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forests

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Review

Global Change and Forest Disturbances in the Mediterranean Basin: Breakthroughs, Knowledge Gaps, and Recommendations

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Summary

- This **review of recent literature (2000–2021)** indicates large **direct and indirect impacts of increasing drought** conditions on the forests of the Mediterranean Basin, their changes in surface and distribution areas, and the main impacts they have suffered
- **Drought conditions combine** with over-exploitation, pest expansion, fire and soil degradation, to synergistically driving to forest regression and dieback in several areas
- These environmental changes **trigger responses in tree** morphology, physiology, growth, reproduction, and mortality

Introduction to Mediterranean biome (I)

- The Mediterranean Basin is **especially sensitive to climate change** due to the nature of transition between arid and temperate regions
- The **increase in aridity in the region has been widely de**monstrated throughout the last decades
- Recent data indicate a **temperature increase in the last century** of 0.85 ◦C globally, and 1.3 ◦C in the Mediterranean area compared to 1880–1920 period
- Aridity is **even projected to increase in the future**: 3–4 ◦C increase in temperature and 20% decrease in rainfall in forested areas

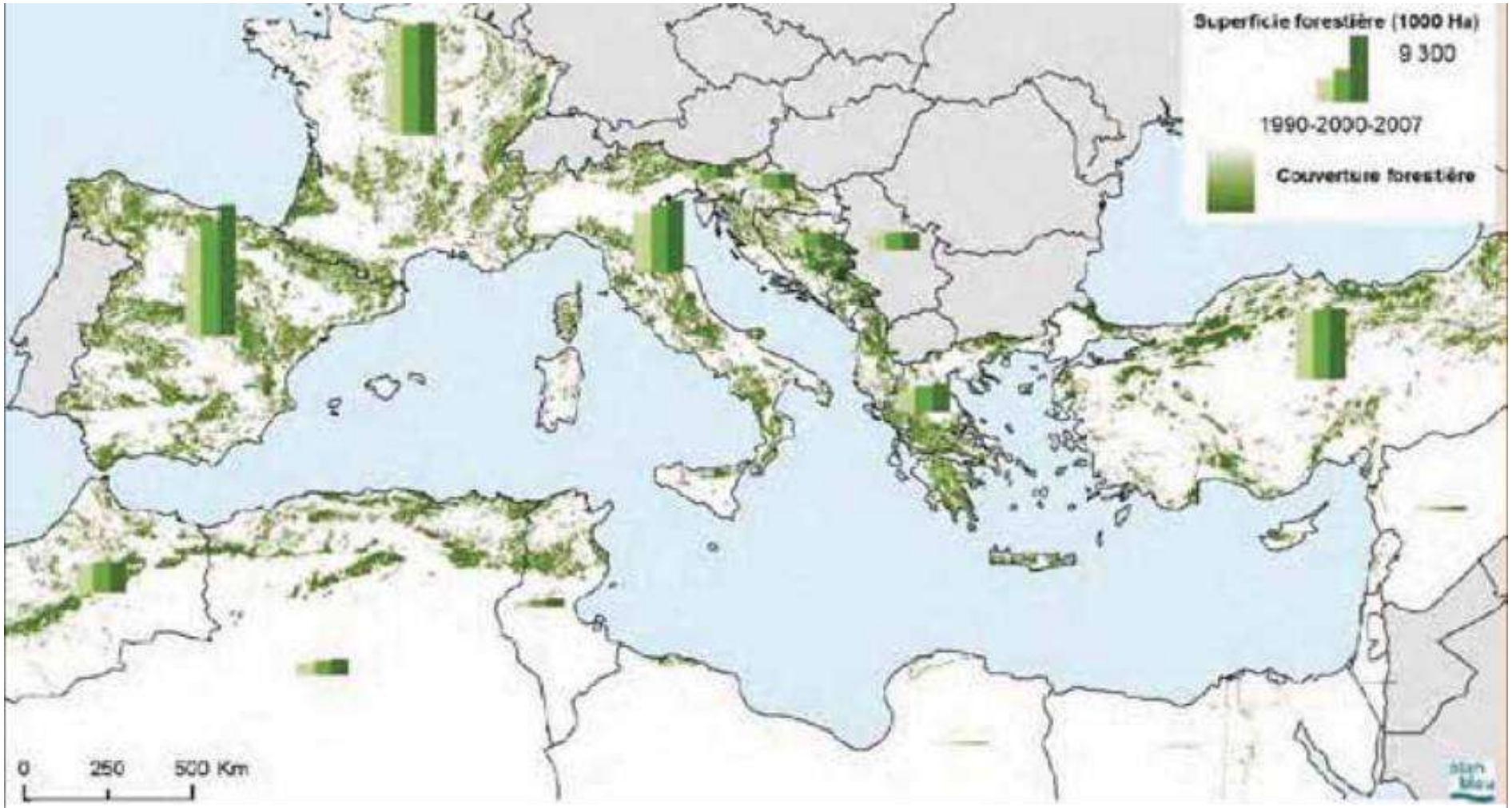
Introduction to Mediterranean biome (II)

