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Ecosystem goods and services as affected by shrub encroachment

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INTRODUCTION

- Shrub encroachment is a global phenomenon characterized by an increase in the density, cover and biomass of generally indigenous, woody or shrubby plants in grasslands biomes *(van Auken 2000; Archer,Boutton & Hibbard 2001).*

- Other synonymous are: thicketization *(Lechmere- Oertel et al. 2005)*, woody weed invasion *(Ayres et al 2001)*, xerification (Archer et al. 2001), shrub invasion *(Noble 1997)* and bush encroachment *(Meik et al. 2002*

INTRODUCTION

- It has been reported in arid, semi-arid, mesic, alpine and arctic areas worldwide.

- The shift from grass to woody domination has important impacts on ecosystem structure, microclimate, and key ecosystem processes such as productivity, hydrology and soil function *(Archer, 2009)*.

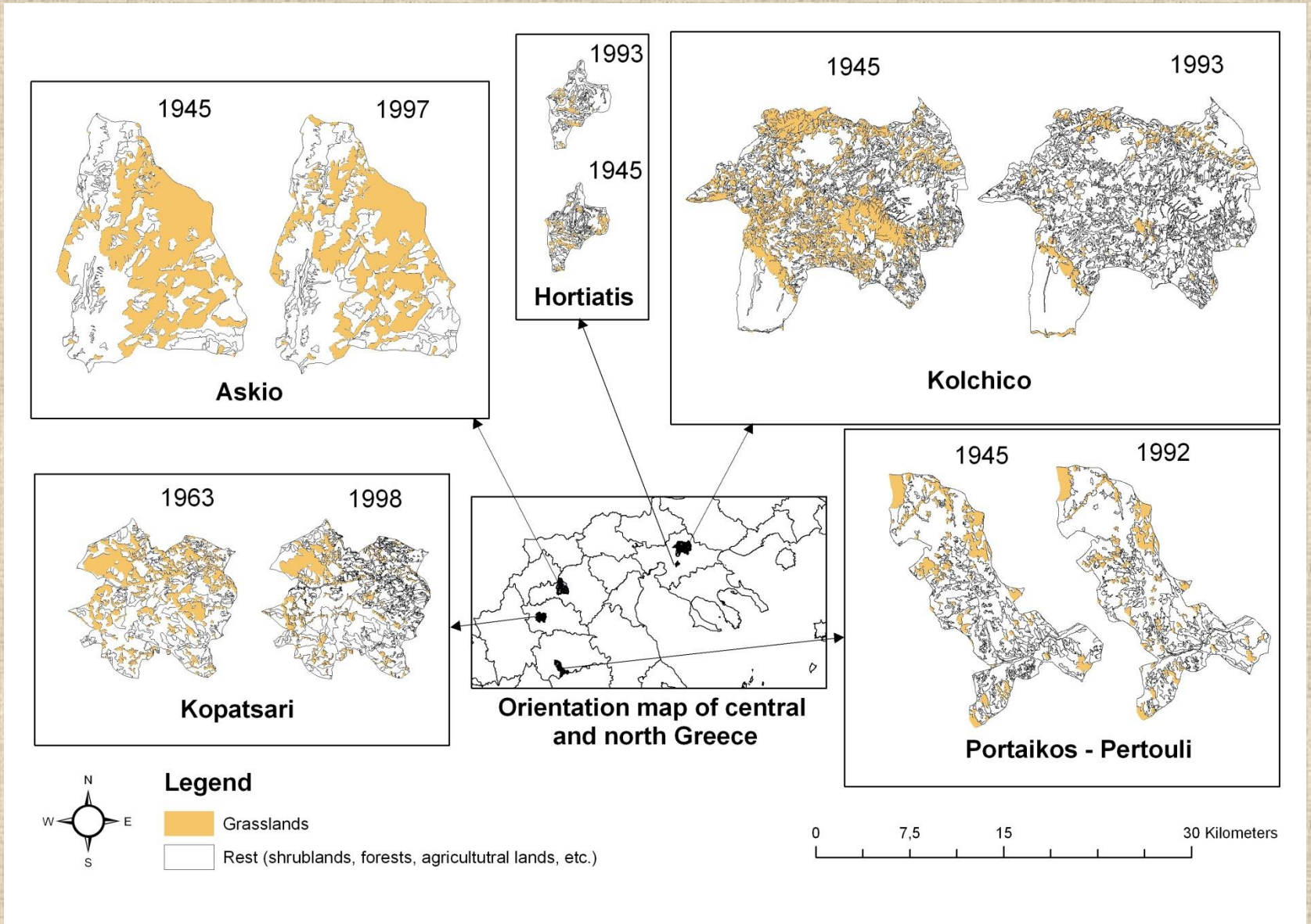
INTRODUCTION

Potential causes of increased woody plant abundance include:

- combination in climatic changes
