as it can provide improved income, stability in terms of the effects of climate change and income opportunities from parallel activities such as agrotourism, beekeeping, etc. In addition, these populations can be an aid to fire prevention.

Agroforestry, applied over large areas, results in reduced total amount of biomass per unit area, giving a real opportunity to suppression mechanisms to stop large fires. However, even relatively narrow strips, a few tens of meters wide, can contribute substantially to breaking the horizontal continuity of fuel, offering fire suppression opportunities either by direct attack or by applying backfire or burn-out, starting from such strips. An agroforestry zone with a width of 50 or even 200 meters has no negative ecological impact, provides income, and does not require annual maintenance by the government, while being extremely useful in forest firefighting. This is in contrast to a firebreak zone cleared to the ground, that cannot be of the same width, has a negative ecological footprint as it is exposed to erosion, and does not provide any income while having significant annual maintenance costs.

If properly supported and integrated into fire prevention planning, agroforestry can greatly contribute to the improvement of the quality of life of rural populations, especially those living close to forests, both financially and in terms of security

Technically, the tree vegetation in the above systems is quite sparse, with a crown cover of less than 30-40%. As a result, it is not possible for a crown fire to spread, and therefore fire behavior is dependent on spread in the herbaceous understory vegetation. The use of trees that are relatively resilient further helps to prevent the occurrence of crown fires. The presence of shade delays the drying of herbaceous vegetation in summer. When crown cover is relatively high (30-40%) this effect can be significant. This vegetation, often remaining green until early July, depending on the area and conditions, reduces the duration of peak fire risk during the summer months. Furthermore, where irrigation is applied, even if limited (e.g. in tree crops, vineyards, etc.), the flammability of the vegetation is reduced. In general, the creation of a mosaic of forest and agricultural vegetation involving agroforestry systems results in a mild pattern of damages in case of a fire, reduces the risk of secondary effects such as erosion and flooding, and enables faster recovery (Figure 1).

Figure 1. *Agroforestry landscape North of the bridge of Tsakona in Messinia. On the left, a satellite image (Google Earth) from 15-5-2020 (before the fire); on the right, a photo taken on August 13th 2021, a few days after the big fire. The burnt mosaic, the variable fire intensity, and therefore the relatively reduced environmental footprint due to the existence of agroforestry systems is evident. © Gavriil Xanthopoulos*

Figure 2. *A photo from the foothills of Parnis Mountain where agroforestry vegetation was not utilized appropriately to stop the spread of the fire that started in Varybobi on 3-8-2021 and eventually burned 8,370 ha. © Gavriil Xanthopoulos*

In order to make agroforestry systems more efficient in contributing to fire prevention, herbaceous vegetation must be reduced and be intermittent during the summer months. Intensive grazing, ploughing of some strips of land, sowing and irrigation of strips with herbaceous vegetation that remains green during the summer period can effectively increase the function of agroforestry systems as fire control sites. At the same time, however, the firefighting organization should be aware of these sites and should include them in their planning in advance, i.e. the sites must be mapped and included in fire planning so that they can be used appropriately. Otherwise, the effectiveness is drastically reduced (Figure 2). The next logical step is for the state to favour or even subsidize the establishment of agroforestry systems in selected locations as part of fire planning, partially replacing fire zones (Figures 3-4). The incentives and implementation framework should be studied in depth, substantially influencing rural policy and empowering the rural population (Goldammer et al. 2019; Moreira and Pe'er 2018; Rego et al. 2018; Tedim et al. 2016), starting with pilot implementation.

Figure 3. *Fire of Mati, in eastern Attica, 23 July 2018. The flame front stopped at places were there were properly maintained vineyards. © Gavriil Xanthopoulos*

CONCLUSIONS

Agroforestry can clearly play a key role in managing the problem of wildfires at the landscape level If properly supported and integrated into fire management planning, agroforestry can contribute substantially to the well-being of the rural population, particularly of people living in proximity to forests, both in terms of livelihoods and safety. At the same time, the need for extensive fuel management programmes can be reduced, achieving significant savings while reducing the ecological footprint of such fuel reduction. Thus, the country will see significant improvement in overall landscape fire management at a substantially lower cost.

With a relatively small investment, agroforestry can largely replace extensive fuel reduction programs, achieving significant cost savings while reducing the ecological footprint of such programs

Figure 4. *The fire of Northern Evia in August 2021 stopped in many places at the border of vineyards and olive groves where the herbaceous vegetation had been removed in advance. © Gavriil Xanthopoulos*

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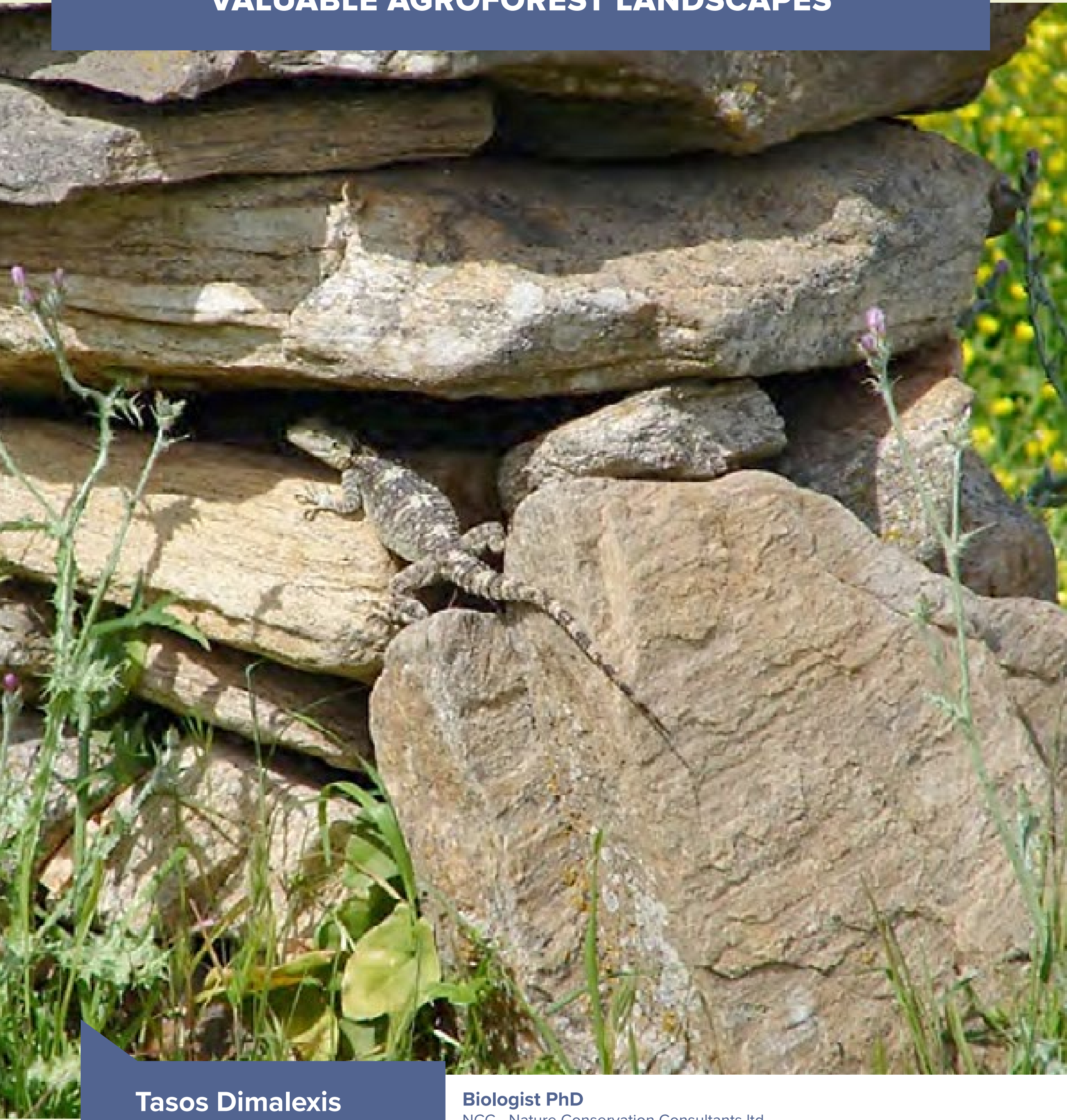
AEGEAN TERRACE CULTIVATIONS - LIVING AND VALUABLE AGROFOREST LANDSCAPES



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© Pafilis, 2014 I Rough-tailed Agama *(Stellagama stellio)* taking advantage of the light gradient (from shadow to full lighting), at a drystone wall of Naxos island (Figure 1)

Terraces cultivations, the common drystone terraces, or “aimasies”, constitute the most important large-scale human intervention in the inhabited island ecosystems for millennia, contributing to the formation of the island landscapes in the Aegean Sea and the wider Mediterranean (Figure 1). Shaped by the hard work of generations of islanders, terraces allowed the cultivation on steep slopes, in poor and particularly arid soils, supporting local activities, agriculture, animal husbandry, beekeeping and essentially the sustainable human presence and self-sufficiency (Petanidou 2015). At the same time, terrace cultivations constitute important habitats for many animal species, thus contributing to the biodiversity values of the islands (Figure 2).

The Aegean Island terraces form a valuable legacy for the sustainable management of a productive island agroforestry landscape and ecosystem

Especially in recent years, during which the impacts of climate change are increasingly affecting the Mediterranean basin, the historical presence and use of terrace cultivations may provide a critical green infrastructure for island ecosystems, with multiple benefits for their adaptation to climate change (Figure 3).

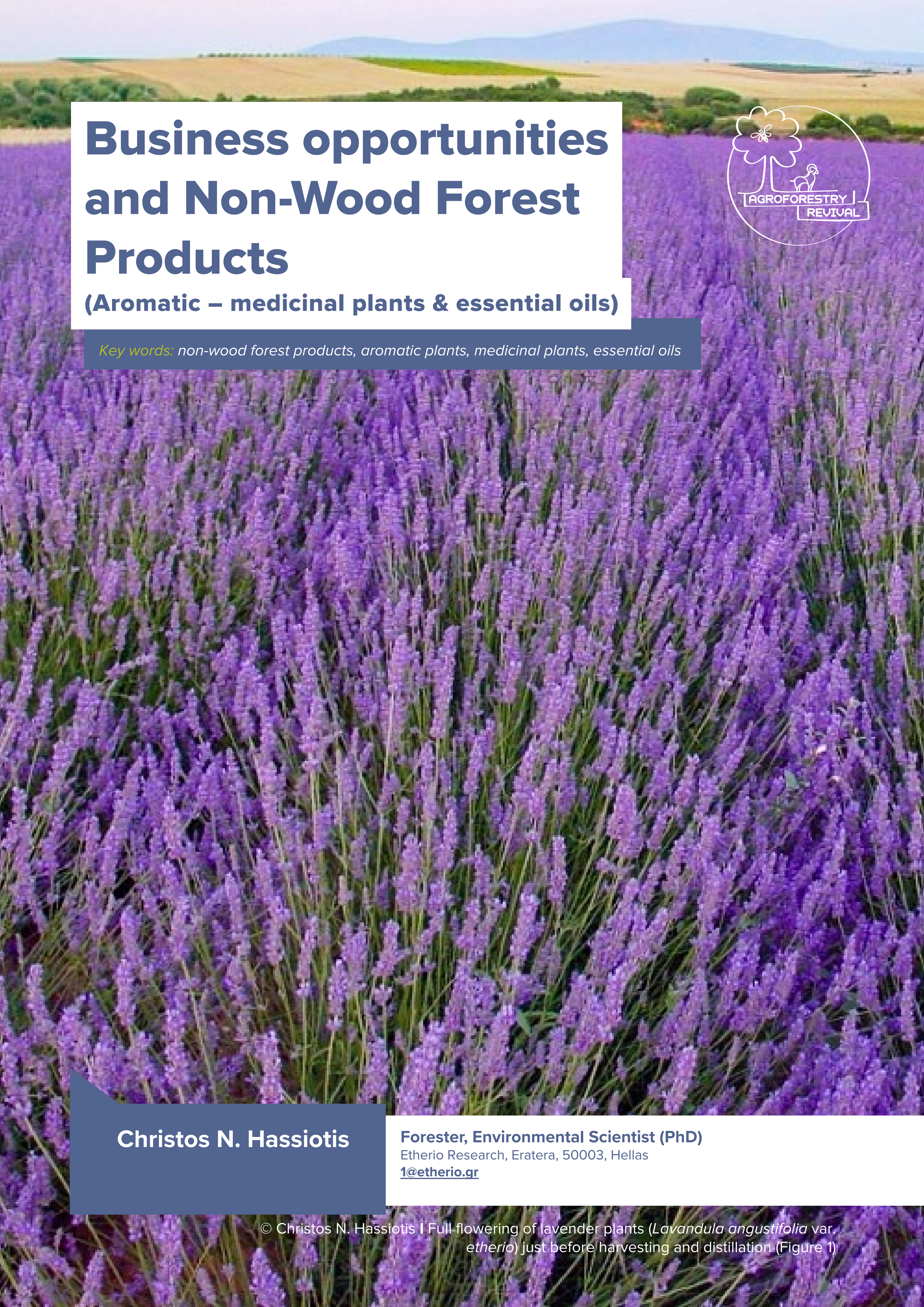
During 2017-2022, to exploit the values of Aegean terrace cultivations as key green infrastructure elements, the University of the Aegean, together with the Municipality of Andros, the Green Fund, the National Observatory of Athens, the University of Athens and Hellenic Agricultural Organization "DEMETER", implemented the LIFE TERRACESCAPE project (www.lifeterracescape.aegean.gr). The project aimed at demonstrating the feasibility of large-scale restoration and re-cultivation of Aegean terraces, and produce biodiversity friendly, climate-smart added-value local products, economically viable under the present socio-economic conditions, as part of a sustainable tourism model, investing in the natural and cultural assets of each island.

In addition to the pilot restoration of drystone walls and re-cultivation of terraces with local crop varieties, the project developed guidelines and a Good Practice Guide, measured the effect of the interventions on local biodiversity, soils and microclimate and organized "Drystone Wall restoration Schools" to provide practical training in traditional stone restoration techniques.

Fortunately, the National Environment and Climate Change Agency is presently exploring the project's legacy and experience, to implement an ambitious new program to support actions for the restoration and re-cultivation of Aegean terraces with local plant varieties, with a total budget of 10 million euros, through the Recovery Fund, for the following years.

©Tasos Dimalexis I Drystone wall terraces, the ancient "aimasies, as a predominant element of the Aegean island landscapes (Figure 2)

©Tasos Dimalexis **I** Representative terrace landscape of Andros island (Figure 3)



Business opportunities and Non-Wood Forest Products

(Aromatic – medicinal plants & essential oils)

Key words: non-wood forest products, aromatic plants, medicinal plants, essential oils

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© Christos N. Hassiotis | Full flowering of lavender plants (*Lavandula angustifolia* var. *etherio*) just before harvesting and distillation (Figure 1)

INTRODUCTION

Non-wood forest products (NWFPs) are defined as products having a biological source originating from forests, woodland and/or individual trees outside forests and, by definition, not related to wood. They can come from the trees themselves, but also from plants of the undergrowth, fungi or even be of animal origin (FAO 1999). NWFPs exclude the harvesting of any wood and technical timber, but can include, for example, the harvesting of branches for handicrafts (e.g. basketry), fire-burning or charcoal production (FAO 1999).

The harvesting and trading of Non Wood Forest Products is considered as an alternative to forest exploitation, beyond wood production

According to the Millennium Environmental Assessment (MEA 2005) and Hassan et al. (2005), there are at least 150 high-value non-woody forest products and services in international trade, covering diverse human needs: from material to spiritual, aesthetic and recreational. Some of the most important non-wood forest products are: aromatic & medicinal plants, essential oils, Christmas trees, resin, heather roots, acorns, chestnuts, pine nuts, mushrooms, cork, recreation, hunting and grazing. Non-wood forest products, particularly in the Mediterranean region, are an important source of income (Merlo and Croitoru 2005, Croitoru 2007a). The harvesting and marketing of NWFPs is an alternative to forest exploitation, beyond wood production. Consequently, it reduces deforestation, especially of tropical forests, and thus plays a constructive role in forest conservation. In addition to their contribution to the rural economy, NWFPs contribute to the nutrition of traditional forest populations, especially in periods of crisis.