- Mediterranean soils often **suffer nutrient deficiencies**, especially of nitrogen (N) and phosphorus (P). This low fertility is especially critical in forests due to their higher demands for water and nutrients
- The effects of **higher CO2 levels are also increasingly affecting foliar composition and P and N contents**, further decreasing nutrient availability

Introduction to Mediterranean forests

- The Mediterranean Basin is **a global biodiversity hotspot in Europe**
- Forests **are estimated to cover 10% of the total land in the Basin** (25 million ha of forest and 50 million ha of other wooded lands)
- Between 2010 and 2015, **Mediterranean forests have increased their cover by 2%,** but forest degradation and vulnerability have also increased
- This increase in the last century is **mainly due to forest regeneration in rural areas following abandonment**, and more recently to the EU CAP
- Models have projected an **area loss of about 11–25% by the end of this century mainly due to desertification**, yet **Mediterranean climate could also expand towards NE** in Europe
- Although, **the Mediterranean forest is still a global carbon sink**

Mediterranean forests



Source: State of the environment and development in the Mediterranean – 2009, Plan, Bleu based on FRA data.

Objectives

This study was aimed to

(i) identify the current status of the diverse human and natural disturbances in Mediterranean forests over recent decades

(ii) identify the main causes of the changes in these forested areas responsible for the current situation, which can provide clues for a future perspective for forested areas in the Mediterranean Basin

(iii) propose actions that could help improve the survival of the forest biome in the Mediterranean Basin

(iv) **identify issues** that help advance our knowledge for obtaining a global overview of the present and future evolution of this biome.

Study sites

Figure 1. Sites with observational/experimental data used in this study.

Several Concurrent Risks

1. Present and Future Aridity: The Larger Threat

- **Dieback, defoliation, and lower growth** in European Mediterranean forests are mainly **due to increasing drought**, often interacting with higher temperatures and pathogenic attack, all associated with further decreases in nutrient-cycling rates, changes to soil trophic-web structure, and lower soil fertility
- **Annual growth and seed production** in Mediterranean forests in recent decades are **strongly correlated with annual drought intensity**.
- **Tree dieback** under drought conditions **is associated with a depletion of reserves of nonstructural carbohydrates, a general increase in tree dormancy and decrease in GPP**
- **Mediterranean trees** in their current distributions **are frequently at the limit of their capacity of positive NPP**, so a further increase in aridity would be catastrophic
- **Several Mediterranean forested areas are on steep slopes** and thus frequently have shallow soils, so they are more sensitive to drought as observed in climate models

Several Concurrent Risks

- **Drought can limit the potential response** to rising atmospheric CO2 concentrations
- Interestingly though, **the increasing patchiness of forests**, however, **can increase the capacity of forests to resist future drought**.

- **The situation of Mediterranean forest** associated to global warming **is especially critical in the southern Mediterranean rim**. The impact of drought-aridity in forest dieback in North Africa has been especially intense from 1970s–1980s
- **This process is especially intense in several areas** where the overgrazing pressure, the expansion of crops, and the urbanization, together with wood exploitation have continuously risen.

