Global Drylands Assessment Using Collect earth tools and opportunities for forest restoration

Results in the Mediterranean Region

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Introduction

Global change and human pressures have led to land degradation in large areas of drylands across the world, and specifically in the Mediterranean region. Because drylands are particularly vulnerable while providing livelihoods and income to many populations, improved management, and restoration of drylands has become urgently needed (Soutsas *et al.* 2004). Efficiently planning restoration first requires identifying restoration opportunities, i.e. areas with a potential for restoration due to their degradation level (IUCN & WRI 2014). As a prerequisite to restoration opportunities mapping, a better knowledge of the geographical distribution and state of drylands is needed.

In this regard, one of the commitments of the Committee on Forestry (COFO) at its 22nd session in June 2014, was to "undertake, within the framework of the FAO Global Forest Resources Assessment (FRA) and contingent upon the availability of extra-budgetary funding, a global assessment of the extent and status of drylands forests, rangelands and agrosilvopastoral systems" (FAO, 2014).

To achieve this goal, it was necessary to combine two ongoing projects, "Action Against Desertification", developed under FAO's dryland forestry program and the "Global Forest Survey", developed under FAO's Forest Resource Assessment program. This resulted on the first Global Drylands Assessment (GDA) on trees, forest and land use, which is based on a wide range of methods and tools for monitoring and assessing different features of drylands based on new and emerging technologies that include free and open source tools developed by FAO such as LADA [1] and Collect Earth [2]. GDA data have been used to report a new estimate of forest extent in dryland biomes in the world. The estimate would be 40 to 47% higher than previous estimates and would increase current global forest estimates in about 9% (Bastin *et al*. 2017).

The objective of the current analysis was to demonstrate how the GDA could serve as a tool to first, show the state of drylands in the Mediterranean region and second, to evaluate regional forest dynamics and forest degradation at the Mediterranean regional level. The Technical University of Madrid (UPM) in a joint effort with FAO analyzed the GDA results at this regional level

GDA methodology and delimitation of the Mediterranean region

The Global Drylands Assessment complements the FAO Global Forest Resources Assessment (FRA) (FAO 2015b) but differs from it in how its methodology is carried out. The GDA is based on the visual interpretation of satellite images in publicly available repositories (such as Google Earth and Bing Maps) and uses support from remote sensing techniques using satellite imagery available in the cloud (Google Earth Engine) (Bey *et al.* 2016). Therefore, no official country information has been used in the GDA and the analysis was focused only in drylands. Results of the GDA were reported at the global and regional levels, not at the country level (FAO 2016).

Another innovation of the GDA methodology was its implementation approach based on a network of partners responsible for data collection at the regional level. The assessment was conducted as a series of regionally focused trainings and the collection of data during the celebration of workshops. Experts from universities, research institutions, governments and non-governmental organizations took part in the assessment. In the first week of each workshop, participants were trained in the use of Collect Earth and in the second week, participants collected data on established sampling sites over the drylands area.

The areas surveyed in the GDA followed the definition of drylands by the UNEP-WCMC (2007). Drylands are areas with an aridity index equal or lower than 0.65, where the aridity index is the ratio between precipitation (P) and potential evapotranspiration (PET) (Fig. 1).

Data of the GDA are still being cleaned and filtered and continuous updates may produce slight changes in the future. Here we present the latest data available in April 2017.

We delimited the Mediterranean region following Olson *et al.* (2001), which defines the Mediterranean Forests, Woodlands and Scrubs as a single biome. This biome includes parts in Europe, Northern Africa, South Africa, North America, South America and Oceania but, in this assessment, the political limits were established by the countries that enclose the Mediterranean Sea, including part of Europe, Middle East and Northern Africa (Fig. 2).