In this article we deal with the possibly most important and undoubtedly the most profitable sector of NWFPs: aromatic–medicinal plants (AMP). The financial annuity of AMPs amounts to tens of billions of dollars worldwide. Moreover, according to the World Health Organization, about 80% of the population of developing countries rely on traditional medicines, mainly derived from forest plants, for their primary health care (EFTEC 2005).

THE CURRENT WORLDWIDE STATUS

In the last three decades there has been a worldwide “botanical renaissance” led by Europe and North America. Indicatively, it is reported that in Western Europe, the consumption of medicinal plants has tripled in the last decade. Also, the systematic study of many plants has provided many new substances and uses, for example herbal medicine and aromatherapy, which uses various essential oils, all of them with therapeutic properties. Its spread began in the 1930s following scientific research. Nowadays, there are hundreds of scientific journals (in the citation index system) that deal with the therapeutic actions of AMP and the use of essential oils against human diseases, animal diseases, bacteria, fungi and viruses, insect repellent, and generally for promoting well-being.

Currently, even the effects of the Covid-19 pandemic could have been effectively reduced using essential oils such as eucalyptus (*Eucalyptus globulus*, *Eucalyptus* sp.) which has bronchodilator and mucolytic properties (Asif et. al., 2020, Usachev et. al., 2013, Punikar et. al., 2021). As has been shown in many cases, chemically prepared substitutes for essential oils have less therapeutic, aromatic and flavouring value than the essential oils which are naturally produced from aromatic plants. It is estimated that over 3000 essential oils are known for their uses, of which 150 are of paramount importance in the global market (Baylac et al., 2003; Burt 2004; Delmare et al., 2007; Sivropoulou et. al., 1997). Essential oils are absorbed by 35% in the food and beverage industry, 29% in perfumes, cosmetics and aromatherapy, 16% in home use and 15% in pharmaceutics (E.F.E.O. 2017).

In parallel with the production process of the AMP, there is an important new activity related to them called aromatourism. In essence, excursions are organized to places with a high production of aromatic plants and their processing units. There, tourists can enjoy the natural beauty of the locations they visit and at the same time get to know various aromatic plants up close by visiting plantations, processing workshops and distilleries and acquiring essential oils and other products directly from the production source. Such tourist activities have until now been developed in Australia, France, Turkey and Indonesia.

THE CURRENT STATUS IN GREECE

The soil and climatic conditions of Greece are particularly favorable for the development of aromatic plants that give products of excellent quality. The Greek flora is rich in species and includes a very significant number of rare species found only in Greece. As such, some of the most excellent spices, herbs and aromatic plants in the world appear in Greece as native species, such as oregano, thyme, mountain tea, mint and many others. However, the collection of native plants presents several problems, such as difficulty in locating the plants, heterogeneity of material, inability to predetermine the quantity of the product according to time and market needs, difficulties in harvesting and preserving the product *in situ* and difficulty in finding labor. It is important to point out that this category of NWFPs should be exploited as drawn crops as close as possible to the positions where the species grow naturally or in other environments with the same environmental conditions. This is more possible for herbaceous or even shrubby species and less achievable for arboreal species such as linden *(Tilia* spp.).

Although Greece has excellent environmental conditions for crops with aromatic plants and production of essential oils, the country has not claimed the relative market share

It is estimated that a business cultivation with aromatic and medicinal plants and the production of essential oils in various regions of the country can give a capable, complementary or main income not only to the traditional forest populations but also to farmers, contributing to their sustainable local production, as well as the utilization of the natural flora. In contrast and despite the large number of aromatic plants and the wide range of soil-climatic conditions in which they are found, their development and commercial exploitation throughout Greece is still in its infancy. Out of a total of 390,000 hectares of arable land in Greece, 44% are mountainous and in disadvantaged areas, but only in 0.1% of these unfortunate areas aromatic plants are grown. Therefore, the production of these plants is obviously insignificant in relation to increasing agricultural income, but also to improving the competitiveness of the agricultural economy of our country.

CULTIVATED SPECIES IN GREECE

The major commercial aromatic and medicinal plants of Greece are: mountain tea, sage, oregano, anise, basil, fennel (fennel seed), chamomile, laurel, spearmint and peppermint, coriander, cumin, and finally the typical products of some regions of Greece such as saffron (crocus) of Kozani, Chios mastic, and dittany of Crete. Saffron (*Crocus sativus*) is the only aromatic plant for which there is highly organized production, processing, standardization and marketing, within the framework of the activity of the Forced Cooperative of Kozani Crocus Producers, with a significant contribution to the exports of the region. Today the crocus is cultivated in an area of more than 1000 hectares which, depending on climatic conditions, has an annual yield of the order of 6-12 tons of saffron. Greek saffron has obtained a quality assurance certificate ISO 9002 and has acquired a certification mark as a product of "Protected Designation of Origin" (PDO) "Krokos Kozanis". Recently, HACCP (Hazard Analysis and Critical Control Points) has also been implemented.

The island of Chios is directly connected with the production of mastic (*Pistacia lentiscus* var. *Chia*). In 1938 the Chios Mastic Growers Association was founded, which until today has the exclusive access to the production of mastic, protects and promotes its trade, utilizes the product and enhances the income of producers. The cultivation of the tree is based on traditional optimized methods and this is because it is not amenable to technological improvements.

Dittany (*Origanum dictamnus*) is a small hairy shrub with a strong smell, which grows in calcareous rocks, in fragments and crevices of rocks, usually in shady places and at an altitude of 300 to 1500m. It is a species endemic to Crete and has been declared threatened due to overexploitation.

The cultivation of lavender (Figures 1-4) extends over many hundreds of acres in Thessaly, Macedonia and Thrace. There are only a few cases of lavender cultivated in agroforestry systems. Essential oil is produced and exported to Bulgaria. In this area, too, our country is disadvantaged because the added value of resale is reaped by Bulgarian producers. The choice of inappropriate genetic material for plantation resulted in many crops being affected by diseases and many others being abandoned due to non-disposal of the plantation product.

CONCLUSIONS

Crops with aromatic plants are a dynamic sector of particular interest which is constantly expanding. This is due to the strong consumer interest towards the use of natural products for health care, the development of research activities towards the utilization of aromatic and medicinal plants, the development of the industry of cosmetics and medicines that have as ingredients aromatic and medicinal plants, the development of the food industry towards the production of foods that contain aromatic plants in their ingredients, the increasing interest in haute cuisine where the use of aromatic plants is widespread, and the shift of chemical industries towards the production of products (e.g. household insecticides) with the use of plant raw materials.

Although Greece has excellent standards for crops with aromatic plants and the production of essential oils, it has not yet claimed the market share that corresponds to the country's potential. The cultivation of aromatic and medicinal plants can be combined with important forest species such as almond-leaved pear, black poplar

© Christos N. Hassiotis I Lavender plantation installation *(Lavandula angustifolia* var. *etherio)* in Kato Sholari, Thessaloniki (Figure 2) and chestnut mainly for Northern Greece and with cypress, olive and carob trees further south, giving a special character to the cultivation and creating agroforestry systems. The intercropping of olives with aromatic and medicinal plants is feasible, and is already being applied in Lesvos island, where their antimicrobial, antibacterial and insect repellent properties can contribute significantly to the reduction of tree infestations. However, we must admit here that the quality of these aromatic medicinal plants will *de facto* be inferior because the limited sunshine due to the shading of the trees will lead to a reduced quality of essential oils and therefore to a lower quality. Nevertheless, the use of these plants inside crops is considered a positive measure.

Given the maintenance of the strong demand for aromatic-medicinal plants and essential oils by both the food industry and by consumers, the maintenance of the growth rate of the sector in the coming years, the increase in world prices and the increase in world exports, the transition to this very important sector of non-wood forest products should be made with coordinated actions and with clear planning. The intercropping of aromatic medicinal plants with forest species or even with cultivated trees is possible to the extent that the latter will not significantly affect the access of the former to direct sunlight. Our proposal is that tree species should be placed in the northern exhibition of the cultivated fields. This shift to the cultivation of aromatic and medicinal plants has to be made immediately and with national planning , as opposed to collection from nature.

© Christos N. Hassiotis **I** Lavender essential oil, after separation from the flower water in a Florentine container (Figure 3)


© Christos N. Hassiotis I Development of lavender plants in a linear arrangement just before flowering (Figure 4)

A WHITE PAPER AND A KNOWLEDGE REPOSITORY ON MEDITERRANEAN NON-WOOD FOREST PRODUCTS

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© Kalliopi Stara I Cornelian cherry 's fruits *(Cornus mas)*

According to the definition by the FAO (1999), Non Wood Forest Products (NWFPs) are those goods derived from forests that are tangible and physical objects of biological origin other than wood. They can be collected from natural forests, but also produced on plantations and/or agroforestry systems. Typical examples are products such as cork and resin, aromatic, medicinal and fodder plants, edible foods, such as nuts, forest fruits, mushrooms and truffles, honey and other products related to animal husbandry or game, traditionally produced mainly in agroforestry systems and especially in those of the Mediterranean basin.

One of the most important future opportunities for agroforestry systems is the promotion and valorization of NWFPs as successful examples of their long-term multifunctional nature

NWFPs have an important place in European everyday life, where 90% of households regularly consume NWFPs, and 26% also collect various NWFPs at least once a year. The economic value of NWFPs collected in Europe amounts to €23 billion per year and shows an increasing trend. These products are important for a sustainable and multifunctional forest management and for a green and sustainable economy. Global and local challenges, such as climate change, land-use changes, uncontrolled harvesting, inadequate management, irregular trade, competition with non-renewably produced counterparts, lack of systematic research and frequently of proper regulation, affect the management, disposal and safe consumption of NWFPs.

In the framework of the INCREdible[1] project (Innovation Networks for cork, resin and edibles in the Mediterranean basin) an international team worked on the drafting of a white paper on NWFPs, which has also been translated in Greek. This is a call for political action aiming to highlight the urgent need for initiatives and policies to: (i) ensure the maintenance and sustainability of NWFPs, (ii) create competitive, fair and sustainable value chains, (iii) improve research and transparency of relevant information, and (iv) create favorable conditions for policies, financing and innovation.

The **white paper** calls on the European Commission to promote coordinated inter-regional, national and regional programs, improve reporting on major NWFPs and encourage traceability, labelling and the use of information on the collection and production processes. It also calls on national and regional authorities to adopt innovative tax and labour regimes and implement traceability systems, but also sectoral organizations and companies to increase transparency in price-setting and encourage vertical and horizontal cooperation along the NWFPs value chains. Finally, it calls on international organizations and academia to support the implementation of the above actions, including the collection and easy access to data and statistics on NWFPs.

The white paper is accompanied by a **repository of knowledge** of successful examples and initiatives related to NWFPs. This includes 16 fact sheets from Greece concerning aromatic and medicinal plants, as well as mushrooms and truffles. It also includes 20 fact sheets of interest to the Greek public and available in Greek.

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1 INCREdible project (2017-2021) aimed to support synergies between research and business innovation for NWFPs in the Mediterranean. It was coordinated by the Mediterranean Facility of the European Forest Institute (EFIMED) and involved 13 organizations from 8 countries. It was funded by the EU's Horizon 2020 program under grant agreement Nº 774632.

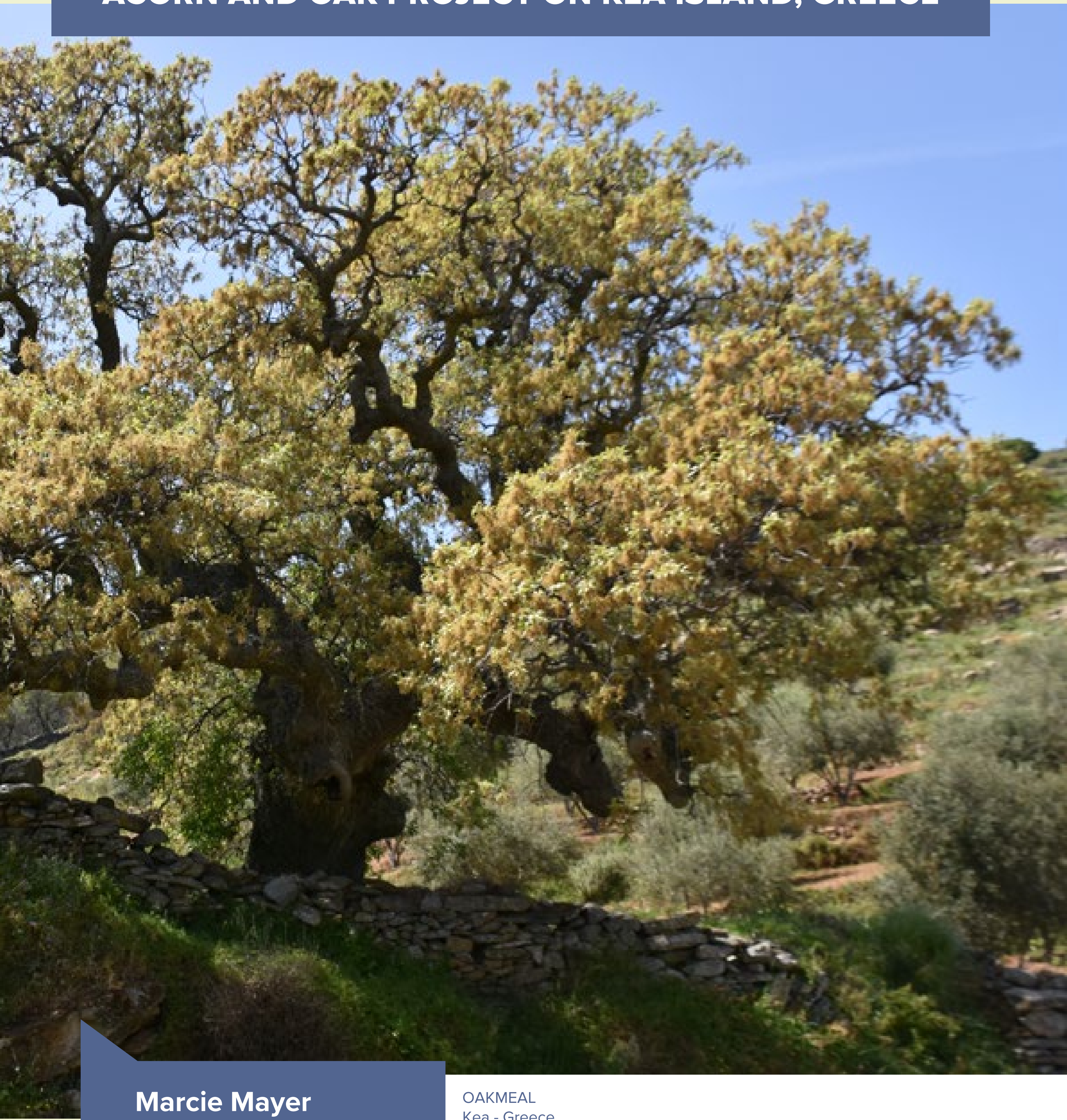
© Kalliopi Stara I Parasol mushrooms *(Macrolepiota procera)*

Further information:

White paper: Martínez de Arano et al. 2021. Non-wood forest products for people, nature and the green economy. Recommendations for policy priorities in Europe. A white paper based on lessons learned from around the Mediterranean. EFI and FAO, Barcelona (English version) / EFI and Department of Biological Applications and Technology, UOI, Ioannina (Greek version)
https://efi.int/publications-bank/non-wood-forest-products-people-nature-and-green-economy

INCREdible Factsheet repository for NWFPs of the Mediterranean basin:
https://www.nwfps.org/factsheet-repository/

ACORN AND OAK PROJECT ON KEA ISLAND, GREECE



Marcie Mayer

OAKMEAL
Kea - Greece
www.oakmeal.com

© Kalliopi Stara I Centuries old valonia oak (Quercus ithaburensis subsp. macrolepis) in the island of Kea, Cyclades Islands

OAKMEAL is an independently owned company with community strong ties due to our fair-trade practices and commitment to helping farming families generate income once again from the ancient Oak forest on Kea, an island in the western Aegean Sea, close to Attika. Farming families can now supplement their annual income from the sale of acorns (fruits of Quercus ithaburensis subsp. macrolepis) for OAKMEAL flour and animal feed as well as acorn caps for the vegetable leather tanning industry. All work involving the reactivated export of acorn caps is done by OAKMEAL on a voluntary basis for the benefit of the island's residents. We believe it is not enough to succeed unless the community also benefits.