- reduced fire frequency,
- rising atmospheric CO_2 concentrations
- other alterations in local land management practices (grazing abandonment) and
- increased grazing intensity

INTRODUCTION

- Particularly this phenomenon has been studied in arid and semi-arid ecosystems throughout the world, where the transitions between grasslands and shrublands occurring during the last 150 years have been dramatic *(van Auken 2000)* and it affects the composition and diversity of plants and other organisms, and influences multiple ecosystem functions and services *(van Auken 2000; Eldridge et al. 2011).*



Chouvardas et al., 2012

Diachronic evolution of shrublands (Ha) in Kolchiko, Hortaitis, Askio and Portaikos-Pertouli pastoral landscapes of Greece

Open shrubland		Medium shrubland		Dense shrubland	
1945	1992-1997	1945	1992-1997	1945	1992-1997
4215,30	3158,93	2959,70	4443,24	1290,59	2504,70

Difference (%)

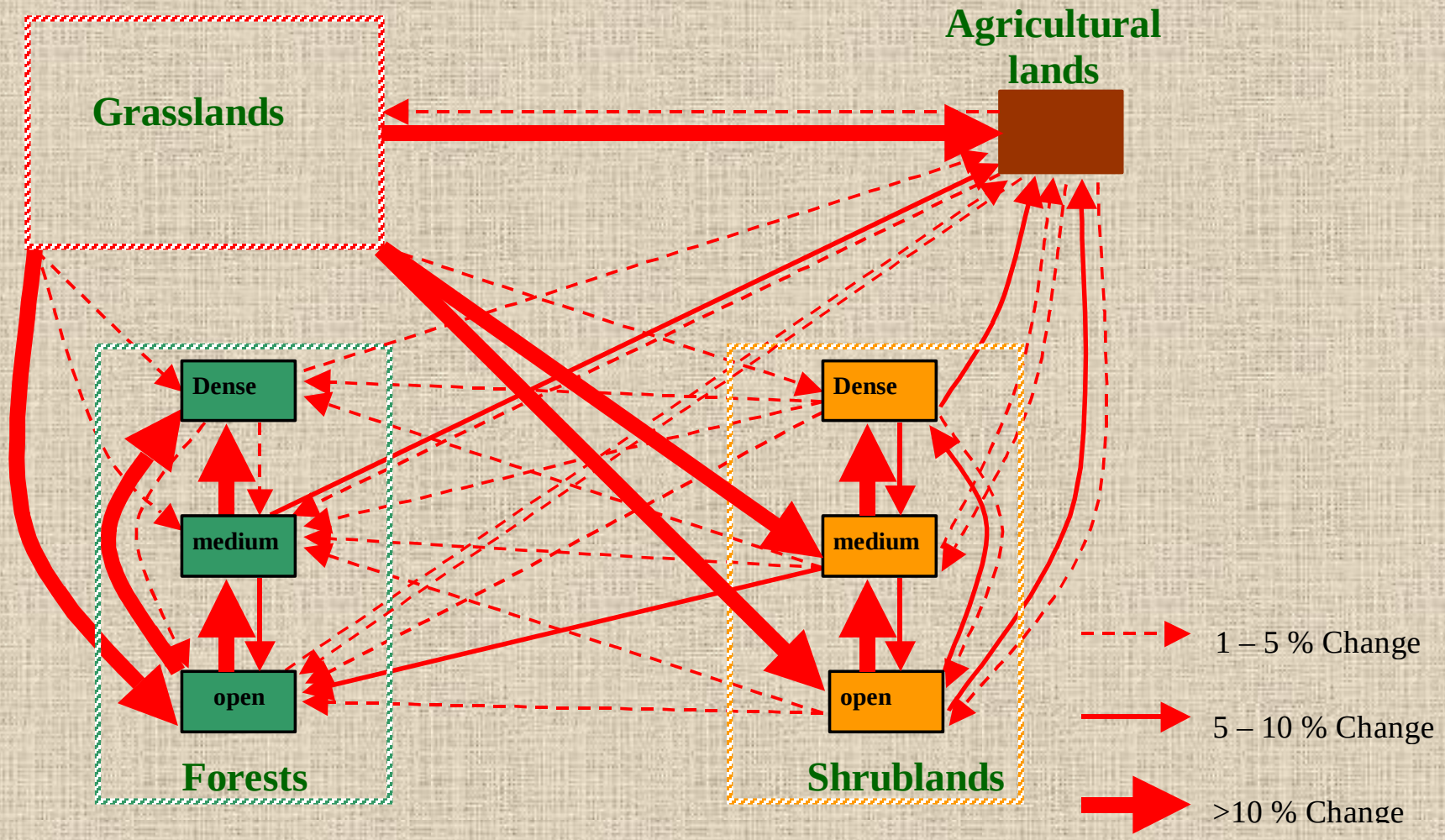
Open Shrubland	Medium Shrubland	Dense Shrubland
1945-1997	1945-1997	1945-1997
-25,06	**50,12**	**94,07**