Drylands spread up to 72.2% of the area in this region. And totalize 6,492 out of the 213,783 plots surveyed in the GDA. (Fig. 3), (FAO, 2016). The extent and number of plots

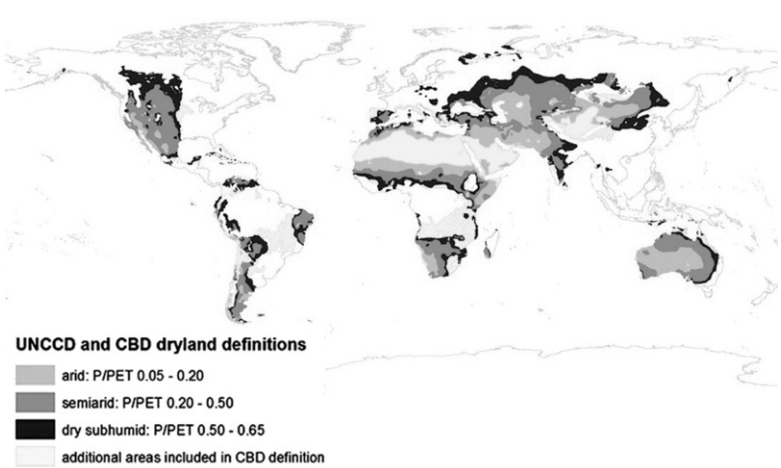

Figure 1: World's drylands distribution as defined by UNEP-WCMC (2007) P: Precipitation, PET: Potential Evapotranspiration. *Source UNEP-WCMC, (2007).*

1 - http://www.fao.org/nr/lada/
2 -http://www.openforis.org/

collected in each dryland category are shown in Table 1. The area of each plot is 0.5 ha, which is the minimum area that qualifies to the forest definition used by the FAO FRA (FAO 2015b).

Drylands in the Mediterranean region occupy an extent of 147,125,865 ha, representing 2.5% of all drylands in the world.

The number of ecoregions (Olson *et al.* 2001) and FAO global ecological zones (FAO GEZ) (FAO 2015a) were accounted within the drylands extent of the Mediterranean region, and compared with the number of ecoregions and FAO GEZ of other drylands in Mediterranean-climate regions in the world, such as Oceania, North America, South Africa or South America.

Although drylands extent in the Mediterranean region delimited in this assessment is the lowest (calculated as the relative percentage of world's drylands extent in Mediterranean-climate regions) compared with other Mediterranean-climate regions in the world, it shows the highest number of ecoregions and FAO GEZ in relation to its size.

If we use this information as a proxy of biodiversity richness and compare it with the other Mediterranean-climate regions, the Mediterranean region presented here is characterized by the highest number of assemblage of species, natural communities, environmental conditions (Olson *et al.* 2001) and relatively homogeneous natural vegetation formations (FAO 2015a).

Land use, land use change, and forested lands

Land use and land use change are key concepts to understand how humans and their activities are changing the natural exchange of carbon between the atmosphere and the terrestrial biosphere (IPCC 2000). Within the aim of this assessment, it is also important to understand these land use changes in detail to identify opportunities for restoration.

Land use categories were defined according to two classification systems:

1.– The Intergovernmental Panel on Climate Change (IPCC) classification, following the methodological approach based on remote sensing techniques to assess land use as required by the United Nations Framework Convention on Climate Change (UNFCCC) and developed by Martínez & Mollicone (2012).

2.– Following the definition of FRA (FAO 2015b)

Figure 2:
Area showing the distribution of the Mediterranean biome in the Mediterranean region (shaded gray) as defined by Olson *et al* (2001).
Source: own elaboration.

Table 1:
Number of plots by dryland category in the Mediterranean Region. Total surveyed area using sampling plots and proportion as a percent of the world's drylands area.
Source FAO.

Drylands category	Number of plots	Area (ha)
Hyperarid	5	236,385
Arid	761	19,710,822
Semiarid	3,836	76,725,238
Dry subhumid	2,340	50,453,421
TOTAL	6,942	147,125,865
% relative to world's drylands	3,2	2.5