OAKMEAL produces acorn flour and acorn cookies and we are currently conducting research and development concerning possible uses in the natural cosmetics industry of tannin and quercetin-rich waste water resulting from the process for preparing acorn into flour. We are committed to joining new technology with past practices to create long-term security for the ancient forest and the local agricultural community, as well as sharing what is learned worldwide.

Local farmers also benefit from the managed introduction of processed acorn into the livestock's diet, especially pigs, chickens and turkeys. Tourism on Kea greatly benefits from the attention directed to the island through OAKMEAL's acorn activities. Volunteers from all continents benefit from a first-hand experience of techniques for harvesting and processing acorn for human consumption and animal feed. Worldwide readers benefit from the publication of the first ever book on the subject, "Eating Acorns", dedicated to gathering, storing, processing and cooking with nutritious, delicious abundant acorns.

OAKMEAL has collaborated with researchers from several Universities in Greece and the USA. Decisions are made concerning best practices in the field with the guidance of Dr. Anastasia Pantera, Professor at the Agricultural University of Athens, Dept. of Forestry and Natural Environment Management (Karpenisi), active member and former President of the Greek Agroforestry Network.

OAKMEAL regularly sponsors workshops to teach best practices for caring for the Oak trees on Kea. Organic pest control and pruning techniques are taught as well as an ongoing awareness program to help stakeholders realise the economic outcomes resulting from proper forest stewardship practices. OAKMEAL has witnessed a great improvement in the local stakeholders' understanding and ability to manage, rather than destroy, the ancient Oak forest. Currently there are 200,000 fully grown trees on the island and the potential for tens of thousands more through proper pruning of wild saplings and livestock management.

At the OAKMEAL product facility, fresh water is used sparingly and recycled through an organic, yeast based, sewage system. We have developed a solar drying technique for acorns and are now making solar drying tables available for farming families that wish to increase their gathering capacity.

OAKMEAL has hosted an annual Acorn Festival on Kea since 2011, to celebrate the tree, the acorn and the families that gather both acorns and acorn caps. Acorn foods, acorn crafts, acorn games and acorn folklore are shared at the much loved festival. A vital part of the project is teaching others the potentials and practical steps for eating acorns. The annual volunteer program receives over 1000 applications for a dozen places to work and learn on Kea during the acorn gathering harvest. The OAKMEAL acorn book, available on Amazon, is designed to be a handbook, field guide and cookbook to help anyone interested in getting started with this generally unrecognized resource.

© Marcie Mayer **I** Acorn leaching in freshwater

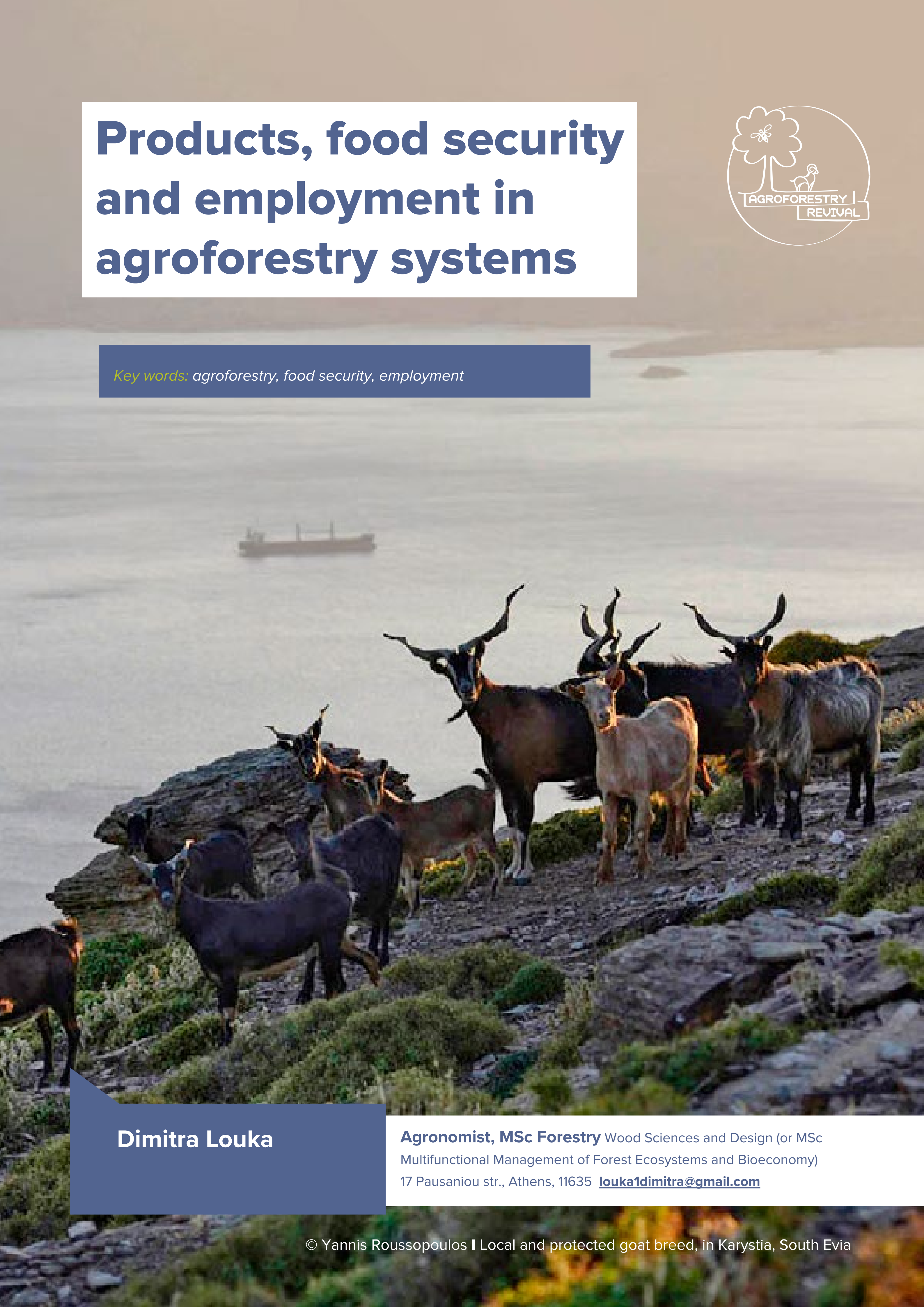
© Marcie Mayer I Acorn gathering in Kea island

Find out some more about what we do at

https://www.youtube.com/watch?v=2drjwGW8Ess

Products, food security and employment in agroforestry systems

Key words: agroforestry, food security, employment



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 I Local and protected goat breed, in Karystia, South Evia

INTRODUCTION

Over the past years, rising concerns regarding industrial agricultural practices and food security have turned the public interest to new, alternative, local, and more sustainable agricultural practices into an imperative need, not only in Greece but internationally. Agroforestry systems present significant advantages in terms of products, food security, and employment prospects, in relation to intensive agriculture and animal husbandry.

The products of agroforestry consist of agricultural, forestry, livestock and non woody forest products

Due to their combined nature, these systems are characterized as multifunctional because they significantly enhance productivity, initially through the co-production of various edible and non-edible products. Furthermore, one cannot overlook their contribution to ecosystem services (provisioning, supportive, regulatory or cultural). The Food and Agriculture Organization of the United Nations (FAO) recognizes agroforestry systems as a means of producing diverse products for the food and energy sufficiency of citizens in both developed and developing countries without discrimination.


© Yannis Roussopoulos I Beehives in the area of Astakos, Xiromero district, W. Greece

1. PRODUCTS

Through agroforestry systems, producers are able to earn an income from the production of a wide range of conventional and special products, while at the same time protecting and conserving natural resources such as soil and water. Agroforestry products can be foodstuffs such as conventionally grown vegetables and fruits, mushrooms, and other non-wood forest products (NWFP) such as medicinal plants, nuts, and resins. They can also include wood products such as marketable timber, but also livestock products such as meat, and dairy products from sheep, cattle, pigs, and goats (Chamberlain et al., 2020).

Moreno et al. (2016a) specify the high nutritional value, but also the willingness of consumers to spend more money on high-quality products with a more positive ecological footprint, such as products produced in agroforestry systems.

It is important not to overlook the high cultural value of the relevant traditional knowledge and the potential for tourism exploitation and local recreation in agroforestry systems. Fagerholm et al. (2016) report that 58% of the places visited by tourists in a rural area with large areas of dehesas in Western Spain were related to the provision of cultural services. In Sardinia, “agriturismi” events are often based on forest-pasture areas that combine multifunctional agriculture with tourist hospitality (Moreno et al., 2016).


© Kalliopi Stara | Mountain tea *(Sideritis raeseri)*

2. FOOD SECURITY

Goals 2.1 and 2.2 for Sustainable Development of the UN 2030 Agenda concern food security in order to provide food at a lower cost, so as not to create a food crisis in economically weaker households (Waldron et al., 2017). Monoculture has prevailed in the primary sector since the end of World War II and although it was characterized by a significant increase in productivity and a reduction in labor costs, it worsened food insecurity. According to the Hellenic Statistical Authority, the risk of poverty threatens 17.1% of the Greek population (ELSTAT, 2022). Agroforestry systems appear to be capable of directly and indirectly constituting an important factor for food security factor in many ways. Initially, the most evident element is the additional income for farmers, by integrating forest species into their production system and directly benefiting from food products and timber. In addition, agroforestry practices are able to protect and conserve relevant biodiversity, reduce soil erosion and improve soil characteristics, which can increase crop yields and food availability for households throughout the year (Félix et al., 2018), including those pressured by poverty in rural areas.

Agroforestry can ensure food security through social as well as environmental factors

© Yannis Roussopoulos **|** Beekeeper in the mountainous region of Nafpaktia, C. Greece

NWFPs that can be produced in agroforestry systems have been shown to be important sources of macro- and micronutrients. At this point, it is critical to note that it is also crucial to encourage business development and innovative actions to meet the growing market demand for these specific products. Furthermore, what is produced in agroforestry systems is related to the need for consumption, combined with the nutritional and market value of each species. As a result, agroforestry encourages the consumption of more nutritious and indigenous foods, reducing malnutrition within social groups which are most vulnerable (Palacios Bucheli and Bokelmann, 2017).

Agroforestry systems can increase employment through their sustainability and increased profit potentials

Altogether, in terms of food security, the role of agroforestry systems is twofold. Firstly, they reduce the risk of failure of one cropping season due to adverse conditions such as prolonged drought and other natural disasters that are increasingly observed as a consequence of climate change. Conserving resources and using them efficiently is the best way to increase the productivity of a system. In addition, agricultural production is also increased through various beneficial processes, such as biological nitrogen fixation, ecological recycling, improvement of soil physico-chemical properties, control of weeds and insect enemies of a crop, and increased water availability (Sarvade and Singh, 2014).


© Kalliopi Stara I Chanterelles (*Cantharellus cibarius)*

3. EMPLOYMENT

Agroforestry systems can also become development factors, especially in less developed areas such as mountainous areas lacking tourism development to date. According to the latest data from the Hellenic Statistical Authority (ELSTAT, 2018), since 2013, in Greece, there has been a 4.1% drop in the family workforce of agricultural holdings. The same pattern is shown in seasonal workers, while an increase of 35.2% is shown in permanent workers (regularly employed) and other workers (mutual help and fixed-rate work). In 2013, during the Greek economic recession, there was an increase of 5.5% compared to the figures of 2009 regarding the family workforce and a decrease in all other categories (Figure 1). Especially, during the last three years the number of seasonal workers has been reduced and the need for a permanent workforce is more adamant than ever.

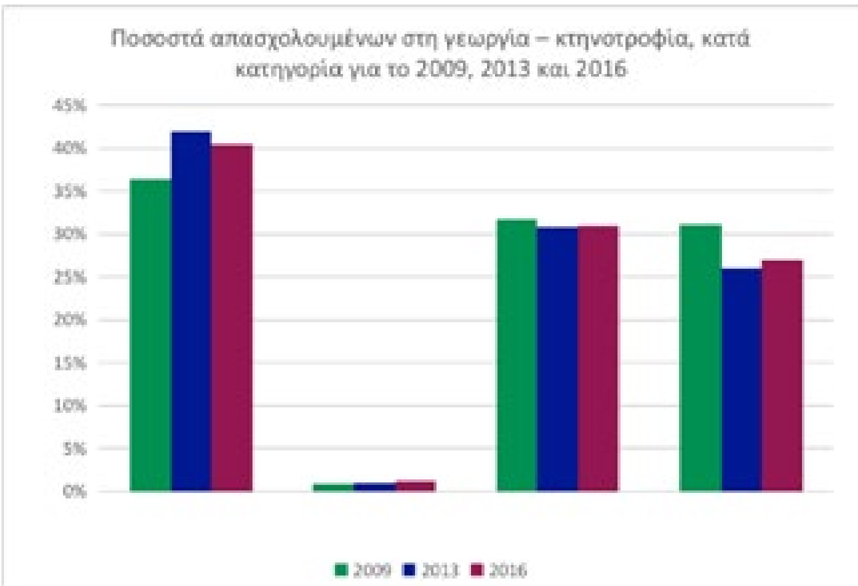

Figure 1. *Percentages of people employed in agriculture - livestock breeding, by category for 2009, 2013 and 2016 (Source: ELSTAT, 2018).*

The gradual increase of monocultures, in addition to the degradation of environmental aspects also poses a threat to family farms. Thus, an increased dependence on wage labor is observed, which has disrupted the organization of family work, leading to an increase in production costs and production specialization. On the other hand, in most rural areas in many countries all over the world there is an increase in the outflow of labor force, mostly in younger aged groups seeking work and study opportunities in urban areas who often do not return to their ancestral lands. This is how urbanization intensifies, which in general amplifies the effects of climate change. Indigenous family labor in agroforestry systems has the potential to contribute to the livelihoods of affected households (Jha et al., 2021).

In the majority of them, agroforestry systems achieve, due to the lower requirements of external inputs, high rates of recycling and combination of crops-livestock. They are a viable option for smallholder farmers with limited resources (Amare and Darr, 2020). However, in many rural areas of Greece, agricultural and agro-livestock holdings are small and often farmers and herders are unwilling or unable to allocate land for the establishment of agroforestry systems. Also, it is likely that in areas where land holdings are leased, producers are reluctant to invest in the long-term effort of establishing agroforestry systems, namely trees, as they fear that they are likely to benefit the next tenant or landowner rather than themselves.

It is therefore understood from the above, that agroforestry systems through the increased income - due to the additional products produced - but also the sustainable development (possible agritourism opportunities) are likely to attract the lost workforce back to rural areas. Also, the possible partnership of multinational companies with the owners of agroforestry systems in Greece, as has happened successfully in foreign countries, would increase profits and result in the creation of new jobs. Successful examples of this action are the movement of the “Masterfoods” group, to support the diversification of cocoa farms into agroforestry systems, as well as the Daimler-Benz car manufacturer that has turned to small agroforestry farmers in Brazil for the production of raw materials for the Mercedes-Benz C-Class cars (Leakey et al., 2006).

In conclusion, the application of agroforestry seems to have beneficial effects in many areas. The increased value of produced products, the assurance of food security, and the increase of employment in disadvantaged areas confirm the role of this practice in mitigating and addressing the problems generated by the increasingly precarious linear production model.

