# Agrobiodiversity threats amid expanding woody monocultures and hopes nourished through farmer and food movements in the Mediterranean

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COMMENTARY

# Agrobiodiversity threats amid expanding woody monocultures and hopes nourished through farmer and food movements in the Mediterranean

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The high biodiversity of food and agriculture (agrobiodiversity) in the Mediterranean exists in rapidly changing landscapes and food systems. The first goal of this Commentary is to explain how agrobiodiverse Mediterranean food cereals and legumes are threatened by the accelerating expansion and intensification of monocultures of woody crops—principally olive, nut, grape, and citrus monocrops—in landscapes of the western Mediterranean (Spain, Morocco, and France). Its second goal is to explain the key countervailing force of specific food and farmer movements, organizations, and practices supporting agrobiodiversity. We argue this food agrobiodiversity support is timely and vital because of growing threats. Intensive woody monocultures have been promoted for climate change adaptation and policies, while the proposed agroecological alternatives to woody monocultures show a mixed record regarding the support of food agrobiodiversity. The Mediterranean's boom of woody monocultures relies on increased irrigation, including groundwater extraction, that undermines water sustainability. We engage with policy to explain how the timely support of food agrobiodiversity by farmer and food movements and practices demonstrates the production–consumption linkages that can strengthen sustainability, biodiversity conservation, and climate change adaptation/mitigation. Our policy arguments focus on the promising bridge of agrobiodiversity's production–consumption linkages to agroecology as an increasingly influential approach in these policy sectors. Finally, as a key complementary goal, we reflect on current agrobiodiversity-monoculture challenges by engaging the broad themes of rural–urban networks and urbanization in the Mediterranean, the land sparing versus land sharing debate, and the Plantationocene concept. Each thematic reflection enhances the understanding of food agrobiodiversity threats and support, landscapes of mixed agrobiodiversity and intensified woody monocultures (monoculture-agrobiodiversity landscapes), and relevant policy insight.

**Keywords:** Sustainable food systems, Food agrobiodiversity, Food movements, Food system sustainability, Farmer movements, Agricultural biodiversity, Crop diversity, Agrobiodiversity conservation, Land use, Agrarian landscapes, Plantationocene, Urbanization, Rural–urban networks, Farmer and food practices, Production–consumption linkages

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## Introduction: Mediterranean agrobiodiversity and agri-food transformations

The biodiversity of food and agriculture (agrobiodiversity) sustains vital ecological, nutrition, economic, and socio-cultural functions among local populations and global societies (Zimmerer and De Haan, 2017). In the Mediterranean region, this biodiversity has evolved in agrosilvopastoral landscapes integrating grains and legumes with tree crops, livestock, and uncultivated biota that have been managed for local and regional farming and food systems (Plieninger et al., 2014; Muñoz-Rojas et al., 2019; Jones et al., 2022). Yet, accelerating agri-food globalization and social–ecological drivers such as climate change increasingly threaten agrobiodiverse landscapes, urging new understanding and alternatives in the Mediterranean region and globally (Zimmerer et al., 2019). This Commentary explains such dynamics by contrasting the