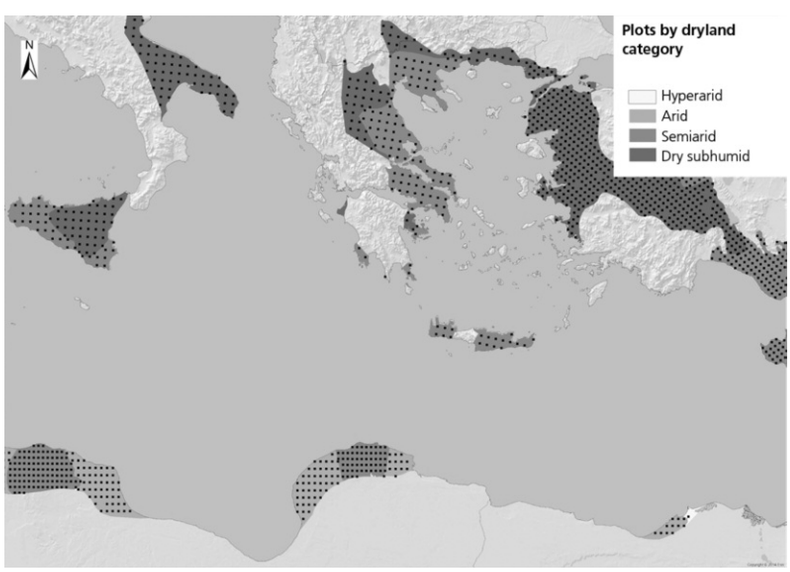

Figure 3:
Detail showing how the plots are distributed by dryland category in the center of the Mediterranean region. The distribution of the plots follows a systematic sampling grid which changes its distance between plots based on the aridity index, with a decreasing distance from hyper-arid to dry subhumid aridity zones and the probability of finding trees.
Source: own elaboration.

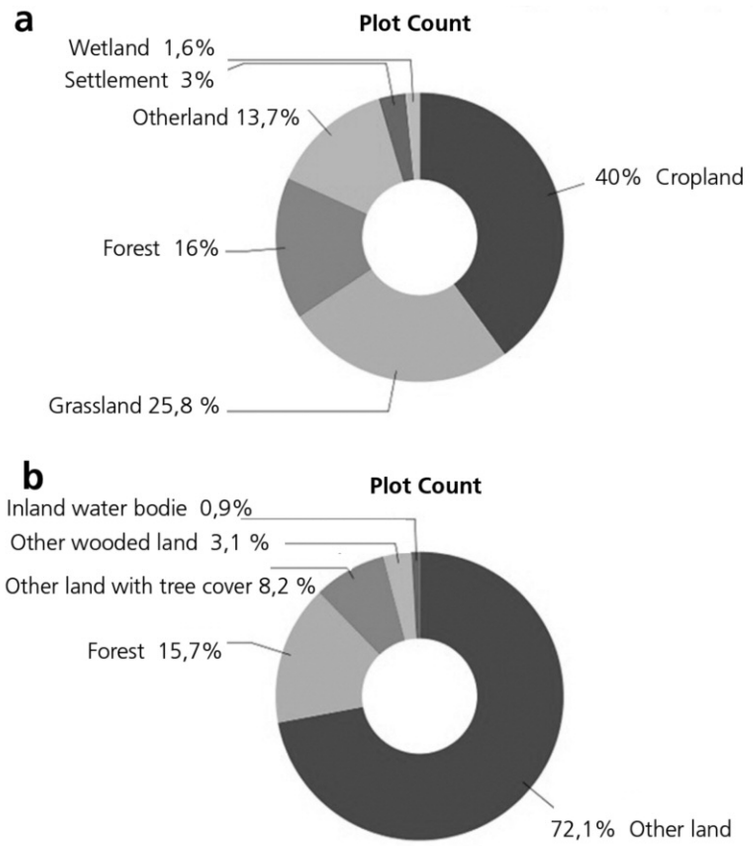

Figure 4: Percent of plots per land use classification, following IPCC (a), or FRA (b). *Source: own elaboration.*

Based on the IPCC land use classification, cropland was the dominant land use in the Mediterranean region and covered 40% of the plots, while forests accounted for 16% of the plots. A very similar forest land use cover was obtained using the FRA classification, where forests were assessed in 14.7% of the plots (Fig. 4). FRA classification also indicated that trees were present in other land uses than forests. The combination of forests, of other land with tree cover and of other wooded land as defined by FRA resulted in a total of 27% of plots with tree presence.

Trees and forests in drylands provide important environmental services, such as biodiversity, protection against water loss and erosion and they also increase the resilience of landscapes (FAO 2015a). Our data confirmed the importance of trees in the Mediterranean region and human environments. The presence of trees (with a tree cover ranging from a minimum of 2% up to 100%) was found in 58% of lands classified as settlements, 29% of croplands, and 24% of grasslands.