© Yannis Roussopoulos | Field near the settlement of Pitsinaeika, Mount Rigani, Nafpaktia, C. Greece

Agroforestry: promoting a circular bioeconomy and innovation to tackle climate change

Key words: *agroforestry, bioeconomy, innovation, climate change*

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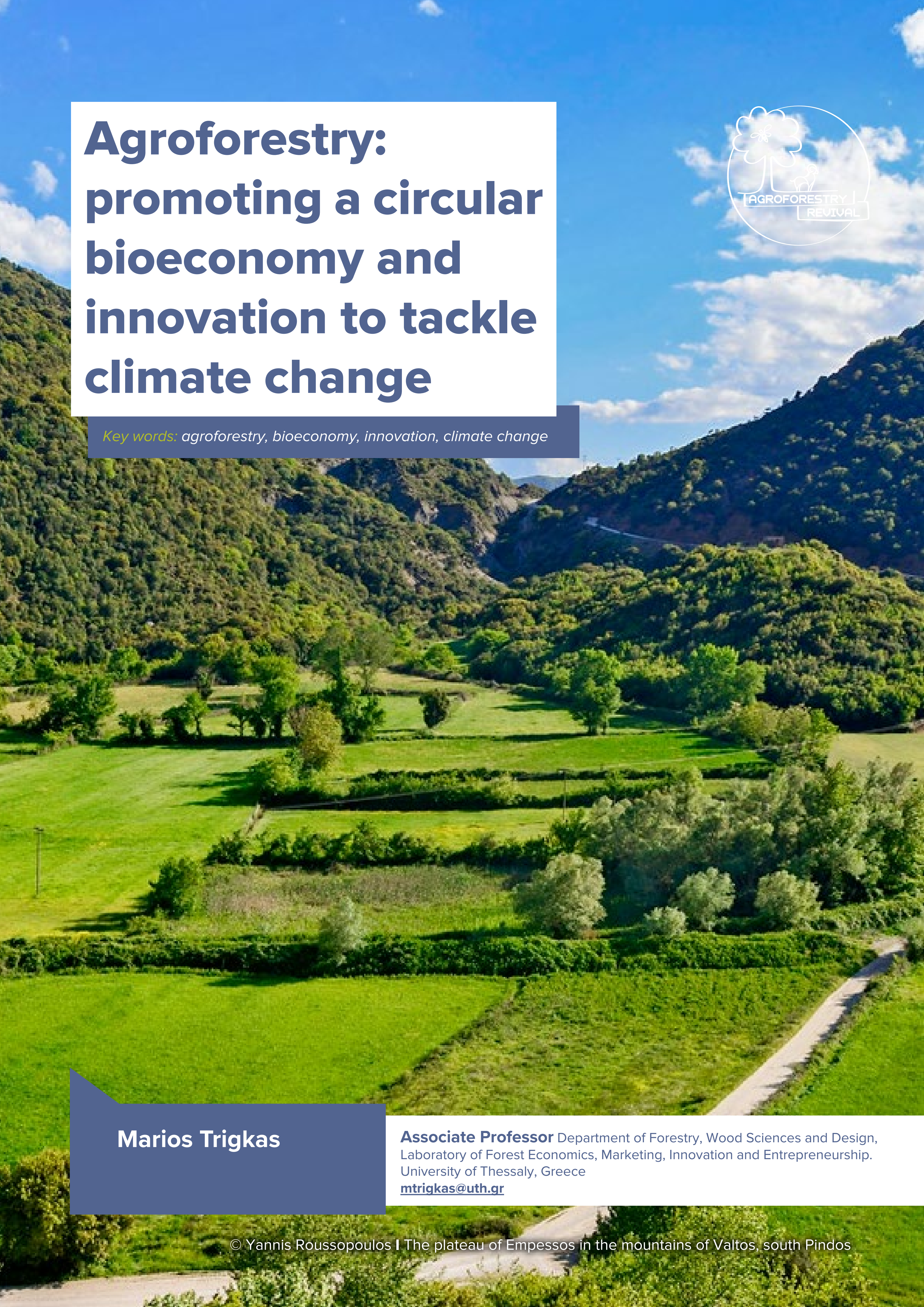

© Yannis Roussopoulos I The plateau of Empessos in the mountains of Valtos, south Pindos

THE TRANSITION TO A BIO-ECONOMIC MODEL OF PRODUCTION

In order to cope with a steadily growing population, rapidly depleting resources, increasing environmental pressures and climate change, Europe needs a radical change in its approach to the production, consumption, processing, treatment, storage, recycling and disposal of biological resources. The European Green Deal sets out bioeconomy and innovation as key tools to improve the management of its renewable biological resources and to create new, diversified markets for bio-based food and products (European Commission, 2018).

The development of a bioeconomy has great potential: it can sustain and create economic growth and jobs in rural areas, reduce dependence on fossil fuels and improve the economic and environmental sustainability of primary production and manufacturing industries. The goal is a more innovative, low-emission economy, combining the demand for sustainable agriculture, food security and sustainable use of renewable biological resources, while at the same time ensuring biodiversity and environmental protection, and achieving five (5) objectives (European Commission, 2018):

- ensuring food security,
- sustainable management of natural resources,
- reducing dependence on non-renewable, unsustainable resources,
- mitigation and adaptation to climate change, and
- enhancing competitiveness and creating jobs.

The bioeconomy development model contributes, beyond the implementation of the European Green Deal, to strategies for a circular economy and innovation.

AGROFORESTRY IN THE BIOECONOMY MODEL

The Land Use, Land Use Change and Forestry (LULUCF) sector has the potential to deliver long-term climate benefits and, by doing so, contribute to the goal of reducing greenhouse gas emissions, as well as to the long-term climate objectives of the Paris Agreement. The LULUCF sector also provides biomaterials that can substitute fossil or carbon-intensive materials and therefore plays an important role in the transition to an innovative low greenhouse gas emitting bioeconomy [REGULATION (EU) 2018/841].

Sustainable management practices can contribute to climate change mitigation in many ways, by reducing carbon emissions and storing them. In addition, they can maintain the productivity, reproductive capacity and vitality of the LULUCF sector and promote economic and social development. The development of sustainable and innovative practices and technologies, including agroforestry, can enhance the role of the LULUCF sector in terms of climate change mitigation and adaptation, as well as increase the productivity and resilience of the LULUCF sector itself [REGULATION (EU) 2018/841; EPRS, 2020; European Commission, 2021].

As the agroforestry sector is characterized by long timeframes for product yields, long-term strategies are important to enhance funding for the development of sustainable and innovative practices and technologies, and for the implementation of related investments. This is a great economic opportunity, as long as farmland owners and forest managers receive appropriate support during the transition period, as such support could create many and diversified business opportunities (Rigueiro-Rodríguez et al., 2008; FAO, 2005).

Conventional agriculture tends to put a strain on the resources it uses and is generally accepted to have a detrimental impact on the environment. Agroforestry systems, thanks to the synergies created by the right combination of woody biomass, agricultural plants and fruits and/or grazing animals, are sustainable, multifunctional systems that can provide a wide range of economic, social, cultural and environmental benefits (Rigueiro-Rodríguez et al., 2008; FAO,2005). The environmental benefits have been analyzed to a considerable extent in the international literature. The economic benefits for farmers and entire rural areas from the development and implementation of agroforestry systems include (EPRS, 2020):

Increase, in many cases, of agricultural production as a combinatory system of both agricultural plants and trees that can in turn lead to a more efficient use of resources, such as solar radiation or water, than each would use individually.

- Reduced need for inputs such as fertilizers or insecticides because soil fertility is improved and pest control can be achieved more naturally.

- Provision of diversified agricultural production, which can increase economic gains by generating periodic and annual income from multiple outputs. In addition, agroforestry systems reduce the risks associated with the production of a single good/crop and are more resilient in times of shortages or catastrophic climatic events. Their products include food, fuel, pasture and animal feed, fibres, wood, resin and gums, construction materials, pharmaceuticals, raw materials for handicrafts, and others.

The transition to a bio-economic model is an economic opportunity, as long as farmland owners and forest managers receive appropriate support during the transition period, as such support could create many and diversified business opportunities

- Diversification of local production that can benefit the entire local economy and local communities as well as boost employment.

- Provision of recreational and agri-tourism opportunities with multiple benefits for residents, possibilities for income diversification, enhancement of the attractiveness of the areas and the landscape.

- Creation of a cultural heritage value and promotion of ecotourism by creating funding opportunities.

Thus, the agroforestry sector can become an important “ally” in the transformation of the economy and the transition to a sustainable economic model.

Moreover, the transition towards a green economy and circular bioeconomy presents huge opportunities for the agroforestry sector. There are many bio-based innovative products, such as dyes, solvents and other bio-chemicals, biodegradable polymers and bio-plastics, energy products, and others around which new business models, synergies and initiatives focusing on sustainable production and consumption, are constantly being developed. Thus, agroforestry is emerging as an important alternative for the management of biological resources, but also for the production of raw materials of biological origin, replacing fossil and non-renewable resources, contributing substantially to climate change mitigation, adaptation and resistance. For example, within agroforestry systems, the residues of logging and deforestation, as well as those of agricultural production, produce biomass that can be used as biofuel, or as composting material, to produce useful timber and even as raw material for the manufacture of textiles and other bio-based products. At the same time, planting trees helps restore biodiversity in rural areas, increases soil fertility and the potential for greenhouse gas sequestration.

The agroforestry sector can become an important "ally" in the transformation of the economy and the transition to a sustainable economic model

© Yannis Roussopoulos I Plateau with former fields, area of Mikro Peristeri, Mt Lakmos Region of Epirus, NW. Greece

THE MULTIFUNCTIONAL ROLE OF AGROFORESTRY SYSTEMS AS A VALUE DRIVER

In the context of bioeconomy, agroforestry cannot be developed without sustainable land management. This is because these areas are a resource for increasing the production of agricultural products, as well as a habitat for living organisms and a living space for human settlements and other facilities/structures. There are therefore conflicting requirements between the individual land uses and ways of utilising the biomass produced and, sometimes, conflicts may be inevitable. The development of innovative practices and methodologies to mitigate these phenomena in the context of viable and sustainable management is therefore required and agroforestry can also make a major contribution in this direction as a catalyst for this vital transition, supporting wealth creation in rural and non-rural areas.

The right "innovation ecosystem" for Greek agroforestry can compensate for the shortages in resources and capacities that are especially important in the agroforestry sector and in the context of tackling climate change

In addition, the European Commission [REGULATION (EU) 2018/841], in the context of the carbon farming initiative announced in the "Farm to Fork" Strategy, aims to further promote a new green business model that rewards climate- and environment-friendly practices of land managers, including forest and agroforestry managers and owners, based on the benefits they provide for the climate. This aims to create a new source of income for farmers, foresters and land managers implementing sustainable agroforestry activities, which lead to carbon removals and storage.

In conclusion, it is crucial to highlight the "value" that is truly contained in agroforestry systems also in Greece, and how they can become a source of real wealth production through innovation, their multifunctional role as well as through the overall value contained in them and their ecosystem services. Therefore, the appropriate "innovation ecosystem" should be created for Greek agroforestry, so that the respective initiatives become a point of attention and strengthening, compensating for the shortages in resources and capacities especially important in the agroforestry sector.

© Yannis Roussopoulos I On the plateau of villages Aetos and Katouna, Xiromero W. Greece

Part D

European and national policies for Agroforestry

EU Policies for agroforestry systems: dangers and opportunities

Key words: Common Agricultural Policy (CAP), agroforestry policies, integration of CAP and agroforestry

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INTRODUCTION

Agroforestry systems and agroforestry practices have been important and valued parts of the agricultural and forestry heritage of Europe for many centuries. Policies for agricultural production and agricultural space in the last decades have contributed towards a separation between "forest" and "agriculture". In this chapter, some European Union (EU) policies are presented and discussed, policies that deal with, or should deal with agroforestry systems and practices, with a focus on the Common Agricultural Policy (CAP). First, the evolution and changes of the CAP are briefly presented and then agroforestry systems and practices in the CAP are discussed. The text concludes with proposals for a closer integration of agroforestry systems and practices in the new CAP.

Agroforestry systems and practices were almost completely ignored for a long time by policies for agricultural and rural development.

EU POLICY FOR AGRICULTURE AND AGRICULTURAL SPACE

Agricultural policy was already important to the first Member States of the EU from 1957, when the Rome Convention was signed. It was the first and the only common policy with an emphasis on food safety and farmer incomes. The approach of the CAP was very strongly sectoral during the first decades of its implementation and its interventions were mostly for big farms and a few widely cultivated crops.

The CAP introduces the concept of the monetary subsidy of farmers in order to face the high production cost of food in Europe. Initial payment mechanisms favored bigger and more intensive farms and accelerated or made easier the transition towards an agricultural production with fewer and much more industrialized and intensive farms, reinforcing spatial and productive separation between agriculture, animal husbandry and forestry.

In the 1990s two parallel discussions began: the first centered on the effort to transform agricultural policies from sectoral to a mix of sectoral and spatial, and the second revolved around the integration of environmental and agricultural policies. The result of the second effort was the introduction of the so-called accompanying measures from 1992 onwards, while the CAP became more spatial after its reform in 2000. Since then, Member States are called to prepare Operational Programmes (OPs) that take space into account, with one of the three axes that they need to rest on is the “environmental” one (the other two refer to the competitiveness of farms and rural development). This turn is very important both conceptually and in terms of objectives and allocated funds. The reform which is to be completed in 2023, includes, for the first time, the so-called “Green Deal” that deals not only with the CAP, but also assumes a zero emission target for 2050. The objectives for agricultural production are:

- ensuring food safety in the light of climate change and biodiversity loss
- reducing the environmental and climate footprint of food systems in the EU
- strengthening the resilience of the EU food system
- leading the global change towards competitive sustainability “from farm to fork”

Especially the “farm to fork” strategy is here to link, for the first-time, farm practices with transport and consumer choice. How these objectives are translated into specific measures and the plan for their implementation are less clear and a vagueness characterizes the type of interventions and their financing. This is due to a reduction of the totally available budget and a simultaneous increase of compulsory obligations for farmers. At the same time, although it is now established that climate change and its impacts are already a reality, this does not correspond to the measures and interventions.

AGROFORESTRY SYSTEMS AND PRACTICES IN THE CAP

An important factor in understanding the place of agroforestry in the CAP and agricultural policies in the EU is the conceptual separation between forestry and agriculture: what constitutes a "forest" and what agricultural land (therefore by definition eligible for the CAP). Scientists that work on "forests" in Central and Northern Europe, but also in the Mediterranean, and scientists that work on agricultural production and development, do not agree on the relationship between forestry and agricultural production. In Southern Europe mostly, the issue of grazing from livestock inside forests is at the center of these differences, in tandem with the so-called "forest plant species"; namely, which species should be considered as "forest" and which as "agricultural" ones (and therefore can be grazed by livestock or not).

We need to strive for the integration of agroforestry practices in the "hard core" of the CAP, namely the Single Farm Payments, Compensatory Payments, but also in investment schemes such as the Farm Investment Schemes, Young Farmers' Scheme, etc.

All these disagreements ignore practices that can be characterized as agroforestry, for which such differences between "forest" and "agriculture" do not exist (Pantera et al., 2018; Debolini et al., 2018). This separation and the subsequent ignorance of agroforestry practices is evident in the existence of two separate policies: forest policy was a responsibility of the Member States and in some cases part of environmental policies, while agricultural policies were shaped by the CAP. Besides conceptual ambiguity, the intensification of agriculture reinforced the spatial and production separation between forestry and agriculture, as practices that combined agriculture with livestock management stopped or significantly decreased.

Agroforestry systems and practices were almost completely ignored for a long time by policies for agricultural and rural development (Varela et al., 2020). In the 1992 CAP reform, forestry was for the first time discussed as part of agricultural production, while after the 2000 reforms, Member States have been allowed the flexibility to plan and apply their own agroforestry measures, as part of agri-environmental measures within their OPs.