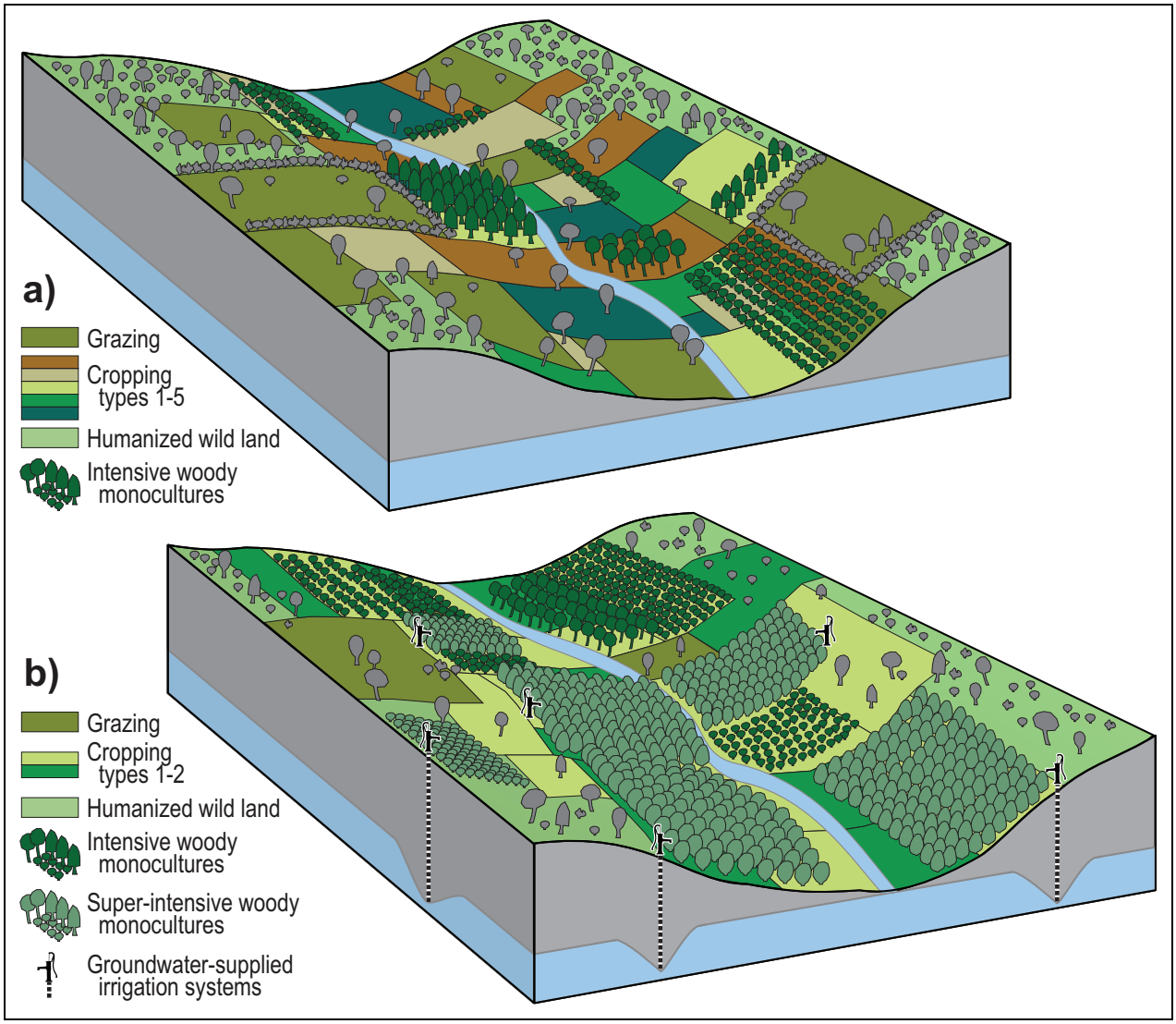


**Figure 1. Schematic illustration of landscape changes in the western Mediterranean in the period from 1990 (a, upper diagram) to 2023 (b, lower diagram).** The schematic illustration of landscape changes is distinguished by the expansion of irrigated, intensive woody monocultures of such crops as olives and the concomitant reduction of diverse cropping types that include agrobiodiverse cereal and legume populations. The upper schematic diagram (a) shows that in 1990, a range of agrobiodiversity-supporting cropping types were the characteristic of many landscapes. The varied cropping types in 1990 existed along with substantial grazing land and some intensive woody monocultures. The lower schematic diagram (b) depicts the significant curtailment of the range of agrobiodiversity-producing cropping types and the substantial expansion of intensive and superintensive woody monocultures, along with expanded groundwater extraction, while the extent of grazing land is reduced.

agrobiodiversity threats of monoculture expansion with the agrobiodiversity support of certain farmer and food movements and practices. We argue the production–consumption linkages of these farmer and food movements are vital and that they can be leveraged to guide policies to support agrobiodiversity conservation and food system sustainability. Our essay draws on examples from the western Mediterranean (Spain, Morocco, and France) that is a well-defined, high-agrobiodiversity area representative of regional and global trends (Jones et al., 2022).

This essay is motivated by the high biodiversity of food and associated biota in the farm landscapes of the Mediterranean (analysis in Jones et al., 2022; case studies in García-Martín et al., 2022) that are increasingly threatened by the transformations driven by neoliberal food system globalization (Zimmerer et al., 2020; Zimmerer et al., 2022). Agrobiodiverse cereal and legume cropping systems are at risk of major reductions associated with recent landscape changes (1990–2024) propelled by the expansion of irrigated, intensive woody monocultures (schematic illustration in **Figure 1**), as we detail for the countries of the western Mediterranean in the following section.

We then highlight our central observation that key support for agrobiodiversity is being provided by a wide range of farmer and food movements and practices. Individuals and groups promoting and participating in diverse, local food chains can range from informal, customary cultural practices to associations organized in