Analyzing tree cover is interesting not only to assess forest extent but also to characterize the "structure" of Mediterranean vegetation in a highly human-driven environment, where intact forest patches are sparse and isolated, whereas secondary forests or other vegetation formations are dominant as a result of human-induced activities. The analysis of the data on tree cover showed two clear vegetation structures corresponding to two modes of the tree cover distribution (Fig. 5). The first structure with a maximum between 0 to 20% of tree cover included isolated trees in croplands and grasslands, olive groves or tree plantations, as well as more complex agroforestry systems such as holm oak or cork oak open woodlands. The second structure, between 80 to 100% of tree cover included most of the closed conifer evergreen forests and broadleaved deciduous forests, but also mosaic landscapes of croplands and vegetation with different fluctuations in tree cover (Arino *et al.* 2012).

Land use changes were measured throughout the period 2000-2015. Land use change detection was done using Google Earth high-resolution imagery and showed that 99.3% of forest lands in the surveyed plots as defined by the IPCC remained unchanged during this time span. Changes from other land use to forest accounted for 0.2% of the total plots, whereas forest conversion accounted up to 0.6%.

Opportunities for forest restoration

In the current study, the Mediterranean region was defined using the FAO GEZ definition (FAO 2015a), which is consistent with the definition by Olson *et al.* (2011) but includes a large portion of Turkey and some Mediterranean eastern countries. The whole area of the Mediterranean region as defined by FAO GEZ (FAO 2015a) accounted for 199,104,150 ha.

Mediterranean forests are very vulnerable to factors such as forest fires, over-exploitation, degradation and desertification and the region has a long history of human pressure, which is largely responsible for these factors (Palahi *et al.* 2008). In fact, it is necessary to understand how human pressure is distributed in the landscape because this factor is the main driver and might be even more important than climate to explain

the distribution and configuration of vegetation in the region. The first objective is to target areas showing current opportunities for restoration. In a second phase, the same, data could be used to predict areas suited for potential forest restoration, taking into account climate change and related desertification.

The World Resources Institute (WRI) atlas of forest and landscape restoration opportunities (WRI, 2017) mapped degraded forests by combining a map of potential forest coverage (derived from data on climate, soils, elevation, and current and historical forest extent), a map of current forest coverage (based on Hansen's 2003 map), and data on land use. According to this atlas, the potential for restoration in the Mediterranean region as defined by FAO GEZ (FAO 2015a) amounts to 78.4 million ha (cumulating wide-scale restoration, mosaic restoration, and remote restoration).

The current study followed a different approach based on the human pressure on forest ecosystems as a proxy for degradation and taking advantage of the new GDA data that provided an unprecedented view on the forest extent in the Mediterranean region. An attempt to quantify human pressure was developed by Venter *et al*. (2016) under the name of "Human footprint index" (HFP). HFP measures the impact of eight typical human activities, namely: (1) extent of built environments; (2) cropland; (3) pasture land; (4) human population density; (5) night-time lights; (6) railways; (7) roads; and (8) navigable waterways.

The cumulative human activities over a given area of 1 km² are weighted and summed together resulting in a standardized index ranging from 0 to 50, with 0 indicating very low or no human impact and 50 very high human impact.

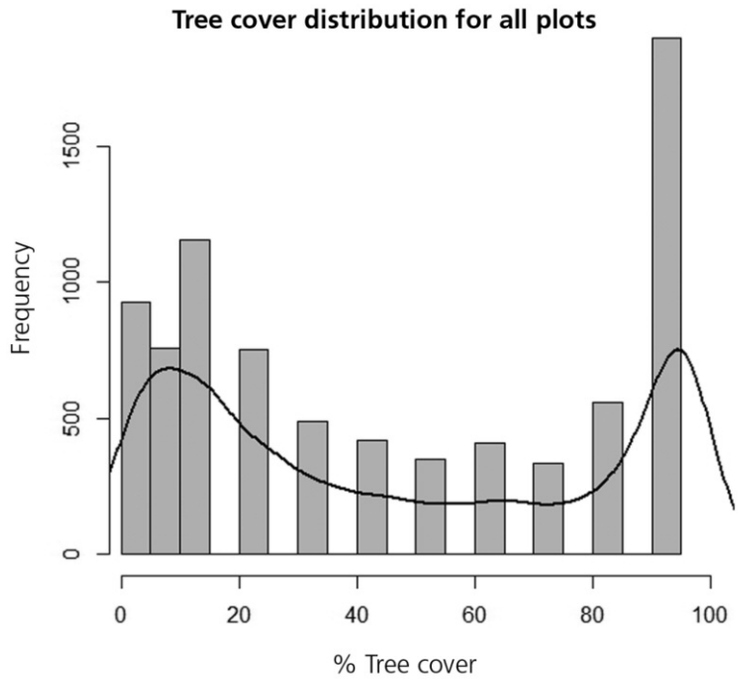

Figure 5:
Histogram and adjusted density line distribution of plots with tree cover higher than 0% in the Mediterranean region. *Source: own elaboration.*

The HFP map was calculated for the years 1993 and 2009. When the difference between these two years is computed, the resulting map can be interpreted as a trend that shows the increase or decrease in the HFP for a 16-year time span (Fig.6).