However, what did not happen then and has not happened since is:

- The integration of agroforestry practices in the "hard core" of the CAP, namely the Single Farm Payment (especially regarding grazing in shrublands, where the presence of "forest species" or woody vegetation decreases the eligibility of the area as grazing land) and the Compensatory Payments, but also in investment schemes such as the Farm Investment Schemes, Young Farmers' Scheme, etc.

- The realization that some cultivated trees and tree crops are essentially forest ecosystems, but also the opposite, that some of the so-called "forest species" can be actively managed by means of agricultural practices and this is desirable from an environmental and ecosystem services perspective (Plieninger et al., 2022).

- The use of new technologies and techniques for monitoring more efficiently the impacts of agricultural and forestry practices on biodiversity and ecosystem services in different spatial scales (from the tree to the field and the landscape) (Georgiadis et al., 2022). In general, new methods and approaches to assess the spatial impacts of policies, especially agri-environmental measures, and evaluate their effectiveness are missing. These could be used to differentiate payments according to the results at the farm / landscape level (with the so-called Result Based Policy Schemes).


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WHAT CAN BE DONE?

The CAP, but also forest policies, moves in incremental steps. Although the proposals that follow are rather limited in scope, they are realistic and can be integrated thematically and spatially.

A. Cultivated trees and tree crops: extensive tree crops such as olive groves, oaks, chestnuts, carobs, are in essence agro-forestry systems when they are managed extensively, i.e. without many inputs. Typically, agroforestry systems require cultivation and/or grazing of the arboreal understory. Thus, an olive grove that is not grazed or where no cultivation of the understory is practiced, cannot be considered as an agroforestry system. Yet despite this, it is probably a good time for policies to move beyond system definitions on the basis of production to definitions based on intensity and ecosystem services. In terms of planning and implementation, it is feasible to immediately establish a specific framework of extensive management for the production of agricultural products, forest products where possible and the provision of forest ecosystem services and climate mitigation goals. It is not clear if this is also politically feasible, as it would potentially decrease payments to farmers who do not apply such services, but it could constitute a brave effort to integrate agri-environmental schemes and Single Farm Payments. In Greece, the approach to the so-called 'regionalization' in the application of the Single Farm Payments includes three virtual "regions": one for arable crops, one for permanent crops and one for grazing lands. Although this model ignores real spatial differences within Greece, it could be used to facilitate the realization of such payments.

> ***We need to realize that some cultivated trees and tree crops are essentially forest ecosystems, but also the opposite, that some of the so-called "forest species" can be actively managed by means of agricultural practices and this is desirable from an environmental and ecosystem services perspective.***

B. Grazing of forest areas: This is an issue that is largely "not up for discussion" for many foresters and environmentalists, especially in Southern Europe. Yet extensive grazing was always an important part of forest ecosystems' ecology and contributes to conservation and an increase in biodiversity, particularly by preserving open areas inside or around extended forests. It is possible to return to such extensive practices. In this case also, the framework for planning, monitoring and auditing the practices is available, but again political decisions need to be made.

C. Instalment of new agroforestry systems: although this scheme was included in the overall list of agri-environmental measures in the two previous CAP periods (2007-13 and 2014-2020) for Greece, it was completely ignored (unfortunately this seems to be the case for the next period as well). It is now mature enough to be integrated in support schemes such as the Farm Investment Scheme and the Young Farmers' Scheme. Thorough descriptions of the systems and the practices are required, but it could be the first indirect recognition of the importance of such systems in the "hard core" of the CAP. Since these systems can be linked with biodiversity and climate change mitigation objectives, they could also potentially provide higher payments.

A small reference should be made to **isolated trees**, namely trees inside cultivated or grazed lands. Despite the fact that many studies display their importance as refugia and biodiversity enhancers, most Member States have ignored them so far. They are included in the so-called "landscape features" of the new CAP implementation period, but without a clear plan for their management and conservation. It is true that any such measure would be hard to manage, but pilot application in the next programming period can provide blueprints for a more general application in the future.

To conclude, this is a potentially favourable period to discuss the direct link between agroforestry practices and systems and the CAP, not as a small, complementary measure, but as one of the most important practices for payment schemes. This is not a management issue, but mostly a conceptual and political one.


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Adapting agroforestry systems management and climate change mitigation

Key words: resilience, microclimate, water management, monitoring

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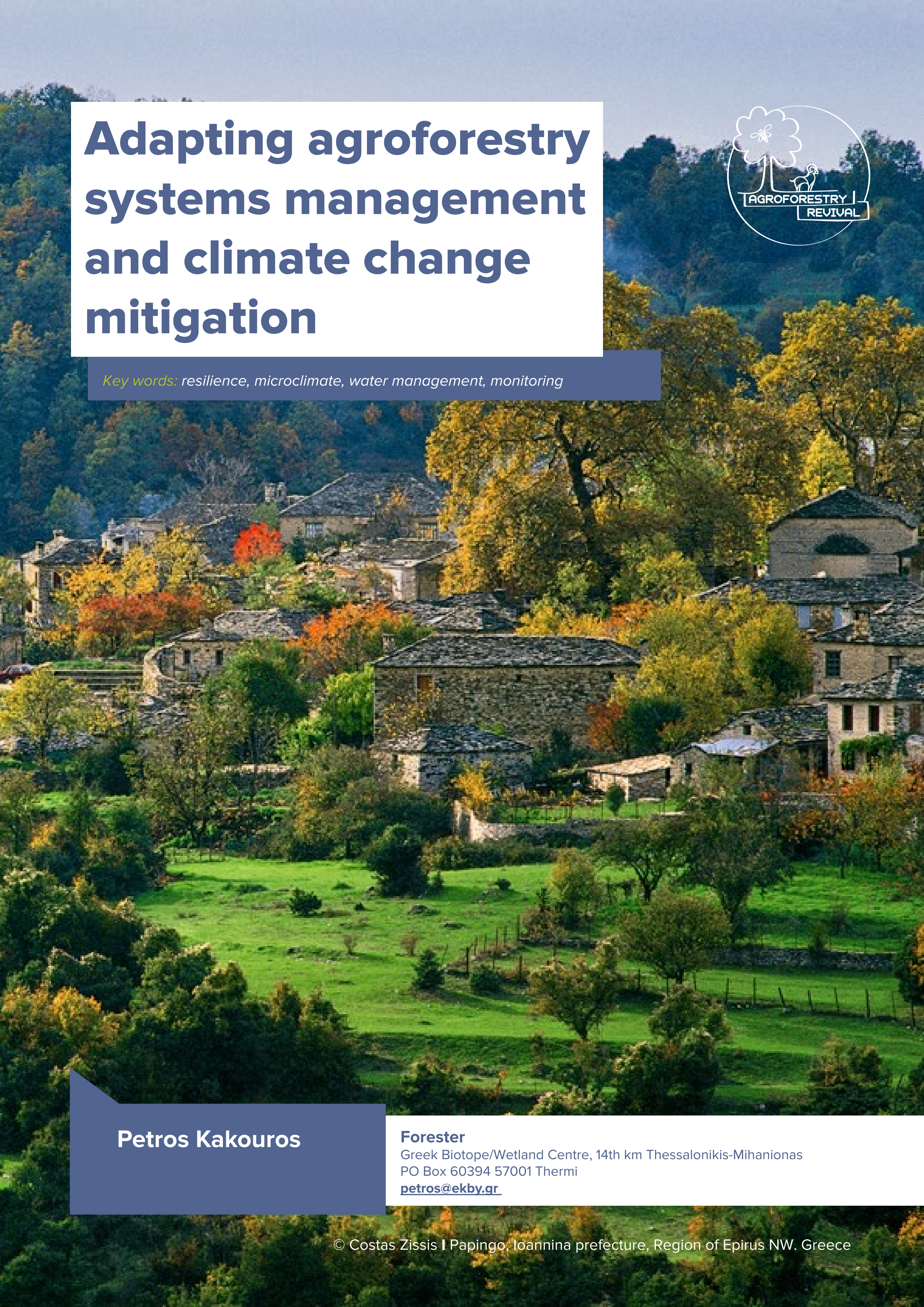

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Agroforestry systems have a multitude of features that make them resilient to climate change and at the same time important for mitigation efforts (Hernández-Morcillo et al. 2018). However, it is advisable to continuously adapt their management so that they continue to provide their desired ecosystem services, including those that contribute substantially to climate change mitigation.

DEFINITIONS

According to FAO (2013), *"adaptation actions to climate change refer to adjustments and regulation of natural or anthropogenic systems in response to the current or expected climate change impacts, in order to minimize the risks and vulnerability of these systems, and at the same time, to take advantage of the opportunities provided. Specifically in the forest sector, adaptation includes interventions and changes in management practices aiming at the reduction of the vulnerability of forests and societies near forest areas to climate change."* Climate change mitigation actions include measures to stabilise or reduce the presence greenhouse gases in the atmosphere. This can be achieved either by reducing anthropogenic emissions of greenhouse gases or by increasing the rate of their removal from the atmosphere. The effects of adaptation actions can be perceived at a specific spatial level or activity sector, whereas the effects of mitigation actions cannot be perceived directly, although they can be applied at different spatial levels or different sectors of the economy.


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VULNERABILITY – ADAPTATION – MONITORING

The adaptation of an agroforestry system to climate change utilises an adaptive management approach in combination with climate models (LIFE+AdaptFor Working Group 2014). More specifically, adaptation proceeds in the following three steps:

- assessment of the vulnerability of agroforestry ecosystems due to climate change,
- adoption of new management measures or modification of the parameters of ongoing measures or even modification of management objectives and,
- monitoring to assess the status of a particular agroforestry system, including the degree of success of adaptation measures and the re-evaluation of management objectives, actions and measures.

A critical step in the whole process is to decide against which climate change scenario to assess vulnerability. The prevailing practice is to use Representative Concentration Pathways (RCPs) up to 2100. In Greece, the three scenarios shown in Figure 1 (RCP2.6, RCP 4.5 and RCP 8.5) are used for these assessments.

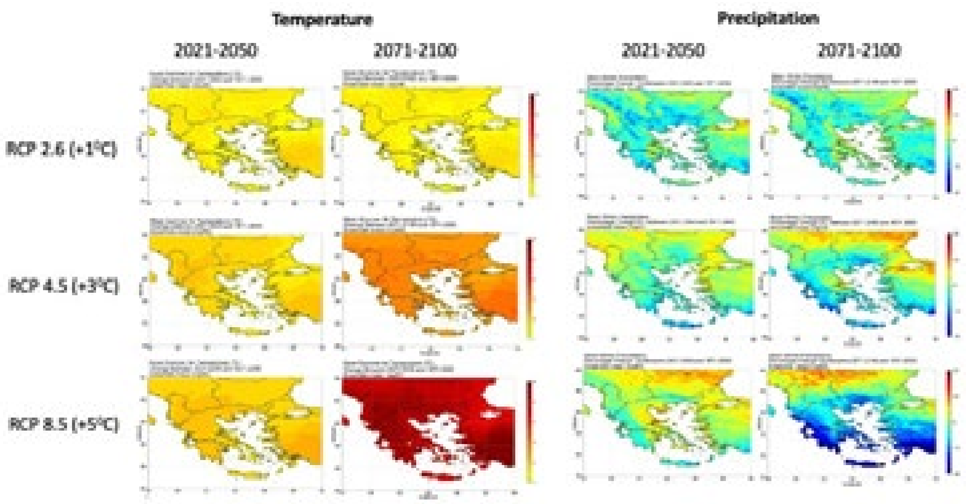

Figure 1. *Projections of the mean temperature (in the left part) and precipitation (right part) in Greece for the period 2021-2050 and 2071-2100, according to the three prevailing scenarios of global greenhouse gas concentrations (RCP2.6, RCP4.5 and RCP8.5) (Source: LIFE-IP AdaptInGR www.adaptivegreece.gr.*

This assessment is already being carried out at national and regional level with the preparation of Regional Climate Change Adaptation Plans (RCCAPs) and it is expected that it will be possible to do this for smaller areas as well (LIFE-IPAdaptInGR project). The vulnerability of agroforestry systems to climate change can be increased both by the direct influence of the abiotic environment (temperature, precipitation, wind, etc.) and indirectly, through changes in their socio-economic environment. These systems are dependent on their management and there are numerous examples of their degradation, either due to land use intensification or abandonment (Papanastasis 2015).

In agroforestry systems, adaptation and climate change mitigation are interlinked actions

In the case of deterioration of the abiotic environment, estimated impacts are sought to be prevented by appropriate management measures, for example by enriching a system with more tolerant species or by reducing the density of trees to ease competition. The intensity of agricultural or livestock farming in the system may also be reduced. In this way, the soil retains a better structure and organic matter, factors that contribute to the maintenance of higher levels of nutrients and moisture.

Socio-economic factors prompt their managers of agroforestry systems to change the level of labour they invest in order to obtain a satisfactory income.

In the case of labour investment reduction, for example due to lower productivity, we have abandonment and gradual establishment of woody vegetation. This increases carbon sequestration, but causes a loss of other ecosystem services, mainly provisioning services, such as low carbon footprint pasture production. In the case of Greece, it is particularly likely that the risks from forest fires are also intensified. The intensity of these risks concerns both the system itself and the possibility of facilitating its function as a ‘corridor’ for the spread of fires. For example, in well-managed silvopastoral systems where the flammable vegetation of the understory is effectively controlled through grazing, the spread of forest fires is impeded on the one hand and their control is facilitated on the other. An increase in invested labour may occur if, for example, the productivity of other areas is reduced, making the agroforestry system at hand more ‘competitive’. In this case, woody vegetation is usually reduced and the use of irrigation, agrochemicals and machinery is increased at the expense of ‘natural’ techniques such as intercropping, reducing water loss by shading with hedgerows, and others. As a result, biodiversity loss, soil degradation and loss of a plethora of regulating ecosystem services are also noted. Addressing these phenomena requires sustained economic and social compensation policies that are documented, such as by matching specific management measures implemented in the countryside with benefits spreading throughout society (Hernández-Morcillo et al. 2018). Such approaches are implemented for example through the EU's Common Agricultural Policy. The common risks for agriculture and livestock from climate change, the related adaptation needs and the practices/management measures to achieve them are given in Table 1.

Table 1. Examples of some risks that landowners may face due to climate change and how agroforestry practices might be used to adapt to those risks.

Risk	Adaptation	Agroforestry practice
Intense precipitation events	Slow water runoff to reduce flooding, soil erosion, and water pollution	Riparian forest buffers; alley cropping
Increased storm intensity (wind & precipitation)	Protect crops from wind damage	Windbreaks; alley cropping
Increased temperatures	Reduce heat stress on animals by providing shade	Silvopasture
Increased frequency and intensity of drought	Reduce evapotranspiration by reducing windspeed	Windbreaks
Changes in growing season due to temperature and precipitation	Protect crops by creating microclimates	Windbreaks; alley cropping; forest farming
Winter storms and cold temperature extremes	Reduce cold stress on animals by providing shelter	Silvopasture; windbreaks
Increased insect and disease problems	Control pests by providing habitat for beneficial insects	Windbreaks; riparian forest buffers; alley cropping
Increased possibility of crop failure due to other risks	Reduce total crop loss by increasing crop diversity	All agroforestry practices

MONITORING

The management of agroforestry systems is inherently a dynamic process, as agroforestry systems are complex bio-socio-economic systems. Climate change adds a further factor of uncertainty to the biological base as well as to the human labour invested. As in the case of managed forests, the application of management measures already in place or new to existing systems (traditional or not), as well as the establishment of new ones, must be constantly monitored and evaluated, and their results used to continuously adapt and correct management (Bolte et al. 2009). As Bodin et al. (2007) point out, adaptation of forest management, due to multiple elements of uncertainty, has to some extent the character of 'learning by doing'.

Using agroforestry systems to address the climate crisis requires long-term public policies

Monitoring through suitable indicators regularly assesses both the vulnerability of the agroforestry system and the design and implementation of climate change adaptation measures. It is recommended that monitoring should focus on the following elements (adapted from the LIFE+AdaptFor working group, 2014):

- changes in climate parameters,
- the most significant impacts of climate change, particularly on the most vulnerable elements of the agroforestry system,
- the effectiveness/success of management measures taken to adapt the agroforestry system to climate change, and
- any social and economic impacts of the implementation of adaptation measures.