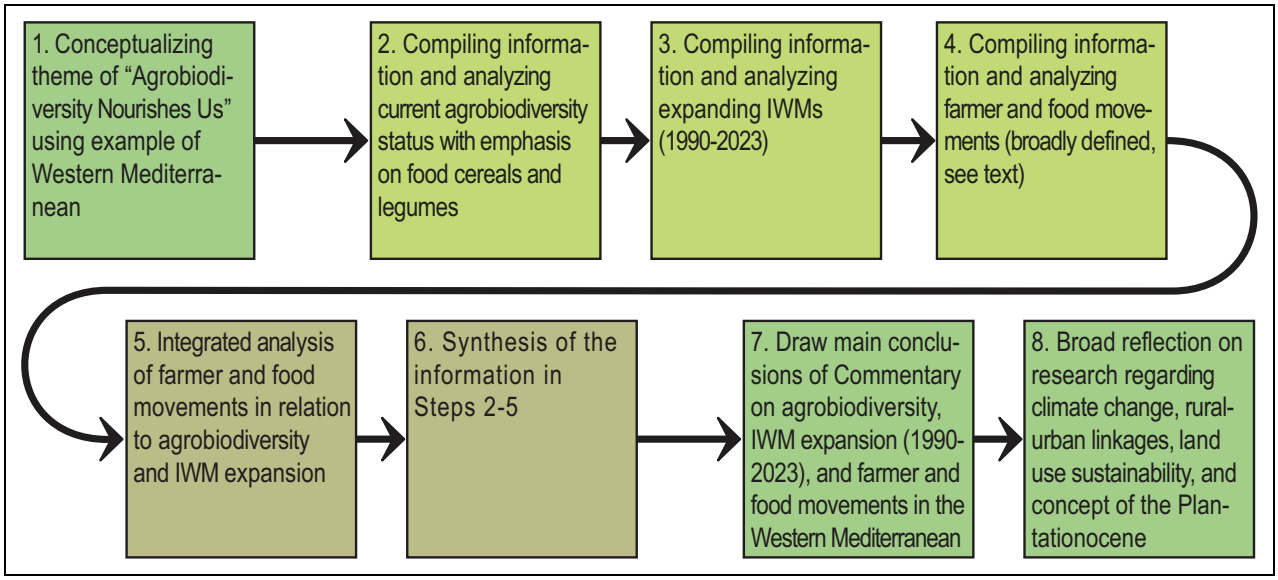


**Figure 2. Methodological framework for the Commentary briefly illustrating the steps for the construction of this explanatory essay.** This work's methodological framework shows the research stages from conceptualization as a Commentary to information-compilation, analysis, and synthesis followed by conclusions and broader reflections The methodology of this Commentary is designed to provide an explanatory essay with accompanying documentation to illustrate the special issue theme of "Agrobiodiversity Nourishes Us/*La agrobiodiversidad nos nutre*."

opposition to intensive woody monocultures. Many are allied to agrarian, peasant, and justice-based organizations with the goals of food and seed sovereignty as explained with specific examples in this essay's second main section on "Farmer and Food Movements in Mediterranean Agrobiodiversity."

The methods undertaken for this Commentary began with designing the conceptual focus on production–consumption linkages of agrobiodiversity to illustrate the special-issue theme of "Agrobiodiversity Nourishes Us" (*La agrobiodiversidad nos nutre*) (**Figure 2**). We then compiled information from published studies and the field research experience of the authors in the western Mediterranean, which were followed by research-based descriptions, synthesis, main conclusion, and focused reflections. The first part of our Commentary (next section) explains how the accelerating expansion and intensification of woody crop monocultures—such as olive, nut, grape, and citrus monocrops—pose worsening threats to crucial *in situ* agrobiodiversity conservation and utilization in each country (Spain, Morocco, and France). In the second part, we explain the roles of wide-ranging farmer and food movements and practices that provide key agrobiodiversity support, thus strengthening food system sustainability. We conclude by discussing the agrobiodiversity threats amid predominant trends in the Mediterranean, distilling our argument for the support of farmer and food movements, and offering focused reflections on policy and conceptual frameworks.

The overarching goal of this Commentary is to strengthen understanding of agrobiodiversity, prominent threats, and food system linkages and thus enhance policy support, political engagement, and public awareness that is centered on food biodiversity sustainability. We are committed to supporting agrobiodiversity in the contexts of socially just, healthy, and viable food landscapes (García-Martin et al., 2022) and the food system sustainability of increasing urban populations (Zimmerer et al., 2021). Water sustainability, climate change, and agroecological alternatives comprise additional key issues since the Mediterranean's expanding intensive woody monocultures draw on accelerating groundwater extraction (Molle et al., 2019). This recent trend differs from much long-term irrigation in the Mediterranean that had been based on sustainable practices (Wolpert et al., 2020). Yet, Mediterranean climate change policy has been mostly unspecific about food agrobiodiversity, while there is notable promotion of "irrigated intensive olive orchards" (Branquinho et al., 2021, p. 2) and woody monocultures as favored adaptations to climate change due to their arborescent growth and root depth (Colombo and Rocamora-Montiel, 2018).

In contrast to the woody monoculture proponents, agroecological studies in the Mediterranean are proposing mixed-use agroforestry landscapes in which biodiversity is protected and contributes crucially to combined climate change adaptation and mitigation. To date, these proposals for new and expanded agroforestry systems tend either to incorporate food biodiversity as monitoring indicators (Aguilera et al., 2020) or do not specify its role (Boix-Fayos and de Vente, 2023). One goal of our work is to highlight the need and opportunity for agroecology and related fields to leverage the production–consumption linkages of agrobiodiversity for new policies to strengthen food system sustainability and biodiversity conservation.

In addition to the main themes outlined above, we introduce here and then reflect in the conclusion on 3 broad themes engaged by this work. First is the pivotal

**Figure 3. Fieldwork photo of superintensive olive production in Jaén, southern Spain.** Superintensive olive fields are characteristic by densely planted monocultures of a single genetic type (genotype) of shrub-type trees that are highly dependent on irrigation inputs increasingly supplied by groundwater extraction. The production systems of superintensive olive fields evidence the enclosed spaces, labor control, long-distance networks, and other plantation characteristics. Broad reflections in the conclusion contain a detailed definition of the Plantationocene as a concept that can be applied to understanding the landscapes and associated social–ecological systems dominated by highly intensive production of olives and other woody monocultures. Photo credit: Yolanda Jiménez-Olivencia.

trend reflected in prominent urban–rural networks of the farmer and food movements supporting agrobiodiversity through production–consumption linkages since the Mediterranean is one of the world's most highly urbanized biodiversity hotspots (García-Nieto et al., 2018). The second and third broad reflections are centered on the land sparing versus land sharing models of sustainable development for conservation (Grass et al., 2021) and the Plantationocene concept (Carney, 2021; Zimmerer et al., 2023). Developed in our Commentary's conclusion, we engage these influential frameworks for agrarian landscapes, agrobiodiversity, and change that shed additional light on policy for food system sustainability. We reflect on the definitions and usefulness of these twin themes to guide research and relevant policy to address combined monoculture-agrobiodiversity dynamics in the Mediterranean and globally.