The decrease of the HFP showed areas where there was evidence that human activities have diminished over a long period of time. To test this idea and see whether there was an effect on tree cover, GDA data was used. The analysis demonstrated that tree cover is higher in areas where the HFP decreased and differs largely and significantly from areas where the HFP index increased, which could indicate favoring conditions for vegetation recovery when human activities are abandoned (Fig. 7).

Using GDA data and the recent land use map GLOBCOVER 2009, characteristics about land use and tree cover were validated

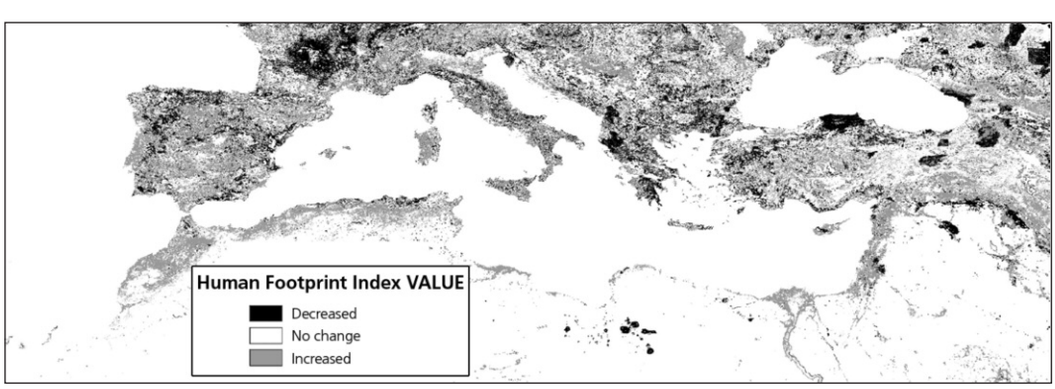

Figure 6:
Map showing the change in the HFP index throughout the years 1993-2009 in the Mediterranean region. *Source: Adapted from Venter et al. (2016).*

between both datasets. GLOBCOVER 2009 provides land use information as well as vegetation coverage and follows the UN land cover classification system (LCCS) (ARINO *et al* 2012). Land use was given a score as more or less suitable for forest restoration. For example, closed forests (broadleaved or needle leaved forests with a coverage >40% and with a canopy >5 m) or settlements (artificial surfaces and associated areas with a coverage > 50%) got the lowest scores, whereas sparse vegetation (sparse trees, sparse herbaceous vegetation or sparse shrubs <15% coverage) or abandoned croplands (rainfed croplands, rainfed shrub crops, rainfed tree crops or rainfed herbaceous crops), were given higher scores.

Additional high scores were given in areas with land use showing a decrease in the HFP index, i.e. showing a positive "recovery" trend, whereas low scores were given in areas where the HFP index increased.

The addition of scores resulted in three categories ranging from priorities 1 to 3, being 1 high priority restoration areas, 2 conditioned restoration areas and 3 no restoration possible:

1. High priority restoration areas: land use showing a decrease in their HFP, little tree cover and offering the conditions to establish forest plantations or reforestations. These lands include rainfed croplands; sparse trees, sparse herbaceous vegetation or sparse shrubs <15% coverage and mosaics of grassland and shrubland ranging from 20 to 70% coverage. These lands are situated mostly in flat and accessible areas, which would also facilitate restoration works.

2. Low priority restoration areas: These areas are targeted over lands that already show some tree cover and where the HFP decreased. These are composed mainly of open woodlands; closed to open mixed coniferous and broadleaved forest with tree cover about 15% or higher and hence a local control of accessibility and vegetation structure conditions its suitability for restoration.

3. No restoration: Areas which did not decrease their HFP and not suitable for restoration such as settlements or closed forests.