Chouvardas et al., 2012

Results

Kolchiko Site

Changes of land cover/use types between 1945 and 1993



Chouvardas et al., 2012

INTRODUCTION

Symptoms that are often attributed to the shrub encroachment phenomenon include:

- declines in grass cover and biomass,
- reduced pastoral productivity,
- altered habitat value,
- spatial distribution of soil nutrients, and levels of soil function such as respiration, decomposition, infiltration and soil water redistribution
- Increase fire risk

(Archer, Boutton & Hibbard 2001; Bhark & Small 2003; Schlesing-er, Tartowski & Schmidt 2006).

INTRODUCTION

- All of these changes are thought to lead to ecosystem degradation and desertification *(Schlesinger, Tartowski & Schmidt 2006)*
- The Millennium Ecosystem Assessment Desertification Synthesis refers to shrub encroachment as the major ecological expression of desertification in arid and semi-arid rangelands *(Millennium Ecosystem Assessment 2005).*

INTRODUCTION

Reports about shrub encroachment effects are varied ranging from positive to negative or neutral *(Eldridge et al. 2011)*

- The differences in effects of shrub encroachment identified at individual plant and landscape levels may be due to differences in:

(i) the degree of woody encroachment, i.e. the percentage of the landscape that is encroached *(Breshears 2006; Riginos et al. 2009).*

(ii) the specific features of the encroacher species *(Soliveres and Eldridge 2014)*

(iii) prevailing environmental conditions, e.g. differences in available moisture, soil texture or grazing intensity among studies *(Knapp et al. 2008; Eldridge et al. 2013).*

- The aim of the present work was to review the reports about the effects of shrub encroachment on ecosystem services.