## Intensive woody monocultures and agrobiodiversity in the western Mediterranean

In Spain, the expansion and intensification of irrigated monocultures of olive, almond, vineyards, citrus, pistachio, and avocado are transforming landscapes and agrifood systems (López-Pintor et al., 2018; Ortega et al., 2020; Zimmerer et al., 2022). Nationwide, this area has nearly doubled (1986–2021, MAGRAMA, 2021), with the expansion increasingly based on superintensive monocultures (especially olive; Rodríguez-Cohard et al., 2020) that are highly irrigation-dependent, plantation-type production systems (see photo in **Figure 3** and schematic representation in **Figure 1**). More granularly, their areal extent has increased 5-fold in southern Spain (1989–2018; Tocados-Franco et al., 2023) and 6-fold in olive monocultures (Sánchez and Paniza Cabrera, 2015). Monocultural olive production now encompasses approximately 500,000 hectares in Andalusia alone (MAGRAMA, 2021) and, drawing on groundwater irrigation, covers areas of hilly uplands. Meanwhile, intensified monocultures of olive, almond, and citrus in Spain have become vulnerable to disease outbreaks and potential epidemics of plant diseases, such as Xylella (*Xylella fastidosa*) (Sicard et al., 2018). The overall effect of reduced intercropping across Spain's agrosilvopastoral landscapes (Sánchez and Paniza Cabrera, 2015; Raggi et al., 2022) is to reduce the agrobiodiversity of cereal and legume species and varieties (also known as landraces) in a wide range of food crops (e.g., wheats, barley, rye, broad bean, chickpea, lentil, Mediterranean lupine, bitter vetch) (Raggi et al., 2022; Peña-Rodríguez et al., 2023). These reductions have accompanied the agroecosystem-scale depletion of wild plants, pollinators, soil organisms, and other agrobiodiversity components that have accelerated notwithstanding European Union conservation policies (Sánchez and Garrido, 2017; López-Pintor et al., 2018).

In turn, Morocco's expanding monocultures of olive, almonds, citrus, and dates were powerfully propelled by the 2008 Green Morocco Plan (Plan Maroc Vert) (Molle and Tanouti, 2017; Molle et al., 2019; Lin et al., 2021). This neocolonial pact with the United States and Europe (Benamar, 2021) vastly expanded woody monoculture plantations of enclosed production systems. Doubling of the area of irrigated olive monocultures (Lin et al., 2021) has been characterized by plantation-style fenced enclosures and the intensifying "drip irrigation fever" fueled by groundwater extraction (Molle and Tanouti, 2017). Recently, the country's Green Generation Strategy, 2020–2030 continues to propel agro-export commercialization. Its stated purpose is to increase irrigation efficiency and lessen water extraction (World Bank, 2020; Hautes Orientations Royales, 2023), though the latter has not been evidenced. A large diversity of cereals and food legumes (e.g., local varieties of wheats, barley, millet, sorghum, fava or broad bean, lentil, and chickpea; Ziyadi et al., 2019; Teixidor-Toneu et al., 2020; Bernis-Fonteneau et al., 2023), as well as diverse herbs and food trees (e.g., olive and fig; Aumeeruddy-Thomas et al., 2016; Aumeeruddy-Thomas et al., 2017), are at risk of being curtailed. These agrobiodiverse biota have been widely replaced by single tree genotypes in the expanding woody monocultures (Hmimsa and Ater, 2008).

The intensified, vineyard monocultures in France, as illustrated in **Figure 4**, reflect overall trends in the western Mediterranean (Molle et al., 2019). Accelerated irrigation expansion in French vineyard production (from 7% to 17% in 2000–2010, with the rate of increase estimated to increase since 2010; Rouillard, 2020) is increasingly reliant on groundwater extraction and drip irrigation that are incorporated into new production systems (Molle et al., 2019). In Mediterranean France, more than one third of vineyard production is now irrigated. This trend is driven by political-economic transformations of the wine industry and by intensifying drought pressure. Already by the mid-20th century, early vineyard monocultures had replaced interplanted and rotational grains and legumes in Mediterranean France (Zimmermann, 2006). Since then, the agrobiodiversity of wine-making grape landraces has lessened across both vineyard and communal scales though still with significant persistence (Doncieux et al., 2022). Food legumes show similar overall trends. For example, French production of field pea has been reduced by half, while lentil and chickpea are now predominantly imported (Divéky-Ertsey et al., 2022; Violette, 2023).