In summary, adding priorities 1 and 2, up to 80,054,780 ha could be potentially restored at the regional level. This accounts for 40.2% of the Mediterranean region as defined by FAO GEZ (Fig. 8).

Ideas on how these areas could be restored in the short to mid-term could be obtained from a survey of ongoing initiatives, projects or environmental policies at the country level. In addition, recent forest fires or other natural disasters must be prioritized as the first targets in these areas.

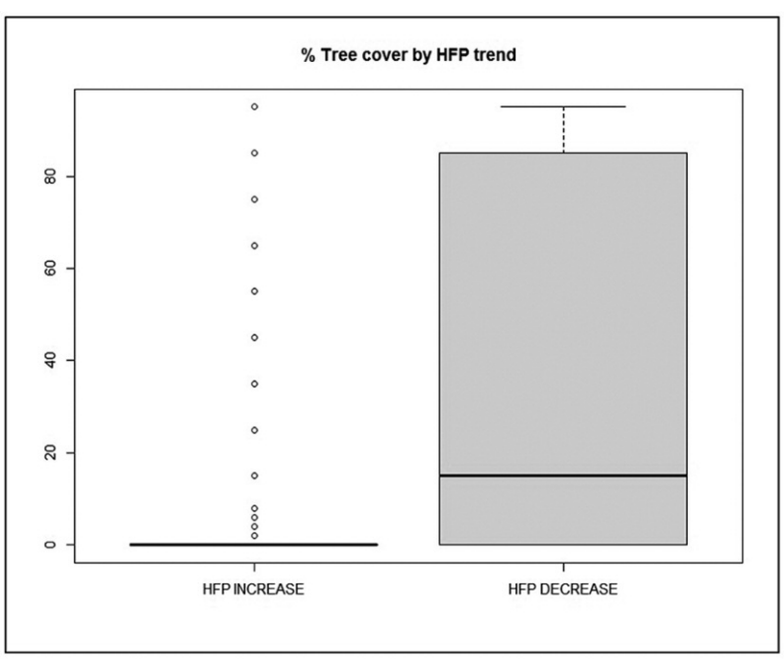

Figure 7: Boxplot showing the distribution of tree cover in areas that increased or decreased their Human Footprint index (HFP). *Source: own elaboration.*

Conclusions

The innovative work developed by FAO using open data, free software and cloud computing offer new perspectives for the management of forests and natural resources. The collaborative work developed between different institutions produced high-quality results at a large scale level. Although GDA data are still being cleaned and complemented with additional data collection, they demonstrated an extraordinary power for regional analyses as the one presented here.

The use of FAO tools has shown to be very valuable to describe the current state of forest lands and their changes, the high diversity of ecosystems as well as the importance and presence of trees in the Mediterranean region. The estimates of potential forest restoration areas using GDA data and other land cover maps, account for up to 40% of the Mediterranean region and show higher estimates than previous restoration maps (WRI, 2017) because we include new areas in the

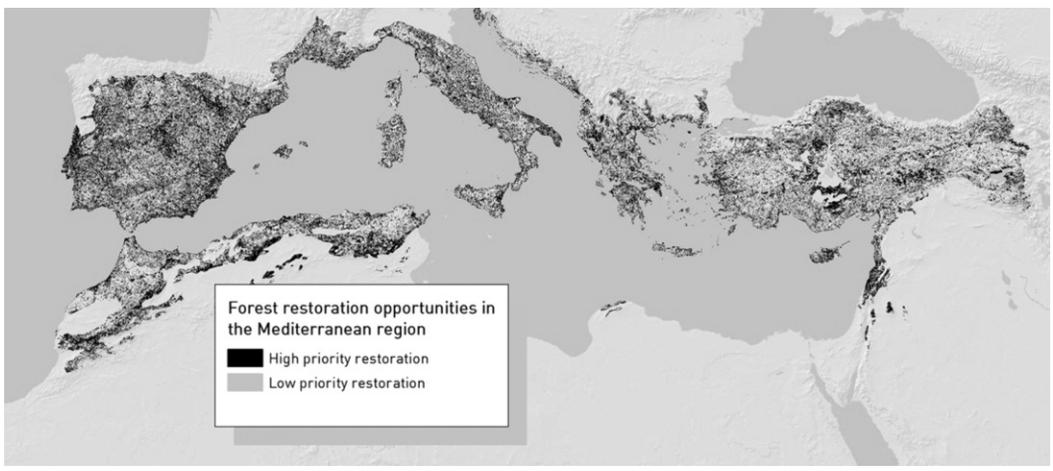

Figure 8:
Map showing areas for potential restoration in the Mediterranean region. 1. High priority restoration (black), 2. Low priority restoration (gray) and 3. No restoration (not shown).
Source: own elaboration.

eastern part of the Mediterranean region (i.e. Turkey).