MITIGATION

The contribution of agroforestry systems to climate change mitigation is mainly related to their contribution to carbon storage. Papanastasis (2015) points out that in agroforestry systems, in addition to the significant amount of carbon sequestered in aboveground biomass, trees also store carbon in the soil through their root system. Therefore, when such systems are established on agricultural soils they substantially increase the carbon sequestration capacity of agriculture. They also contribute directly to maintaining the carbon storage potential through their highly positive effect on the water economy. Their contribution lies in preventing erosion, increasing the movement of water to groundwater aquifers, and reducing wind speed, among other things. Water is a critical factor in carbon sequestration, since when water is scarce, plants reduce biomass production. This positive effect also applies to adjacent forests and wetlands, which have a huge potential for carbon sequestration.

Monitoring the continuous improvement of their environmental and social effectiveness is a crucial element of policies supporting agroforestry systems

Additionally, according to Hernández-Morcillo et al. (2018), agroforestry can enhance the resilience of agricultural crops by reducing the impacts of extreme weather events. This is achieved, for example, by the ability of agroforestry systems to reduce extreme wind or soil temperatures. Agroforestry systems offer greater economic stability through diversified crops, allowing for different sources of income and products, providing a cushion against yield fluctuations caused by socio-economic factors or extreme weather events. For example, silvopastoral systems allow farmers to establish a tree crop that can provide timber and firewood while maintaining pasture and livestock production. Given their potential to produce high quality technical timber, agroforestry systems can also contribute to the substitution of high carbon footprint materials such as steel.

As in the case of adaptation, the mitigation potential of agroforestry systems should be monitored, evaluated and, using the same approach, optimised, both in terms of their biological and socio-economic dimensions.


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Agroforestry in the Green Deal

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THE GREEN ARCHITECTURE OF THE NEW CAP

On 11th December 2019, the draft **European Green Deal** was published. This overarching document aims to guide European policy for the following 10 years and recognizes the strategic importance of agroforestry: for example in the following section *"…The Commission will ensure that Strategic Plans are assessed against robust climate and environmental criteria. These plans should lead to the use of sustainable practices, such as precision agriculture, organic farming, **agro-ecology**, agro-forestry and stricter animal welfare standards. By shifting the focus from compliance to performance, measures such as eco-schemes should reward farmers for improved environmental and climate performance, including managing and storing carbon in the soil, and improved nutrient management to improve water quality and reduce emissions".*

Then came the Farm to Fork Strategy and the Biodiversity Strategies, both published on May 20th 2020. These, too, contain important commitments to agroforestry!

The **Farm to Fork Strategy** states that: *"The new 'eco-schemes' will offer a major stream of funding to boost sustainable practices, such as precision agriculture, agro-ecology (including organic farming), carbon farming and agroforestry. Member States and the Commission will have to ensure that they are appropriately resourced and implemented in the Strategic Plans. The Commission will support the introduction of a minimum ring-fencing budget for eco-schemes"*

The **Biodiversity Strategy** states that *"the uptake of agroforestry support measures under rural development should be increased as it has great potential to provide multiple benefits for biodiversity, people and climate. The new forest strategy … will include a roadmap for planting at least 3 billion additional trees in the EU by 2030, in full respect of ecological principles. Tree planting is particularly beneficial in cities, while in rural areas it can work well with **agroforestry**, landscape features and increased carbon sequestration."*

Finally, and let's shout it from the rooftops: **the "*100 tree/ha rule" for basic payment eligibility is dead!!!*** *Member states can ensure agricultural land under agroforestry is fully eligible for Direct Payments "when justified based on the local specificities* *(e.g. density/species/size of the trees and soil-climatic conditions) and the value added by the presence of trees, to ensure sustainable agricultural use of the land".* Note, too, that *"this encompasses all possible agricultural land uses, avoiding the inclusion of trees only on arable land, as agroforestry systems are present also on permanent grassland and permanent crops".*

© Yannis Roussopoulos I The area above Perdikaki village, Valtos Mts,, south Pindos, C. Greece

EURAF'S AGROFORESTRY POLICY BRIEFINGS

In a series of 22policy briefings, EURAF has summarised the agricultural, climate or environmental policies most relevant to farmers, practitioners and policy makers. They can be reached in www.euraf.net.

1	Agroforestry & the Green Deal	12	EURAF reacts to the EU "Fit for 55 Package
2	Agroforestry & the EU Forest Strategy	13	EURAF welcomes the "EU Soil Strategy for 2030"
3	Agroforestry & Direct Payments;	14	Agroforestry in the CAP post 01/01/2023
4	Agroforestry & Enhanced Conditionality	15	Monitoring Trees Outside Forests in the EU
5	Agroforestry & Ecoschemes;	16	Agroforestry for the Green Deal transition
6	Agroforestry & Pillar II	17	Agroforestry and the LULUCF Regulation
7	Agroforestry & Monitoring Strategic Plans	18	Agroforestry and the Nature Restoration Law
8	Agroforestry & Carbon Farming	19	Agroforestry and the Agricultural Block Exemption Regulation
9	Agroforestry & Farm Advisory Services (in draft)	20	Agroforestry and the Framework Regulation for Certification of Carbon Removals
10	Agroforestry & EU Research	21	Agroforestry and Landscape Features in CAP Strategic Plans
11	EU Agroforestry Policies- an overview	22	Agroforestry definitions in the new CAP

WHAT IS AGROFORESTRY?

In the EU, agroforestry has a simple and flexible definition: ***"a land use system in which trees are grown in combination with agriculture on the same land"*** (Reg 1305/2013). This definition is complemented by Article 4 of the EURAF Constitution: ***"Agroforestry practices include all forms of association of trees and crops (silvoarable systems) and/or animals (silvopastoral systems), on a parcel of agricultural land, whether in the interior of the parcel or on its edges (hedges)"***.

Member States have also summarised their definitions of agroforestry and these are listed in EURAFPolicy Briefing #22 (Feb 23). The definition provided in the Greek CAP Strategic Plan (section 2.1.2.1) is:

“Agroforestry systems are systems with scattered trees or trees in rows, or on the margins of plots. They can be either forest trees (oaks, pines, poplars, cypresses) or fruit trees (citrus, apple and stone fruit trees, acacia trees), olives, carob and mastic trees. They can be combined with the cultivation of cereals, horticultural crops, fruit and vegetables and/or grazing. Trees, if planted in rows, should have a minimum distance of 10 metres between rows, the distance between trees in the same row should be greater than 4 metres. Trees may also be present at the boundaries of the field in the form of a living fenceto protect the agricultural crop from the wind and to create a zone that will support wildlife. The maximum number of trees is 250 trees per hectare.Agroforestry also includes partially forested areas (sparse forests) of pasture with the tree cover up to 40% and understorey with herbaceous and woody vegetation. In this case the minimum tree density may be 5 trees/ha and the maximum 40 trees/ha trees/hectare depending on the slope, tree species and climatic conditions”.

The agroforestry classification in Table 1 has been recommended to Member States by EURAF to be used in monitoring of the CAP as part of the annual “Integrated Administration and Control Returns” (IACS) made by all farmers.


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Table 1: Typology of agroforestry suggested by Dupraz et al (2018) and Mosquera Losada et al (2017)

Tree Location	Agroforestry System	Type of "Land"	
		Agricultural Land	Forest Land
Trees inside parcels	Silvopastoral agroforestry	1 Wood pasture	9 Forest grazing
	Silvoarable agroforestry	2 Tree alley cropping 3 Coppice alley cropping 4 Multi-layer tree-gardens	10 Multi-layer tree gardens
	Permanent crop agroforestry	5 Orchard intercropping, 6 Orchard grazing.	
	Agro-silvo-pasture	7 Alternating cropping and grazing	
Trees between parcels	Tree Landscape Features (protected by CAP Conditionality Rules)	8 Tree-Landscape-Features: (protected hedges, scattered individual trees, trees in line, small groups of trees)	
Trees in settlements	Urban agroforestry	homegardens, allotments, etc.	

The typology is focused on the fact that all “active farmers” in the EU must complete an annual Integrated Administration and Control System (IACS) return of the land uses and crops on their fields (i.e. parcels).They must check the boundaries of their “declared area” using the online Land Parcel Identification System (LPIS), showing Landscape Features - including trees and hedges.

EURAF’s recommendations are:

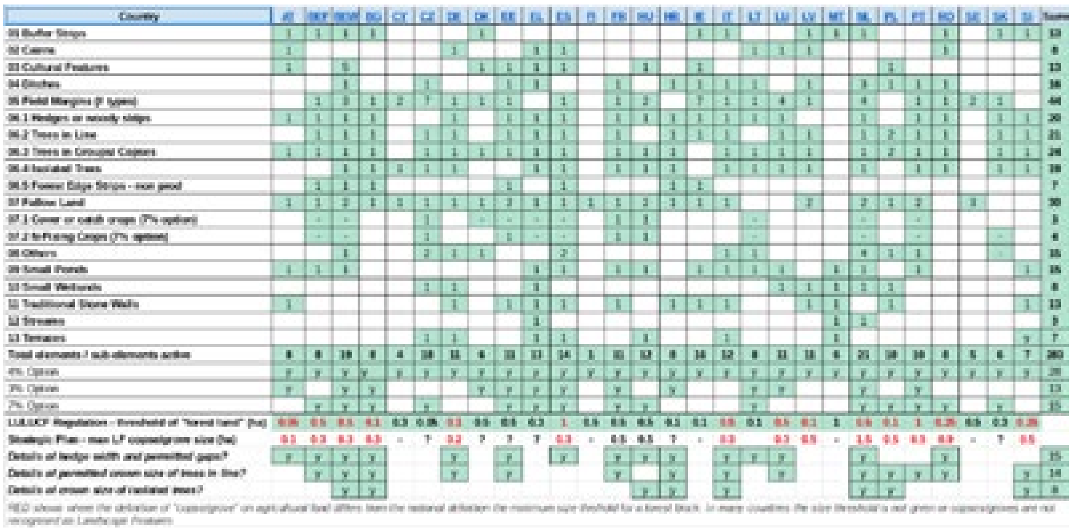
1. In the new CAP, starting in 2023, the ten agroforestry practices tabulated above should be included as IACS/LPIS codes, and the 8 practices on agricultural land should be counted as part Landscape Features (GAEC 8)

2. Landscape Features should be marked centrally by Member States on LPIS ortho-images, and farmers asked to check the areas annually.Farmers should be reassured that Landscape Features are always fully eligible for basic payments.

VERDICT ON AGROFORESTRY IN THE GREEN DEAL

Despite the encouraging advice given by the Commission to Member States in the Green Deal and Biodiversity Strategy, there remains great reluctance in Agricultural Ministries to implement agroforestry options. Recent analysis of CAP (Lawson & De Boeck 2023) strategic plans shows that few Member States have adopted agroforestry measures on a significant scale in Pillar I or Pillar II of theCAP.An analysis of Landscape Features in the 28 EU Strategic Plans shows that not all countries have chosen to record tree based features (Table 2) of: hedges or woody strips (20), trees in line (21), trees in groups (24), isolated trees (19) and forest edge strips (7).

Table 2: **Elements of Landscape Features and Non-Productive Areas (including numbers of sub-elements) selected in the CAP Strategic Plans of Member States.**



Semi-confidential monitoring statistics for the previous CAP also show very disappointing fulfillment of earlier promises for both afforestation (Measure 8.1) and agroforestation (Measure 8.2).Commitments were made to plant 600 000 ha of new forest in the period 2015-2020, and by Feb 2023 only 20 000 ha of planting was recorded. Commitments were made to establish 74 000 ha of new agroforest in the same period, and by Feb 2023 only 4 000 ha had been achieved. While more will be planted in the next few years as the 2015-23 CAP is completed, these statistics demonstrate the inability of Member States to take their own forestry and agroforestry targets seriously.

Failure to achieve these planting targets will also negatively affect the ability of Member States to achieve their 2030 LULUCF goals.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EU POLICIES FOR SOIL CONSERVATION AND AGROFORESTRY

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© Yannis Roussopoulos I Long-lived pubescent oak next to a field in Xiromero, W. Greece

Soils provide crucial ecosystem services such as the provision of food, carbon sequestration and water purification. The soil is the largest terrestrial carbon pool, hosts more than 25% of all biodiversity and provides 95–99% of food to 8 billion people. It is a fragile and non-renewable resource that is threatened all over Europe and globally. It takes 100-500 years to “generate” 1 cm of soil due to atmospheric deposition, though this may be lost in few minutes during a heavy storm. The main drivers of soil degradation in Europe are human activities, such as intensive agriculture, drainage, and the spread of persistent pollutants.

About 60-70% of the European Union’s soils are degraded. The main threats to soils include: soil erosion, soil organic matter decline, soil compaction, salinization, decline of soil biodiversity, soil sealing, landslides, acidification, loss of nutrients and soil contamination. The soil sealing definition refers to the destruction or covering of the ground by an impermeable material. Soil loss by water erosion is a major threat in the EU as 24% of land has unsustainable soil water erosion rates (>2 t ha-1 yr-1) with a mean erosion rate at 2.45 t ha-1 yr-1). In addition, wind erosion shows a mean rate of 0.53 t ha-1 yr-1 in arable lands. A soil loss rate of about 12 tons per ha per year (t ha-1 yr-1) is equal to loss of 1mm of soil surface. The mean soil organic carbon content in EU soils is less than 5% while the Mediterranean areas have extremely low carbon content (circa 1%). Moreover, soil sealing is a threat for EU soils as the land take rate is about 539 km2 per year (period: 2012–2018). The loss of high value agricultural land poses an important problem for future food security, as the land take can be translated into potential crop losses. In terms of soil compaction, 23% of EU land has critically high densities. As for local contamination, for a larger area which includes EU countries plus 12 neighbouring countries, Joint Research Centre (JRC) reported c.a 2.8 million potentially contaminated sites. The land degradation costs in the EU are estimated to about 50 billion Euros annually.

Given the European Union’s objective to become the first climate neutral continent by 2050, the European Commission has adopted a series of policy communications for a greener Europe. In 2020, an ambitious package of measures was presented within the Biodiversity 2030, Farm to Fork and Chemicals Strategies, as well as the Circular Economy Action Plan and the European Climate Law, which included actions to protect soils. In 2021, these were followed by the Fit for 55 package, the Zero Pollution Action Plan and the EU Soil Strategy for 2030. All these policies include provisions relevant to soils to achieve the ambitious objectives of the EU Green Deal. The European Commission will propose a Soil Health Law in 2023. Such a legal framework will contribute to granting soils the same level of protection as water and air and radically improve their condition to better provide the ecosystem services that we depend on.

During the last decade, the European Union's Common Agricultural Policy (CAP) introduced conservation measures to reduce soil erosion and enhance soil organic carbon. Among the most important measures for soil conservation, scientists propose conservation tillage, cover crops, grass margins, terraces, crop rotation, plant residues maintenance and contour farming.

Agroforestry is a combination of trees and grassland or trees and cropland. It is a very ancient agricultural practice that is still widely implemented in certain EU countries, and is gaining renewed interest due to its many economic and environmental benefits. It is a dynamic system combining trees, crops and/or livestock on the same area of land in some form of spatial arrangement or temporal sequence. Agroforestry can contribute to climate change mitigation; as it involves more biomass than conventional agriculture; it can store more carbon in plants and soils. Agroforestry practices can contribute to climate change adaptation: the shade provided by trees helps keep the local microclimate in check by retaining water in the soil. They also enhance biodiversity by providing food, shelter and habitat for birds, insects and mammals. In relation to soil biodiversity, agroforestry maintains and restores the topsoil with its organisms (earthworms, insects) and nutrients.

Agroforestry is positively highlighted in many literature findings and has started to be mentioned in some policy frameworks (Common Agricultural Policy, Nature Restoration Law). In the last 10 years, agroforestry has been described as a sustainable practice or recommended as an eligible activity in more than 20 EU-Commission strategies, parliamentary resolutions and EU-regulations. In the new CAP, new agroforestry systems (where trees and agricultural crops or pastures occupy the same land) can be considered as measures financially supported for forestry.