In the past 30-plus years, climate change mitigation has emerged as an increasing justification in policy discourse and implementation favoring woody monocultures. In Spain, for example, the promotion of tree crops and the absence of regard for agrobiodiversity began as early the Agri-Environmental Climate Schemes of European Union Common Agricultural Policy by the early 1990s. While this approach was recognized by 2015 to deplete soil fertility and biodiversity (Gonçalves et al., 2021), the carbon-sequestration and expanded irrigation of intensive olive monocultures continued to be advocated as integral to climate change mitigation in the Mediterranean (Colombo and Rocamora-Montiel, 2018). This policy interpretation likewise underlay the climate change adaptation and mitigation of the Morocco Green Plan (Ziyadi et al., 2019). Even the current agroecological interpretations and biodiversity initiatives in the European Green Deal (Boix-Fayos and de Vente, 2023) have yet to suggest policy awareness of food agrobiodiversity notwithstanding the scientific evidence showing its adaptive capacities (Labeyrie et al., 2021; Renard et al., 2023).

In sum, the agrobiodiversity of diverse food in the western Mediterranean has not gained a firm foothold of support in the existing climate change adaptation discourse and policy nor is it consistently represented in the predominant agroecology-based approaches. Our Commentary turns next to an explanation of the crucial importance of farmer and food movements in supporting agrobiodiversity through production–consumption linkages amid the current deficiencies in key scientific and policy approaches.

## "Agrobiodiversity Nourishes Us": Farmer and food movements in Mediterranean agrobiodiversity

Farmer and food movements are increasingly vital to agrobiodiversity and food system sustainability in the western Mediterranean in the face of intensifying monocultures (**Figures 3** and **4**), food system globalization, and accelerating water extraction and climate change. These agrobiodiversity-related movements include well-organized peasant, sustainability, social justice, and food sovereignty organizations—some well-known such as the French *Confédération Paysanne* ("Peasant Confederation") and the Andalucian Seed Network, Red Andaluza de Semilla, that supports food agrobiodiversity through initiatives for seed and food sovereignty—in addition to a growing number of other seed and agroecology initiatives. This gamut of groups and practices encompasses networks of individuals, households, and communities that currently support and utilize extensive multifunctional agrobiodiversity in the western Mediterranean (Jones et al., 2022).

Farmer and food movements and practices show national-level distinctness across Spain, Morocco, and France (**Figure 5**). The individuals and multiscale groups actively supporting agrobiodiversity are themselves enmeshed in supportive rural–urban networks, as addressed in the following. We highlight these characteristics, taken together, as exemplifying the production–consumption perspective of "Agrobiodiversity Nourishes Us," as the theme of this special issue suggests.

In Spain, pro-agrobiodiversity farmer and seed groups with smallholder, peasant, and agroecological orientations (González de Molina and Guzmán, 2016; RAS, 2024) are allied to food movements supporting biodiversity-rich "mixed farming" to provide affordable, nutritious food threatened by the "increased specialization of olive groves" (Peña-Rodríguez, 2023, p. 13). Movements with these goals, such as Salvemos la Vega, Somos Vega, Somos Tierra, Federación Intervegas, La Red Agroecológica de Granada, and La Red Andaluza de Semilla, have developed rural–urban approaches to food security and sovereignty.

**Figure 4. Fieldwork photo of intensive vineyard production in southern France.** Intensive vineyard production is characterized by dense plantings that are pruned and trellised to create a growth form that is extremely vertical and low-medium height. Resulting distinct morphology of the grape vines is combined with vineyard field design and management that enable and depend upon new mechanical harvesting equipment. Groundcover is often nominal or absent in these vineyards, as are coordinated grazing as well as the shade and habitat typically created by intermixed horizontal branching of vines and their associated 3-dimensional canopy formation. Often irrigated, the commonness of these vineyards is increasing in southern France. It coincides with the restructuring of the French wine industry and is also strenuously contested because of impacts both on the flavor of vine production and the increased threat to water sustainability. Photo credit: Scott Prudham.

Their rural–urban networks and food-based solidarity have become crucial to the support of agrobiodiversity. For example, urban and peri-urban civil society groups focused on food system sustainability in cities such as Valencia have forged territorial alliances and profitable market opportunities with the ecological food producers in surrounding rural areas (Sarabia et al., 2021).

The governance initiatives in Valencia's urban–rural food territory emerged in 2018 with a Municipal Food Council (CAM) and later the Agri-food Strategy and "Ley de Protección de la Huerta" (law for the protection of peri-urban farming and water systems). These multilevel territorial and agrarian development approaches unite the public sector with the participation of social movements (Sarabia et al., 2021). While estimates for populations involved in these initiatives are mostly specific to case studies, survey methods have been used to estimate that between 550 and 850 groups farmer-to-consumer groups in Spain encompass approximately 50,000 consumers as well as the regular farmers' markets estimated to number between 150 and 200 (>10,000 farmers and consumers) (López García, 2016)—these alternative food networks reflect vital, widespread urban–rural linkages.