Ecosystem services

"the benefits people obtain from ecosystems" *(Millennium Ecosystem Assessment, 2005)*

Ecosystem services are increasingly promoted as a means for documenting the values humans place on ecosystems and evaluating benefits derived from natural resources *(Millennium Ecosystem Assessment, 2005)*

Source: www.metrovancouver.org

Supporting services

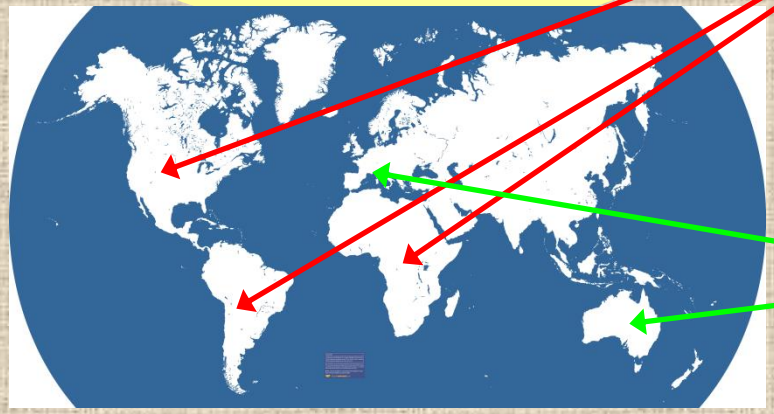
1. Biodiversity and habitat value

- Shrub encroachment affect plant community composition and species richness.

Is this effect positive, negative or neutral ?

Encroachment had no net effect on species richness globally

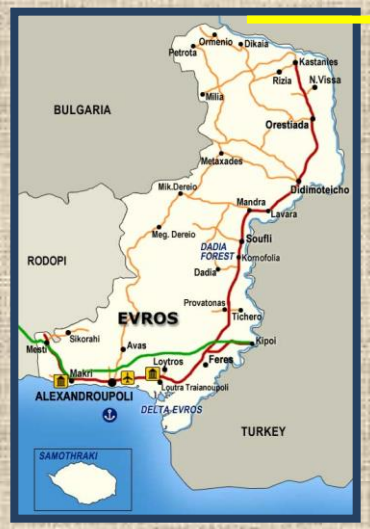
Negative (*Ratajzak et al. 2012)*



Positive or neutral *(Eldridge et al 2011)*

Study case in Greece

- **Altitude:** 380 m
- **Mean air temperature:** 13.7º C
- **Mean annual rainfall:** 560 mm
- **Vegetation:** grasslands with some woody species (*Juniperus oxycedrus* subsp. *oxycedrus* and *Cistus incanus* subsp. *creticus*)
- **Experimental areas with different shrub cover regimes:**



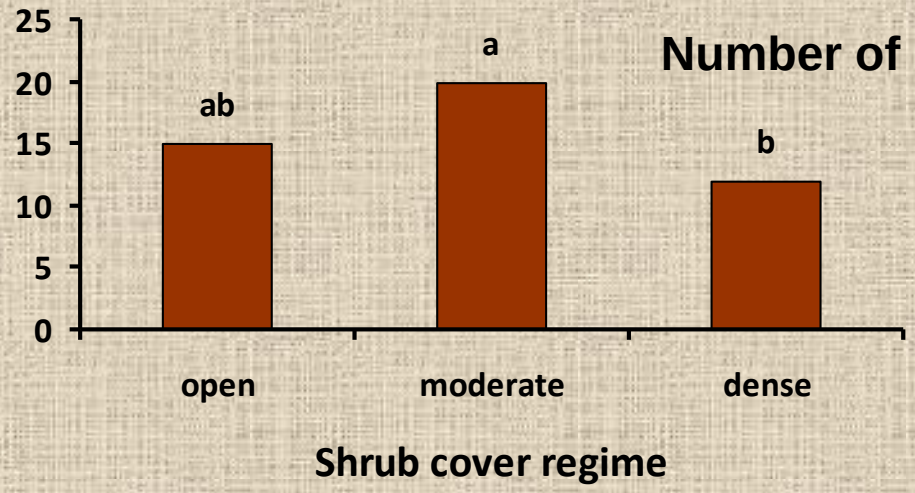
Megalo Dereio

i) open shrub cover (10%)