Several Concurrent Risks

Drought Is Currently Shaping the Structure of Mediterranean Forests

- **Tall shrubs such have a higher capacity** than trees to adapt and resist intensive droughts
- Thus, **the expansion of shrublands at the expense of forests is expected** from the interaction of more intense and extreme recurrence of droughts and large fires
- **The impact of drought on defoliation and dieback can asymmetrically affect species and individual trees** in the same species: shorter trees are more resistant and resilient to increases in drought than taller trees, both in intra- and interspecific comparisons
- **The effects of drought on the fitness of various species of Mediterranean forest trees seems to be much more detrimental to mesic** than to more xeric species
- Contrasting results, however, have been reported

Several Concurrent Risks

Grazing Pressure under drought enhancement

- **Disturbance by livestock and over-exploitation have frequently increased**, thus aggravating the negative effect of the reduction in natural precipitation
- **These disturbances have been especially observed in savanna woodlands and dehesas,** where the Mediterranean evergreen genus Quercus is dominant
- However, **the livestock pressure is decreasing very fast in large parts of the northern Mediterranean rim**. This is leading to dense pioneer forests going hand in hand with loss of plant (and insect) diversity, especially regarding gap colonizer species

Several Concurrent Risks

Aridity and Warming: An Open Door for Pests

- **The increases in heatwaves, warming, and droughts have been associated with pathogens** in Mediterranean forests, such as the pine processionary moth (*Thaumetopoea pityocampa*)
- **Infestation by *Phytophthora* species (mainly *P. cinnamomi*), is currently the main direct cause of declines in *Q. ilex* and *Q. suber* forests** in southern Europe .The spread of this fungus is favored by warmer temperatures and increased aridity. The decline is concurrent with losses in soil biological activity and nutrient availability. Attacks by pathogenic fungi also are intense in some forests of the North Africa
- **Insect outbreaks may also have strong impacts on the Mediterranean trees**, affecting their resistance to drought. Species like *Limantria dispar* or *Tomicus* spp have largely affected Spanish forests in recent times.

Several Concurrent Risks

The Particular Case of Temperate and Boreal "Forest Islands"

- **Microclimatic conditions driven by topographic features allow the establishment of sub-Mediterranean, temperate, and even boreal forests** in the Mediterranean biome, particularly in southern Europe (e.g. in the main mountain ranges)
- However, because of their higher resilience to drought, **Mediterranean species are expanding into these forest islands**
- Clear and increasing **symptoms of declining crowns and increased defoliation and mortality are observed in non-Mediterranean species** (e.g. *Pinus sylvestris*), mainly in stands at low altitudes
- The **effects of drought have been largely detrimental to the populations of those species** in the border of their distribution area
- The **dieback and substitution of temperate/boreal by Mediterranean forest species is even faster where browsing pressure by ungulates is high**, as in Southern Spain

Several Concurrent Risks

2. Species Invasion

- Forests are generally **the least invaded habitats particularly in Europe and the Mediterranean Basin**, where forests are currently not especially affected by species invasion
- **Peri-urban forests, however, are the most vulnerable to invasion due to the presence and activity of humans** that apply pressure for dispersing invasive species and promote open ecological spaces that allow new species to invade while maintaining high resource availability
- **Many species have been intentionally introduced for afforestation and silvicultural management** (e.g. *Acacia, Eucalyptus, Robinia, Ailanthus*)
- In any case, **further increase in aridity and/or N deposition would favor the spread of some current invasive forest species** in the Mediterranean Basin

Several Concurrent Risks

3. Soil Fragility and Forest Maintenance and Regeneration

- **Low and irregular precipitation is the main factor limiting tree establishment and growth** under Mediterranean conditions, which is particularly harmful in areas where the **soil has a poor capacity to retain water**
- The **unstable balance between the trees and soil water content**, together with anthropogenic actions on forest environments and their degradation, which affect floristic composition, **act against soil stability and fertility**
- **Difficulties in regenerating forests** after clear-cutting or fire **accelerates the conversion of forests to pastures**, degraded areas, and ultimately to desertification thus complicating forest sustainability
- **The quality of soil is key ensuring the health and regenerative capacity of Mediterranean forests**. An, in turn, **forests are the best types land cover for maintaining soil quality** and avoiding its degradation in Mediterranean climates