Morocco's agrobiodiverse grains and legumes, as well as other food and livestock diversity, are threatened by intensive woody monocultures (e.g., Elder, 2022). Similar reductions potentially impact the agrobiodiverse green leafy vegetables produced in multispecies agroecosystems (Powell et al., 2014). In response to the rapid expansion of irrigated-promoted monocultures, which represent a modern phase of the colonial agro-export model (Benamar, 2021), many Moroccan farmers have practiced everyday forms of resistance in support of their livelihood strategies that incorporate agrobiodiversity (Rignall, 2016; Elder, 2022). The specific area and demographic extents of this resistance are unknown since they are mostly unreported,

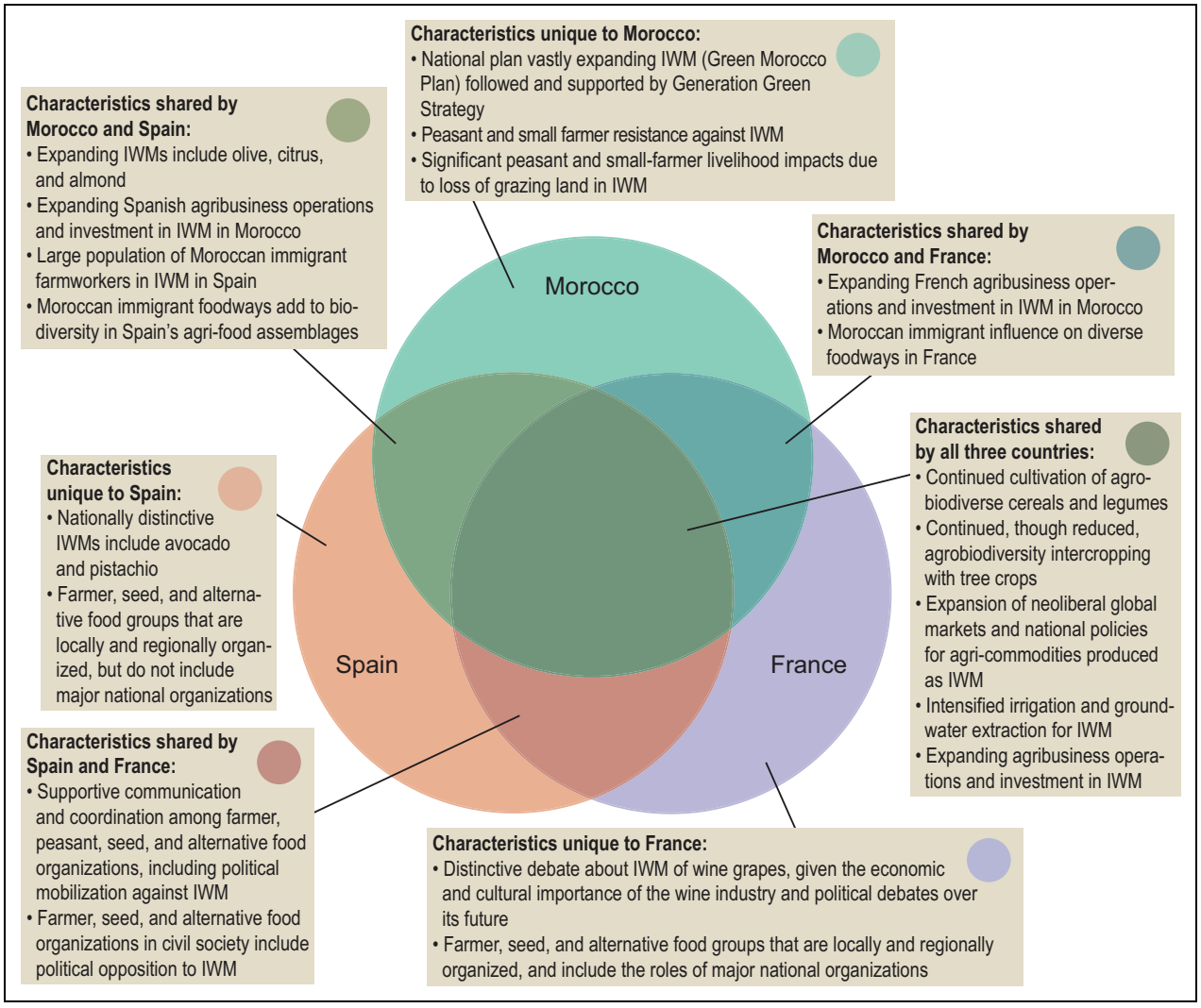


**Figure 5. Diagram illustrating the key characteristics of the farmer and food movements and the agrobiodiversity-monoculture systems of farm landscapes in Spain, Morocco, and France.** Multiple characteristics that provide keys to the explanation in this Commentary are common to all 3 countries (see "characteristics shared by all 3 countries" in the center of the diagram). Other key characteristics are shown as being common to specific pairs of these countries (see Morocco–Spain, Spain–France, and Morocco–France). Meanwhile, other key characteristics are unique to each of the 3 countries. The suite of factors shown in this diagram is streamlined according to this Commentary's explanations and thus is not comprehensive.

though it is possible to describe the practices and estimate the general population of potential practitioners (see the following).