Despite its undisputed benefits, agroforestry is still largely unknown to national/regional policy makers. Therefore, the CAP Strategic Plans proposed by the 27 Member States could include more agroforestry measures. Such agroforestry applications can reduce soil loss, nutrient leaching, improve resilience of farms in case of extreme conditions (e.g. floods, heatwaves) and in general improve soil health. It is the responsibility of Member-States to propose agroforestry measures in their national CAP Strategic Plans, for actual implementation from 2024.

© Yannis Roussopoulos | The whinchat *(Saxicola rubetra)* is a common migratory passerine

Agroforestry as a Rural Policy priority

Key words: *Agroforestry systems, HNV Farming, CAP strategic plans, Ecoschemes, Protected Landscape elements*

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© Yannis Roussopoulos I The area between Farsala-Velestino, Region of Thessaly, C. Greece

AGROFORESTRY SYSTEMS AND RURAL DEVELOPMENT

The need to intensify efforts to maintain and expand agroforestry systems has long been extablished, both at the European level and in Greece. However, a parallel discussion has been taking place since the 1990s, focusing on the importance of certain land use and management practices which, apart from the production of food, fiber and energy, contribute to the provision of environmental services (Bignal and McCracken, 1996). Those farming systems contributing to biodiversity conservation are characterised as High Nature Value systems (HNV). The pressures exerted on these systems are of a dual nature. Intensification of farming activities, on the one hand, which involves altering practices that contribute to nature conservation and moving towards practices associated with the prevailing productivist, high-yield model. On the other hand, abandonmentof farming which could have damaging consecuences on environmental conservation. Clear signs of this dual process can be seen in almost all EU countries and Greece in particular.

The importance of agroforestry systems in Greece and Europe is fully documented

Most of the time, agroforestry and HNV systems spatially coincide, for obvious reasons, though they also share another characteristic. All the discussions advocating for the need to maintain these systems have been limited among academic circles, with minimal or even non–existent reflection on the policy-making nexus, especially at the lower levels of policy making (Andersen et al., 2004). The intense concern of environmental policy supporters for the successful implementation of the NATURA 2000 framework at the national/regional level, left a very limited margin for efforts towards the protection of ecosystems outside the NATURA 2000. These agroecosystems, although undoubtedly contributing to nature conservation, have been placed lower in the hierarchy of priorities, especially when compared to the main issues at stake, namely protected habitats and species. This prioritisation by environmental stakeholders seems to have heavily influenced the public debate during the design phase of rural development policy. On the other side of the dialogue, that of rural policy makers, the ambiguity on the nature of agroforestry systems has caused a reluctance to promote their maintenance and at the same time a defensive stance, in order to avoid the expansion of protective measures beyond the limits of NATURA 2000 sites, perceived as inhibiting the productive use of agricultural land.

Another factor that has obstructed the inclusion of agroforestry systems maintenance in rural development policy design has been the rather restrictive term included in Annex 2 of the Agreement on Agriculture, within the foundational agreements of the World Trade Organisation (WTO). According to this term, in order to classify support to farmers within the "green" box of WTO, that is for payments that are exempted from trade retributions, there are three prerequisites:

a. they must be part of a government programme

b. the link of the support with specific environmentally friendly obligations should be documented, and

c. "*The amount of payment shall be limited to the extra costs or loss of income involved in complying with the government programme*" (WTO, Agreement on Agriculture, Annex 2).

It is obvious that this clause promoted changes in practices and systems and therefore left very small to inexistent margins for stakeholders to support the maintenance of traditional extensive systems and practices. Even when the argument that policy inertia would allow undesirable changes was expressed and system conservation measures have been proposed, policy makers have been reluctant to accept that a farmer could be offered incentives in order to change nothing but to merely continue as always even if the usual practice was highly beneficial for the environment. This could be an explanation for the fact that the only reference to agroforestry systems during the 2014-2020 period has been the incentive for the installation of new agroforestry systems and not the maintenance of existing ones. Regardless, even this measure has not been implemented during the whole programming period in Greece.

THE 2023-2027 PROGRAMMING PERIOD

The situation changed decisively when the post 2020 CAP proposals came to light, thanks to two choices made by the European Commission. The first was the proposal for 25% of the resources that were intended to go to decoupled direct payments to be directed instead towards a new category of interventions, programmes for the environment and climate (ecoschemes), which would take the form of (mostly) annual payments in order to address two at least of the following issues:

However, neither rural nor environmental policy measures have been implemented in Greece despite their well established value and the petitions from academia

a. climate change mitigation, including the reduction of GHG emissions from farming, as well as maintenance of carbon sinks and increased carbon sequestration

b. adaptation to climate change, including improvement of food systems' resilience and biodiversity

c. protection and/or improvement of water quality and reduction of pressure to water resources

d. prevention of soil degradation, soil restoration, imrovement of soil fertility and soil nutrient/biota management

e. biodiversity protection, conservation or restoration of habitats and species, including landscape characteristics

f. sustainable and reduced plant protection products, especially substances that present risk for human health and biodiversity

g. improvement of animal welfare and mitigation of microbial resistance (Reg 2115/2021).

The second crucial proposal of the European Commission has been the flexibility allowed to Member States to either comply with the strict WTO rule mentioned above or resort to the option of considering ecoschemes as top-up direct payments that do not create market distortion, since they are completeley decoupled from the quantities produced, prices and production factors, meaning they could be classified within the green box payments.

Apart from the above, quite indicative as far as the promotion of agroforestry is concerned, it is important to highlight the fact that the maintenance of agroforestry systems has been among the actions explicitly suggested by the EC (EC, 2021a), but that have been also included in the EC recommendations to Greece, refering to the national CAP Strategic Plan. Within these recommendations, the low presence of landscape features on Greek farming areas was clearly mentioned as a deficiency, suggesting the need for remediation actions to be taken (EC, 2021b).

All these new developments have made possible the inclusion of agroforestry systems maintenance in the programmes for climate and the environment (ecoschemes of the new Programming Period). The relevant intervention “Improvement of Agroforestry systems rich in landscape features”, covers annual crop areas with the presence of either forest (oaks, pines, cypress, poplars etc.) or productive trees (citrus, pome, stone fruits and nuts, olive, carob etc.), scatered, aligned or at the field margins, but also in extensively cultivated tree plantations coinciding with annual crops.

Furthermore, this intervention also targets wooded pastures with a tree cover up to 40% and herbaceous or woody undergrowth. The support provided for the maintenance is 100 €/ha. The obligation of beneficiaries comprises of the clearance of undesired trees and bushes without the use of synthetic herbicides, while in cases of grazed areas, alternate grazing must be observed. Finally, in order to receive the support, farmers have to remove all invasive alien species from the eligible area adjacent to their parcels during the winter period. In order to ensure the apporpriate implementation of the provisions under this intervention, it is deemed necessary and supported financially, to design, implement and monitor of a biodiversity conservation plan, as well as a plant protection programme, in order to provide the right care to trees and bushes, to remove invasive species, but also to complete cease of synthetic plant protection products´use.

It is worth noting that the supported action under this ecoscheme, especially for farmers managing more than 10 hectares of arable land, goes beyond the obligation they already have to maintain a proportion of their arable land uncultivated or under non productive uses including land left fallow and/or hosting/including landcsape features. Within the landscape features included are terraces, ditches, ponds, wildlife sites (e.g. rocky habitats), footpaths, small rural constructions and hedgerows. Furthermore, cutting and pruning hedges and trees is forbiden during the bird reproduction period.

The changes in EU rural policy and the insistent advocacy of the Commission resulted in the inclusion of an intervention explicitly focusing on the conservation of agroforestry systems in the CAP strategic plan

On the one hand this ecoscheme provides an incentive for farmers to continue their farming activities and not abandon the land. And, on the other hand, to actively improve planning and their performance, based on specific practices like cease the use of synthetic plant protection products, clearance, removal of invasive species, and alternate grazing among other actions, with the objective to conserve biodiversity and the landscape, but also contribute to fire prevention and combat erosion.


© Yannis Roussopoulos | Hoopoe *(Upupa epops),* nests in old trees

© Costas Zissis I Prokopi, Euboea island

Part E

Conclusions, recommendations

© Yannis Roussopoulos I Spring in the Thessalian plain

GENERAL FINDINGS

1. In Greece and in other Mediterranean and Balkan countries, **there is a wide variety of agroforestry systems** associated with traditional land use practices that contribute both to rural resilience to climate change and mitigation of the biodiversity crisis.

2. **The long-term resilience of agroforestry systems is due to their bio-social character,** a result of the continuous interaction between nature and culture in different spaces and different times. As such, agroforestry offers alternative practices of conservation and a sustainable use of natural resources and ecosystems, while also ensuring the sustainability of local communities.

3. In Greece, the majority of agroforestry systems are **traditional and often have a long history**. They represent the ways in which humans exploited the available natural resources and interacted with the local environment in previous eras. This has gradually accumulated to become what is known as **'indigenous human wisdom'** or **'local ecological knowledge'**, a valuable piece of cultural heritage often inscribed in age-old trees, the only living organisms linking us to the past of a particular place.

4. The adaptation of agricultural, livestock and forestry land uses to climate change is strongly linked with the need to increase their resilience. Thus, **it is critical that agroforestry systems are maintained as successful examples of human societies' adaptation to ongoing socio-ecological and climate change.** Not through a 'museological' approach, but as active ecological and social laboratories of applied practice and research, which will add new dimensions to local knowledge with the aim of preserving existing agroforestry systems and **testing new ones**.

5. **Preserving local ecological knowledge must be a priority for rural policies**, especially in the light of the continuing population outflow to cities, the aging of remaining rural residents and the abandonment of productive land that could provide food and raw materials but is often economically unsustainable in the modern international competitive context. In fact, **agroforestry systems are the most valuable allies for achieving most of the UN Sustainable Development Goals**.

THREATS

1. Agroforestry systems and landscapes are threatened by two opposing trends, **abandonment** and **intensification** of their use, which result in reduced provision of ecosystem services, their degradation and eventual disappearance. At the same time, they are threatened by **land use change**, either through urbanization/expansion of settlements & new buildings dispersed across the countryside without any special planning, or through the installation of infrastructure not related to agricultural activities (mainly renewable energy power plants, industrial plants, quarries, transport projects such as expressways, among others).

2. The **abandonment of agroforestry systems** and landscapes leads to the cessation of agricultural cultivation and/or periodic grazing and the **cessation of tree management**, especially of cultivated trees **and undergrowth**, which leads to their aging and eventually to the alteration of their active structure. This is followed by the invasion of native or even alien species due to natural vegetation succession, at first herbaceous and then woody, and often flammable shrubs, transforming them into dense young forest, which according to new **climate models** is highly vulnerable to **forest fires**, especially in dry thermal environments.

3. Contrary to the above, **the intensification of land use** in agroforestry systems and landscapes involves the removal of trees and hedgerows, the cessation of periodic grazing, and their conversion to **agricultural monocultures**, often accompanied by extensive use of agrochemicals, which ultimately lead to a dramatic loss of biodiversity (especially pollinators), degradation of ecosystem services, as well as soil erosion and eventually **desertification**.

4. Particularly in **silvopastoral systems**, abandonment implies **under-grazing** or complete **cessation of grazing**, resulting in the densification of vegetation, homogenization of the landscape, and increased fire risk. Intensification, on the other hand, is often accompanied by **overgrazing**, which leads to the exposure of the soil to erosion, the inability of trees to regenerate naturally, and ultimately to **desertification**.

5. **These two contrasting trends** (intensification - abandonment) in the current management of agroforestry ecosystems **have a similar result** in the way they impact on the habitats of endangered agricultural species, especially birds. Either through intensification or abandonment, the result is **homogenization of**

the landscape and reduction in the mosaic of microhabitats, which is the main and most valuable feature of agroforestry landscapes, both for birds and for their particular biodiversity generally. The removal of small but distinctive landscape features (such as isolated trees and dry stone walls) through major projects, such as land reclamation, or the afforestation of forest openings due to abandonment of grazing, leads to the loss of edge zones between different habitats (e.g. forest - grassland) and to the **reduction of ecotone**.

A POLICY FRAMEWORK FOR AGROFORESTRY SYSTEMS

1. **Recognition of agroforestry as a distinct land use that must be mapped separately**

A) Agroforestry is a separate land use from forestry and conventional agriculture. This is because it combines woody plants (mainly trees) with agricultural crops or grassland vegetation available for grazing by farm or wild animals, **resulting in multifunctional agroforestry systems**.

B) This is also confirmed by the fact that in the European **Corine** land cover system, agroforestry systems, called “agro-forest areas”, are classified as “**heterogeneous agricultural areas**”, which are a separate subcategory of “agricultural areas”, while they are not mentioned in the category “forests and semi-natural areas”. Furthermore, the term “agro-forest” areas is not sufficient as it excludes those areas where grazing is included.

C) **The area** occupied by agroforestry systems in Greece **is not exactly known**, but it is estimated that it covers **twenty million hectares**, of which about 50% is attributed to agricultural land and the rest to forestry. The systems are found throughout Greece, but mainly in semi-mountainous, mountainous and island areas.

D) It is now **urgently necessary to map these areas** in Greece in order to enable the formulation of national support policies and the better use of relevant European funding. In addition, mapping documentation will help to clearly distinguish them from other land uses and encourage farmers and land managers to adopt good/proper agroforestry practices.

2. Diversity and cultural value

A) There is a wide **variety** of agroforestry systems based on their **structure and function**, particularly in relation to the type of tree (forest or cultivated) that dominates the canopy and cover areas from the coast to the tree limit of mountainous areas.

B) The coexistence of these systems in an area, together with other natural, geomorphological and cultural features, leads to the creation of diverse agroforestry landscapes that are a main feature of the cultural landscapes of each region. Therefore a **classification of all agroforestry systems in the country is urgently needed**, following an appropriate typology that takes into account and fully integrates their bio-cultural character. The above mapping process is necessary both in the context of the implementation of the "**International Convention on Landscape**" and the possibilities for some of them to be included in the FAO's "World Important Agricultural Heritage Systems".

C) **Of particular cultural value** are the agroforestry landscapes on **terraces** in many mountainous and island regions of Greece. In all cases, terraces are living '**green infrastructure**' necessary for mitigating or halting the effects of climate change, so special care must be taken to preserve and restore them. This is particularly true for the islands, which are directly threatened by desertification.

D) It is striking that in the country's National Inventory of Intangible Cultural Heritage (ICH), the majority of registered goods are related to the cultural heritage of rural areas. ICH is a living cultural phenomenon that changes, evolves, transforms, adapts and is passed on to future generations by following social and cultural transformations. It is closely linked to the concepts of community and sustainability and can provide an additional tool for the promotion of agroforestry landscapes.

3. Biodiversity – Specific strategic objectives

A) **The agroforestry landscapes of Greece** are characterized by great structural and spatial heterogeneity, which simultaneously makes them **global hotspots** as they host an extremely high percentage of the biodiversity of the Mediterranean basin.

B) The richness of the species concerns both the aboveground and underground (soil) environment, as well as the flora and fauna. Particularly with regard to the latter, it is worth mentioning **the great importance of agroforestry landscapes for endangered species in Europe and worldwide**, such as birds of prey and farmland birds, bats, many species of insects (such as butterflies, bees, various other pollinators), mammals, amphibians and reptiles. The populations and distribution of many of these species are rapidly declining due to the dramatic changes occurring in agroforestry systems. Dry stone terraces are an important factor in species richness as the walls themselves support a significant diversity of microflora and fauna within them. In addition, old-growth and monumental isolated trees support a range of organisms using them as a habitat, and agroforestry systems also support highly active microfauna throughout the profile of soils where they occur.

C) It is therefore necessary that the conservation of biodiversity of agroforestry landscapes, for general and specific objectives, as well as horizontal measures and actions, is **mentioned in all strategic EU policy documents**, such as in the 10-year forest strategy, in the management and protection of water resources, in the conservation of cultural heritage, in regional development plans and sectorial policies, in social cohesion and in tourism policy documents.