Several Concurrent Risks

4. Depopulation and abandonment of rural areas

- The abandonment of rural areas in several parts of the Mediterranean Basin in the last 80–100 years has been associated with an increase in forest cover

- The resulting secondary new forests in the initial-medium stages of the succession process have frequently poor age structure, non adequate density, diversity, and maturity and are thus more prone to wildfires

- However, **high biodiversity in the Mediterranean biome is driven by the coexistence of early- and late-successional forests**

To sum up

Seven main causes have of changes in forests in the last three decades:

(i) **The direct effect of increased aridity** due to more frequent and prolonged droughts

(ii) **The indirect effects of drought,** mainly by the spread of pests and fires

(iii) **The direct and indirect effects of human activity** associated with environmental degradation, fire, species invasion and pollution

(iv) **Human pressure and intense management** of water resources

(v) **Cropland abandonment in the northern Mediterranean** without adequate management of new forests

(vi) **Very high pressure on forests in the southern Mediterranean,** coupled with demographic pressure, crop and livestock expansion, and water overexploitation

(vii) **Scarcity and inequality of human management and policies** that are unable to counteract the previous changes

Human Management

How can it help Mediterranean forest health and conservation?

- **The maintenance of forest patches between croplands** in rural areas can be a suitable management strategy throughout territories with adequate planning
- **The appropriate management of livestock and logging** ensures the equal representation of different stages of forest succession among forest patches of different sizes, which would be the best tool to maintain the diversity of woody plants and forest services among landscapes
- **The extensive management of livestock** as a potential alternative tool for maintaining biodiversity and avoiding the risk of fire in Mediterranean landscapes is under debate

Human Management

How can it help Mediterranean forest health and conservation?

- **Reforestation and afforestation** are the most direct human actions that can counteract the progressive degradation of forests in Mediterranean landscapes.
  - The use of nursery species that provide shade can allow the replantation of late-successional forests
  - The use of mulches and organic amendments and of soil conditioners with water-absorbing polymers favors the early establishment of tree seedlings.

- **Appropriate management** is also necessary to maintain Mediterranean forests in their current structure and areas.
  - An adequate level of thinning a few years after a fire can enhance forest regeneration and allow the control of fuel load
  - Conserving a specific amount and density of logging remnants after a fire has been associated with the better conservation of bird abundance and richness

Human Management

How can it help Mediterranean forest health and conservation?

- **Integrative approaches** are the most efficient to prevent fire, ensure adequate forest cover, maintain forest quality, and favor regeneration in current Mediterranean forest areas
- They should be based on **optimal and moderate forest thinning and livestock pressure** and on the appropriate management of the distribution of forest species
- It should be complemented in non-urban areas with the **maintenance of cropland and adequate and sustainable socioeconomic conditions for rural populations**
- We must, however, also account for the **different realities of southern Europe and northern Africa.**

Some conclusions (I)