These Moroccan farmers have relied on resistance practices to produce local foods and thus maintain substantial traditional agrobiodiversity. In undertaking these practices, the farmers craft the concepts of subsistence-food spaces (*beldi*) that are distinguished from commercial fields (*romi*) (Delplancke and Aumeeruddy-Thomas, 2017), which is a distinction employed to access and utilize agrobiodiversity while resisting and strategizing against threats (**Figure 6**). For example, farmers' olive trees intended for production under the Green Morocco Plan can be discretely diverted to biodiverse, mixed-species fields. In other situations, inconspicuous openings in monocropped fields can be used to surreptitiously obtain and transplant the woody crops into their own diverse food spaces as a secondary planting. We estimate that as many as 500,000–1 million of the approximately 12 million peasant smallholders in Morocco (World Bank, 2022) live in proximity to the widespread areas of woody monocultures that have been established through the policies of the Green Morocco Plan and more recently the Green Generation Strategy 2020–2030. This is an estimate of those *potentially* practicing food-resistance techniques, whereas the actual number is lower. More generally, local food production and vibrant informal marketing in towns, villages, and cities (Johns et al., 2013) reflect the extensive rural–urban connectivity of farmer and food-related practices that are vital to livelihoods and agrobiodiversity in Morocco.

Finally, farmer and food movements in France recognize agrobiodiversity as important to strengthening autonomy, agroecology, and well-being (Caillon et al.,

**Figure 6. Fieldwork photo of the agrosilvopastoral landscape combining the intercropping of olive trees and cereals with grazing land in northern Morocco.** This general type of intercropped food landscape characteristic of the Mediterranean continues to exist though it has been reduced during the 1990–2023 period. The agrobiodiverse cereal cropping in this Moroccan landscape consists of local varieties (landraces) of wheat. Gene flow with nearby semi-wild and wild olive trees in this landscape enhances agrobiodiversity among the landrace populations of cultivated olives. The type of landscape in this photo has become reduced in areal extent and is much patchier in occurrence in Morocco than previously while it is now uncommon in parts of Spain with extreme rarity in other areas of Spain and throughout France. This Commentary explains how these agrobiodiverse farm landscapes are threatened by intensive woody monocultures and other factors. We recommend the understanding of combined monoculture-agrobiodiversity dynamics to understand actual landscape processes and inform policy. Photo credit: Yildiz Aumeeruddy-Thomas.

2017; Mazé et al., 2021). For example, the French Peasant Seed Network (RSP) and Biodiversity and Experience Exchange (BEDE) were founded with goals that include the support of agrobiodiversity small-scale farming and local food systems (Demeulenaere and Bonneuil, 2011; Bové and Dufour, 2013; Martin, 2021). They oppose large-scale monocultures (Brac de la Perrière, 2014), including the intensified monocultures of single-species woody crops. Movement strategies have relied on widespread rural–urban interconnections of political, cultural, and market-support networks (Darolt et al., 2016).

Powerful French public support of diverse food production is evidenced in the levels of participation and the economic viability of local farmers' markets, direct sales, and equivalents of community-supported agriculture (Hiroko, 2018) that are utilized by an estimated 42% of households nationally (François et al., 2014). Moreover, approximately 48% of total food sales in France involve organic and short supply-chain products (AGENCE BIO, 2014), reflecting scalability. Other examples include initiatives for rural–urban food territories of connected producers and consumers motivated by the goal of food citizenship that is proposed to foster food sovereignty, security, and democracy (Gerard, 2023).

## Conclusions and reflections: Food linkages key to agrobiodiversity support

Intensification and expansion of irrigated woody monocultures are propelled by the neoliberal globalization of agri-food systems in the western Mediterranean. These changes illustrate the growing threats to agrobiodiversity of

monoculture development beyond the well-known global examples of major field crops, such as hybrid maize, soybean, and sugarcane. Climate change rationales are being marshalled to justify intensifying and expanding woody crops without, in some cases, understanding the threats to food agrobiodiversity, groundwater, small-farm livelihoods, and other deleterious impacts of intensive woody monocultures. This leads us to urge that this climate justification be critiqued and replaced by approaches to support the suite of Mediterranean food agrobiodiversity in science-policy platforms such as the European Green Deal (Boix-Fayos and de Vente, 2023). *Intensive woody monocultures*, not the woody crops per se, are the focus of our concern since the latter's intercropping remains integral to persistent agrosilvopastoral-based ecosystems and landscapes throughout the Mediterranean (Jiménez Olivenciaet al., 2015; Luján Soto et al., 2021).

Strengthening current and emerging farmer and food movements along with individual and group practices that support diverse production–consumption linkages is increasingly vital to the future of agrobiodiversity. In Spain, Morocco, and France, these movements and practices supporting agrobiodiversity are enacted by short food-chain consumer groups, activist small-farmer organizations, territorial approaches, various farmer and seed networks, and crucial individual and practices, such as food gathering and harvests, food preparation, and cooking that often rely on women's knowledge, sociocultural capacities and power, and labor (**Figure 5**). These linkages provide crucial support for agrobiodiverse Mediterranean food grains and legumes. The existing agrobiodiverse, species- and varietal-level populations of wheat (including hard wheat, spelt, and einkorn), barley, rye, millet, and sorghum, as well as several important food legumes (field pea, broad bean, chickpea, lentil, Mediterranean lupine, and bitter vetch) are maintained through a range of production–consumption coupling. Additionally, rural–urban networks actively support agrobiodiversity's multilevel market and trade practices that continue to evolve (e.g., village and city-based food flows in Morocco) while elsewhere they are notably emergent (e.g., urban-based neo-rural linkages in France), and a mixture of types (e.g., southern Spain) (**Figure 5**). This reflection urges policies strengthening the sustainable food system roles of pro-agrobiodiversity urbanization processes in the western Mediterranean and elsewhere (Zimmerer et al., 2021), rather than assuming that pro-agrobiodiversity processes are predominantly or exclusively rural.