Finally, FAO tools could be implemented on a periodical basis to assess forest restoration monitoring worldwide and also at regional levels.

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Summary

The Global Drylands Assessment (GDA), developed by the Food and Agriculture Organization of the United Nations (FAO), represents a collaborative work between institutions that has increased our knowledge of tree cover and forests with a level of detail higher than previously achieved with remote sensing techniques. The estimates show up to 47% of forest in the world's drylands never reported before. Here, we analyze some of the features of forests and trees in the drylands of the Mediterranean region and explore opportunities for forest restoration using the GDA dataset. Drylands in the Mediterranean region account for 147 million ha. The GDA surveyed 6,492 plots of 0.5 ha in this region and forest land was detected in 16% of the plots. The data also confirmed the importance of tree presence in human environments outside forests with values of 29% of tree cover in croplands or up to 58% in settlements. Using GDA data and other land use maps, the extent of areas for potential forest restoration were calculated, accounting for 80 million ha which accounts for 40% of the Mediterranean region. These results highlight the importance of FAO developed tools and the need for their implementation in forest monitoring and restoration.

Résumé

L'évaluation globale des zones arides (GDA) développée par l'Organisation des Nations-Unies pour l'Agriculture (FAO) représente un travail collaboratif entre institutions qui a amélioré notre connaissance sur la couverture arborée et sur les forêts à un niveau de détails supérieur à celui atteint précédemment avec des techniques de télédétection. L'estimation porte sur 47% des forêts des zones arides jamais recensées auparavant. Ici nous analysons quelques unes des caractéristiques des forêts et des arbres dans les zones arides de la région méditerranéenne et examinons les opportunités pour la restauration forestière de l'ensemble de données GDA. Les zones arides de la région méditerranéenne s'élèvent à 147 millions d'hectares. GDA a inventorié 6 492 placeaux de 0,5 ha dans cette région et la forêt est présente dans 16% des placeaux. Les données ont aussi confirmé l'importance de la présence d'arbres dans les environnements humains hors forêt, avec des valeurs de 29% de couvert arboré dans les cultures et de 58% dans les zones habitées. En utilisant les données du GDA et d'autres cartes d'utilisation des sols, l'extension des zones de restauration forestière potentielle a été calculée, s'élevant à 80 millions d'hectares représentant 40% de la région méditerranéenne. Ces résultats font ressortir l'importance des outils développés par la FAO et le besoin de leur mise en œuvre dans le contrôle et la restauration des forêts.

Resumen

La Evaluación Global de las Tierras Áridas (GDA), desarrollada por la Organización de las Naciones Unidas para la Agricultura y la Alimentación (FAO), representa un trabajo colaborativo entre instituciones que ha aumentado nuestro conocimiento de la cubierta arbórea y de los bosques con el nivel de detalle más alto nunca alcanzado anteriormente con técnicas de teledetección. Las estimaciones muestran hasta un 47% más de bosque en las tierras áridas del mundo no detectadas anteriormente. Aquí, analizamos algunas de las características de los bosques y árboles de las tierras áridas de la región mediterránea y exploramos las oportunidades para la restauración forestal utilizando la base de datos de la GDA. Las tierras áridas de la región mediterránea suponen 147 millones de hectáreas. La GDA analizó 6.492 parcelas de 0,5 ha en esta región y detectó uso de la tierra forestal en el 16% de las parcelas. Los datos también confirmaron la importancia de la presencia de árboles en ambientes humanos fuera de los bosques con valores de 29% de cobertura arbórea en cultivos o de hasta el 58% en asentamientos. Utilizando los datos de la GDA y otros mapas de uso del suelo, Se calculó la extensión de las áreas de posible restauración forestal, que representan 80 millones de hectáreas, lo que supone hasta un 40% de la región mediterránea. Estos resultados ponen de relieve la importancia de las herramientas desarrolladas por la FAO y la necesidad de su empleo en el monitoreo y la restauración de bosques.