4. Valuable ecosystem services

A) Agroforestry systems provide many ecosystem services with minimal inputs beyond human labor. **Provisioning services** include agricultural and forest products, as well as pasture, which are based on the principles of the circular bio-economy. **Regulatory and maintenance services are also important**, such as protection of soil from erosion, help to avoid desertification or soil formation and nutrient recycling.

B) A top ecosystem service, particularly of trees, is the **capture of carbon dioxide** from the atmosphere and its storage both above and below ground, contributing decisively to mitigating the effects of climate change. An **agroforestry field** with a density of 50-100 trees per hectare can capture and store between 1.4 and 4 tons of carbon per hectare per year, which is **5-10 times more than a similar field with herbaceous crops**.

C) The valuation of the economic and social importance of these ecosystem services will contribute significantly to the recognition of the **contribution of agroforestry systems to the economy** not only of local communities in the countryside but also for the rest of the country as well, and so **needs to be a priority of national and European agricultural policy**.

5. Agroforestry systems and local communities

A) The contribution of agroforestry systems to climate change adaptation and mitigation is particularly important, because they undoubtedly **offer many opportunities for the well-being and social cohesion** of small and medium-sized local communities. Both history and recent research confirm their ability to maintain a high level of autonomy through local and regional circular economy networks.

B) The possibility to co-produce a variety of products, either "modern" (such as Non-Timber Forest Products) or "traditional" (such as livestock and wood-based products), but also "innovative" ones, makes today's local communities maintaining agroforestry systems **attractive both for older residents and for young people** seeking a high quality of life, by providing job security and creating employment in areas no longer isolated due to the possibilities of the digital age. All these benefits help to consolidate social cohesion, which is a challenge in our times.

C) Preserving and strengthening pastoral communities in particular in mountainous areas has a direct positive impact on **mitigating the risk of rural fires**, especially forest fires, an extremely serious risk that is exacerbated by climate change. Active management of the flammable vegetation involved in the operation of an agroforestry system **is one of the most important measures for preventing major fires** and is a responsive means of facilitating their suppression.

D) The multi-level support of communities linked to agroforestry systems, especially wood pastures, both at the producer level and in terms of social infrastructure and institutions, will have maximum return on investment, especially if **the overall economic benefits of the ecosystem services provided are taken into account**.

6. Common Agricultural Policy (CAP) Strategic Plan

A) **The European Union has recognized the importance of trees and agroforestry systems since 2005**. In the 2007-2013 and 2014-2020 programming periods of the CAP, Pillar II included an agri-environmental measure for the establishment of new agroforestry systems that were used by all Mediterranean Member States but was never implemented in Greece.

B) In the National Strategic Plan of the new CAP (2023-2027), **trees and agroforestry systems are now included in Pillar I of direct payments**, but **no agroforestry**

measure is foreseen in Pillar II of rural development, which is necessary to be done in the context of its forthcoming revision.

PROPOSALS FOR IMMEDIATE ACTION

1. **Agroforestry should be recognized as a distinct land use/land cover** and agroforestry systems should be included in the EU definition of "agricultural land" in addition to the three categories that already exist: "arable land", "permanent crops" and "permanent pasture". These agroforestry systems may be included in the CORINE land cover classes, in the corresponding category of "agricultural and forestry areas" or in another distinct category. In addition, the potential legal consequences of this possible recognition on their protection and ownership status should also be explored.

2. To recognize and **integrate agroforestry land use horizontally in all EU policy documents and strategies** (CAP, Biodiversity, Forests, Soil and Desertification, Regional Policy, Less Favorable Areas, etc.) and define specific measures for management, restoration, and creation of new agroforestry systems, as well as provide economic support for areas where agroforestry systems have been registered according to the above criteria.

3. **A complete inventory of agroforestry systems and landscapes** should be completed immediately, including the one of terraced landscapes. This data should be integrated into the OPEKEPE's [Greek Payment Authority of Common Agricultural Policy (CAP) Aid Schemes] Land Parcel Identification System, **so that their owners can benefit** from the ecoscheme "Improvement of agroforestry systems rich in landscape elements" of Pillar I of the new CAP. Priority should be given to mapping agroforestry systems in all areas of the NATURA 2000 network, so that direct funding for restoration/maintenance measures can be obtained for these areas. Equally important is the promotion of the inventory in Areas of High Natural Value.

4. **Greece should support legally binding EU initiatives** that lead to the conservation of Europe's most important agroforestry areas. Such policies could be:

   I. supporting the conservation of traditional systems with special natural values, combined with support for the establishment of new ones in areas important for the interconnection of NATURA 2000 network sites (corridors between sites),

II. the creation of agroforestry systems on the surrounding areas of large cities; and

III. the use of agroforestry systems around sensitive water bodies, in flammable Mediterranean ecosystems where a mixture of forest-housing exists as well as in other similar areas.

5. A **"Red List of Agroforestry Areas"**, should be defined with the most threatened with collapse in accordance to habitat types and priority conservation species within the EU. Within 5 years, a **declaration of the 30 most important/ representative agroforestry landscapes** in the country as **'Landscapes of Special Natural Beauty'** should take place.

6. **During the preparation of the Grazing Management Plans** (based on Law 4351/2015 and the relevant Common Ministerial Decision of 2017), the Forest Service should prepare specific actions for the integration of traditional agroforestry systems found in forests and woodlands into the category of "grazing lands". Based on the principles of preserving biodiversity at all levels, ecosystem functions, the need to address the climate crisis and create a sustainable economy, as well as maintain vibrant local communities located in such areas, special actions need to be taken that include:

   I. Guidelines for the recognition of these systems while safeguarding public rights.

   II. Formulation of guidelines for sustainable management of these systems, with emphasis on their restoration, rehabilitation and creation of new ones where necessary.

   III. Specific guidelines for their management in cases where agroforestry systems are part of the forest-urban mix zone.

   IV. Staffing of central and regional forestry departments with personnel specialized in rangeland management and agroforestry for the preparation, implementation and monitoring of relevant policies.

Such actions can be directly financed by the Structural Funds and by the emergency funds for the recovery of the declining rural economy, as well as by regional funds, particularly in marginal and Less Favorable Areas (island and mountainous areas).

7. During the aforementioned **inventory** creation, individual trees or clusters of trees, tree and shrub rows, as well as **other landscape features**, such as dry stone structures and terraces, small ponds, seasonal small wetlands, stone walls, field margins with hedges, streams and cultural features and rural infrastructure (such as huts, sheds, threshing floors, watering troughs, etc.) should also be

recorded. These fall under Standard 8 of Good Agricultural and Environmental Condition (GAEC) of enhanced conditionality, meaning that **owners of parcels with such features can claim the relevant direct payments under Pillar I of the new CAP.**

8. In the first **revision of the National Strategic Plan of the CAP 2023-2027** at least ¼ of the European funding needs to be allocated to support and restore agroforestry systems including:

   I. The measure "**Installation of new (modern) agroforestry systems" under Pillar II** (of rural development) as well, which should address the serious environmental problems of the country's intensively cultivated lowland areas, **including the agri-environmental measure 8.2.** of the previous programming period (or a similar one).

   II. An agri-environmental and climate measure for the "**Conservation, restoration and upgrading of traditional agroforestry systems**", which are of high environmental value, such as those containing old-growth trees or hosting rare or endangered species of flora and fauna. For example, olive groves and other tree crops, even in terraced areas, have traditionally been cultivated with great advantages in terms of seasonal production of special products and fodder, while enriching the soil. Often these olive groves were grazed by sheep and it is necessary to maintain them with appropriate incentives.

   III. Concerning forest measures of the Pillar II, **a separate measure to maintain grazing in extensive agroforestry systems should be designed** with a view to **protect them from forest fires** and halt the loss of their biodiversity. Additionally, the ecological schemes for silvopastoral systems should be enriched by conditionally reinforcing the use of traditional practices such as tree shredding, prescribed burning, and others.

9. Recognize **the environmental role of trees outside the forest and include afforestation in the reforestation projects of the Ministry of Environment and Energy**, which is being implemented in the framework of the EU new Forest Strategy. Accordingly, the European target of planting 1 billion trees by 2030, should give priority to the creation of new agroforestry systems, with 50% of these plantings allocated for the revival of agroforestry systems (new and old ones). In this context, abandoned forest nurseries could be used for the production of native trees species for the implementation of a "**National Project for the Restoration of Agroforestry Areas**".

10. Include the above proposals in the update of the **National Strategy and in the Regional Climate Change Adaptation Plans (RCCAPs**) with the implementation of a special project "**Agroforestry 2030**", which could include specific measures with emphasis on the restoration of rural infrastructure (e.g. small stone walls to stop erosion, water dams, terraces, etc.).

11. Recognize the important role of agroforestry systems and landscapes in **forest fire prevention** and the need to establish them **in the intermediate zone between settlements and forest for fire protection.** As part of fire prevention projects and studies, priority should be given to examining necessary conservation measures for existing or abandoned agroforestry systems and proposing ways of providing financial support for their users to help maintain their effectiveness, particularly around scattered settlements in the Greek countryside.

12. Greece should establish and continuously operate the **National Commission for Combating Desertification**, which was abandoned in 2005 and was only reactivated for one year in 2021-22. The support and contribution of this committee in protecting, restoring, properly managing and establishing new agroforestry systems to protect soils, address soil erosion and the overall effort to increase resilience to climate change should be pivotal.

13. To design **a communication campaign on the need for the re-cultivation and restoration** of agroforestry land with priority to **newly forested fields** for the removal of young forest vegetation and set up a compensation scheme for 20 years of agroforestry use (equivalent to the measure of "Reforestation") with the safeguarding of the State's rights to their ownership, in order to constitute a "**National Reserve of Agroforestry Land**".

14. Link the conservation of agroforestry systems with the **production of "agroforestry" products** (such as fruits, honey, resin, foliage, mushrooms, acorns, etc.), especially products of national importance, such as "feta" and other fine livestock and food products that are part of the "Intangible Cultural Heritage" of our country and are at the same time environmentally friendly. Create **a special certification brand for agroforestry products along the lines of Protected Designation of Origin (PDO) and Protected Geographical Origin (PGO).**

15. Provide additional **financial incentives for the resettlement of new farmers in agroforestry areas** under regional policies from the respective regional funds for Less Favorable areas in mountains and islands. These could include grants in the form of providing abandoned houses, farmhouses and abandoned fields. Priority should be given to communities living in isolated areas (e.g. Pomak communities in Rhodope) and to measures for the reduction of unemployment by providing

opportunities for the production of innovative certified products of agroforestry areas.

16. Considering the recognition of the exceptional importance of agroforestry systems in the context of the CAP 2023-2027, the FAO recommendations **and the results of EU research projects**, as well as the corresponding experience from the US, it is proposed to:

   I. Encourage the inclusion of agroforestry **in the curricula of the Forestry and Agriculture Departments** of the country's universities, which should also be taught as an agricultural practice in the Institutes of Professional Training for farmers and livestock farmers. Also, as there is a significant shortage of agricultural extension officers (agronomists providing practical advices to farmers), exploring the way to train relevant specialists in this subject.

   II. Support **scientific research and innovation** on agroforestry systems, both new and traditional, with specific funding including scholarships for postgraduate and doctoral theses leading to modern and innovative approaches to the management of agroforestry systems and the production of quality products such as those of Protected Designation of Origin (PDO), Protected Geographical Origin (PGO), etc.

17. Establishment of a "**National Working Group on Agroforestry**", with the aim of drafting a "**National Action Plan for Agroforestry**" and a "**White Paper on Agroforestry**" with the participation of sector experts and professionals from Greece and the EU. Also, establish an international organization for the creation of an "**Alliance for Agroforestry**" with the participation of universities, businesses, social groups and environmental NGOs, with the aim to help the European inventory, while also setting the guidelines for preserving and implementing restoration actions of agroforestry landscapes in Greece, the Mediterranean and Eastern Europe.

18. To recognize the actions of the **European Agroforestry Federation (EURAF)** in solving issues related to agroforestry at European level, and the **Hellenic Agroforestry Network** - member of EURAF, at national level, to have a **closer cooperation with the implementation services** of the competent ministries in the inventory, rescue and revival of agroforestry systems of the country, as well as in the **information and training** of geotechnical officials and farmers in agroforestry.

© Yannis Roussopoulos I Historical place of Souli in Epirus Region, NW. Greece. The Meadow of Vrytzaha

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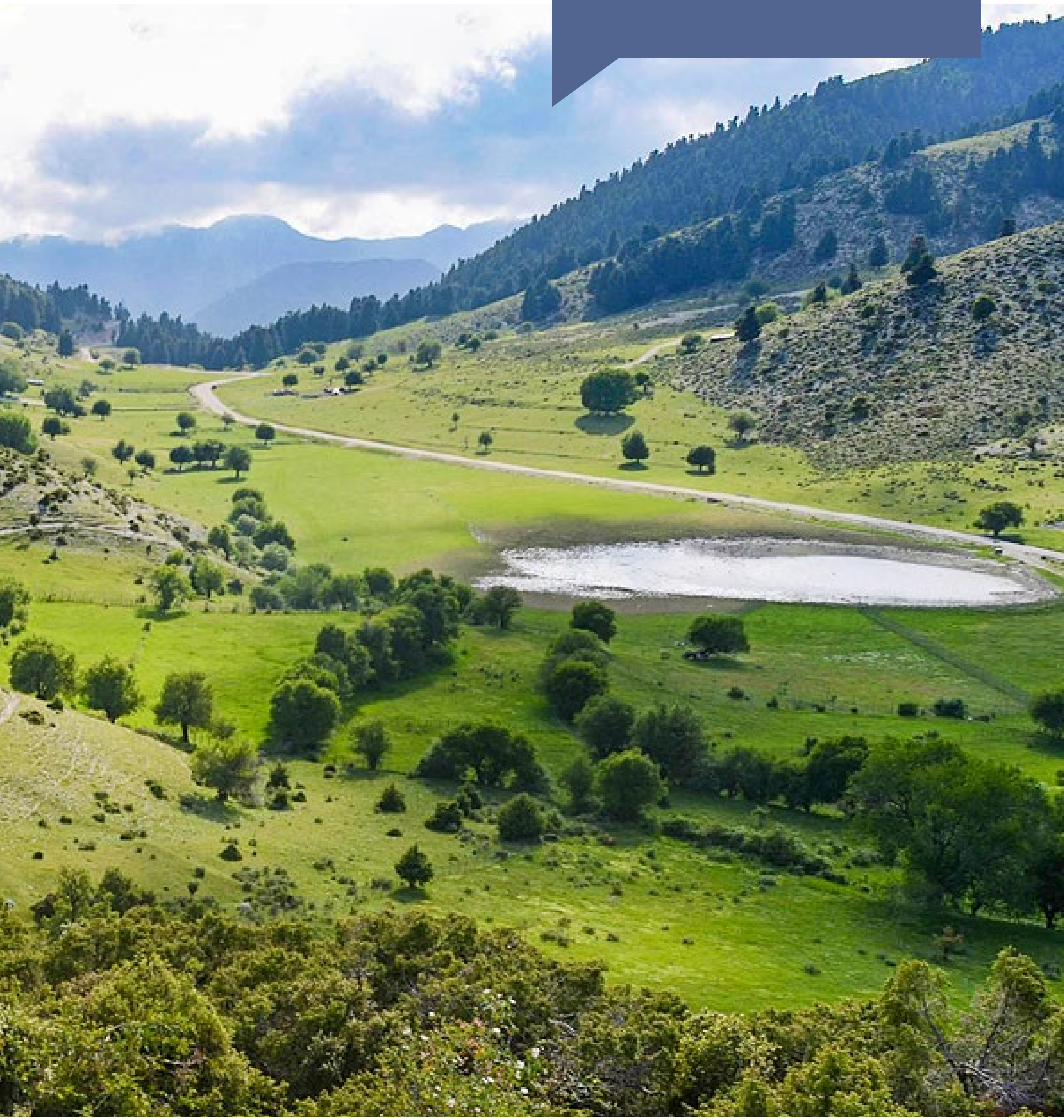

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