We support a range of agrobiodiversity-based approaches to food system sustainability that can benefit by allying to farmers and food movements. In terms of broad science-society trends, agrobiodiversity represents a distinct assemblage of social–ecological dynamics that can potentially become compatibly enmeshed in the approach of agroecology (Chable et al., 2020). This is a promising collaboration for agrobiodiversity utilization and conservation since the approach of agroecology is influential in the proposed New Green Deal of the European Union and other major agri-food sustainability and climate change policy proposals. Policy-directed agroecology in the western Mediterranean has begun to recognize the opportunity and challenge of how to incorporate the combined social–ecological dynamics of food agrobiodiversity (Aguilera et al., 2020; Chable et al., 2020; see critique in Pe'er et al., 2014). To date however, these key roles of agrobiodiversity in farmer and food movements have not been strategically bridged to, nor situated in, agroecology through the strengthening of production–consumption linkages.

One clear message here is to urge policies for climate adaptation/mitigation among governments and civil society that focus on mixed-use agroforestry systems that incorporate the intercropping of food biodiversity. Strategies that prioritize the multiple functions of food agrobiodiversity, such as the agrobiodiverse cereals and legumes highlighted in this essay, could link to farmer and food organizations and movements. The learning point here is that the production–consumption linkages of these groups would create a social–ecological *raison d'être* for agroforestry-with-food-biodiversity that would be quite different from both mix-use agroforestry planning without food agrobiodiversity (critiqued in the opening section) and widespread monocultural tree planting and plantation establishment. More generally, we suggest the crucial social–ecological linkages of agrobiodiversity to farmer and food movements and practices are potentially well suited to careful integration in interdisciplinary and transdisciplinary agroecology in the Mediterranean and elsewhere. Critically leveraging these dimensions of agrobiodiversity with links to agroecology agendas will strengthen both agri-food sustainability and climate change policies.

Additional brief reflection is focused on how the documented expansion of intensive woody monocultures in the western Mediterranean can illuminate the much-discussed land-use trajectories of hypothesized land sparing (i.e., intensification-based) and land sharing (i.e., promoting multispecies agriculture) (Grass et al., 2021). This is an important reflection because the policy scenario of assumed land sparing is promoted as a generalizable global-scale guide for land-use and conservation planning. Currently, this assumption undergirds global conservation plans such as the thirty-by-thirty ($30\times30$) agenda—30% of terrestrial and marine habitats to be set-aside in conservation protected areas by 2030. Alternatively, the perspective of land sharing underscores the conservation value of sustainable farm landscapes with agrobiodiversity and humanized wild lands managed through combined high- and low-intensity use (Zimmerer et al., 2015). Region-scale studies can elucidate this debate (Grass et al., 2021). The western Mediterranean's expansion of intensive woody monocultures has not yielded evidence to-date of either reductions in overall agricultural area or the increase of wildlands. It suggests an empirical absence of regional land-sparing that can inform future scientific debate and policy analysis.

Finally, these reflections lead us to recommend that the Plantationocene concept and framework can be used to further elucidate combined monoculture-and-agrobiodiversity dynamics incorporating the roles of farmer and food movements. The Plantationocene concept posits the global proliferation of agri-food monocultures through long-distance and colonial power (e.g., long supply chains); extractive logics

(e.g., water or minerals); systemic large-scale and corporate domination, territorial control, and enclosures (e.g., globalization of the countryside); and cross-scale mobility (for full definition and examples, see Wolford, 2021, Zimmerer et al., 2023). To-date, the approach to monoculture-agrobiodiversity landscapes described using the Plantationocene concept have included historical sugar cane, wheat, and cotton monocultures and their relations to concurrent food agrobiodiversity (Carney, 2021; Zimmerer et al., 2023). Present-day intensively produced irrigated tree monocultures and agrobiodiversity dynamics in the Mediterranean exemplify Plantationocene landscapes and historical antecedents since they share many of the plantation features this concept notes. This Plantationocene-guided reflection highlights that joined monoculture-agrobiodiversity analysis elucidates interaction dynamics and relational perspectives. Advancing the understanding of landscape and food system relations, rather than treating each separately, can help in current efforts to decolonize agrobiodiversity knowledge, policies, and politics.

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## Competing interests

The authors declare no competing interests.

## Author contributions

Contributed to conceptualization: KSZ, YAT, SC.
Contributed to methodology: KSZ, YAT, SC, YJO, LPR.
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Contributed to data and analysis: KSZ.
Contributed to writing—original draft: KSZ.
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