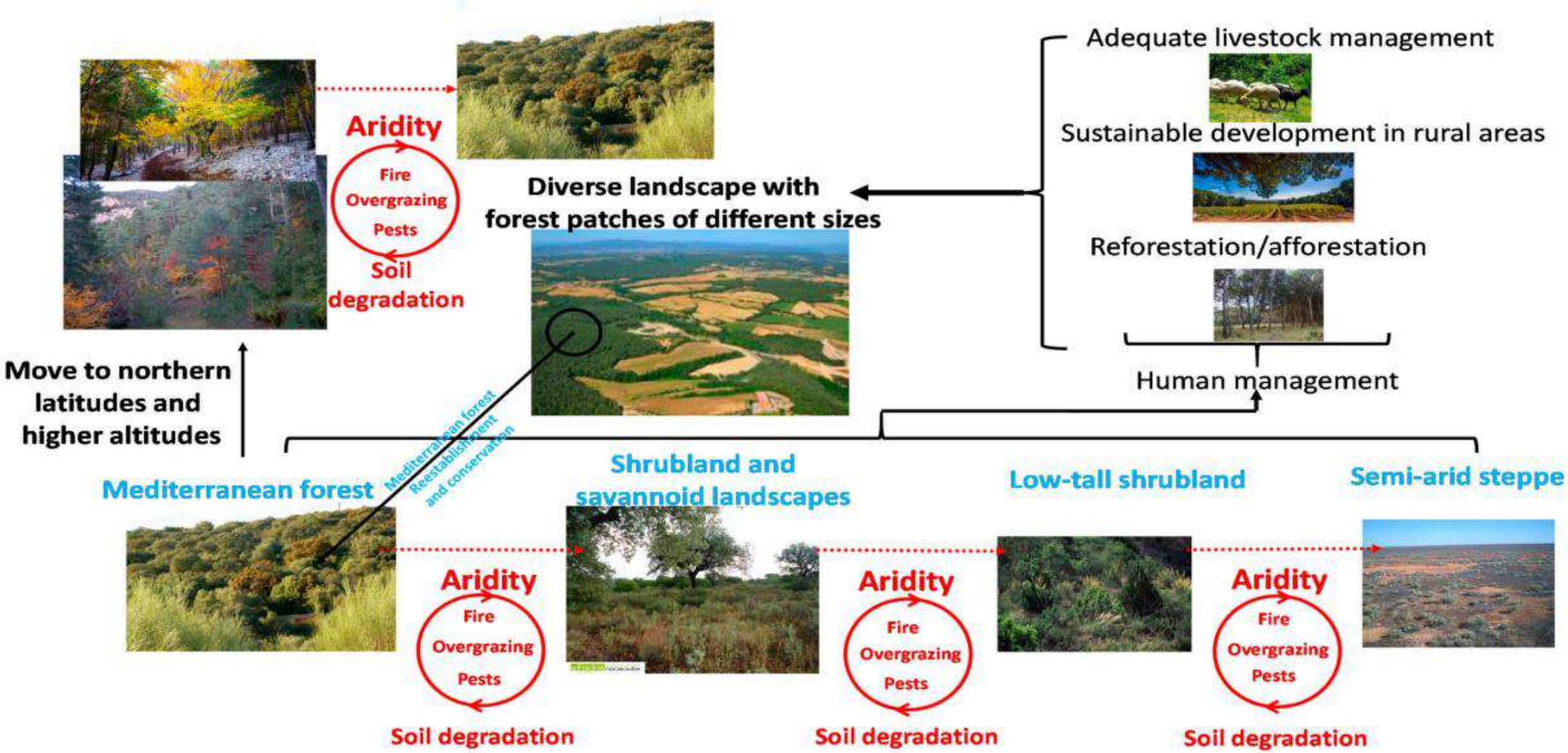
- **Aridity is the main climatic constraint for Mediterranean forests**, that should be considered in their management. Drought-driven alterations can become stronger if climate change, its associated disturbances and changes in other components of global change continue at current rates or are enhanced.
- Therefore, **we need to know more about properly managing forests to increase their resistance to drought and the interacting disturbances**. Little is known about improving soil conditions to ensure a good supply of nutrients. Land-use planning is a key “pending question” in several areas of the Mediterranean Basin.
- **A strong alliance is needed** to avoid excessive depopulation of rural forested areas and unmanaged secondary forest expansion in Mediterranean Europe, and on the other extreme, to control population expansion and forest over-exploitation and loss in North Africa.

Some conclusions (III)

- All the data strongly suggest that **maintaining biodiversity, as well as a variety of goods and services from cropland and forested areas will be necessary to reach these objectives**, combining forest patches of different sizes, including the most appropriate crops for maintaining environmental quality and food security as much as possible, and promoting sustainable economic sources for the maintenance of an optimal human density.

- **The management of forested areas should incorporate a hierarchical landscape planning at different scales**, including a large-scale plan that considers the combination of areas of different types, multiple users, and the effects of disturbances and especially drought, to a local-scale action such as the improvement of stakeholders' education and tools availability for an adequate management of their territories

A graphic summary to sum up



Thanks!!

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