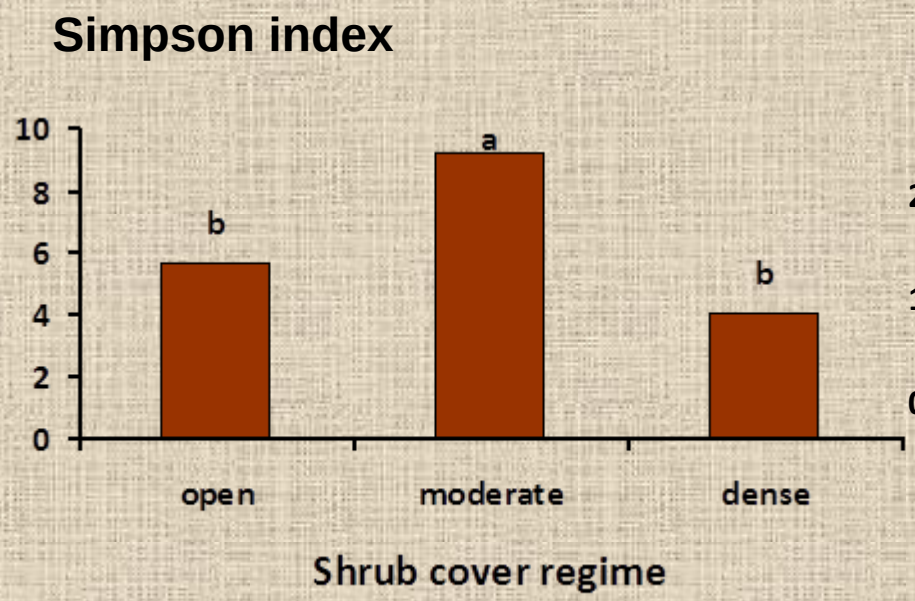
ii) moderate shrub cover (25%)

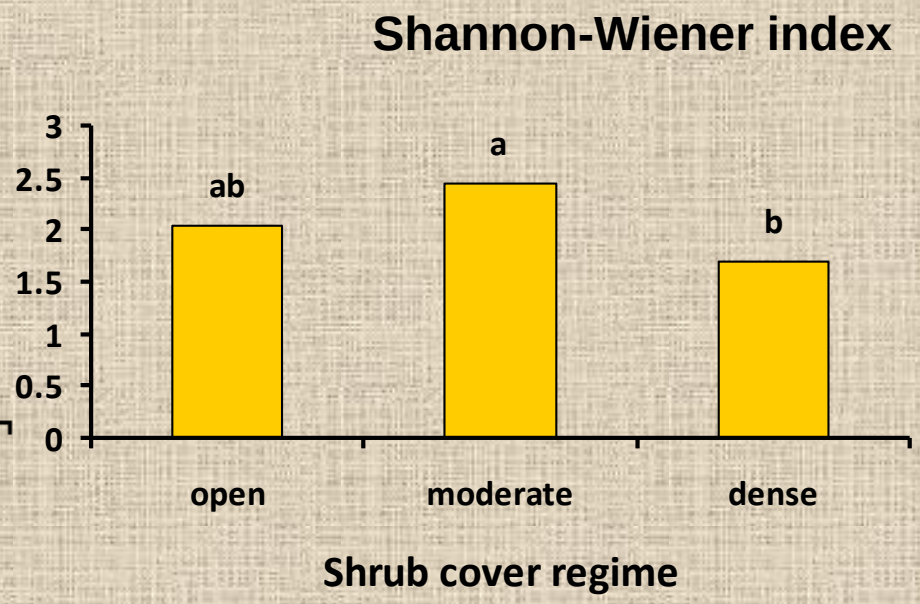
iii) dense shrub cover (50%)

Study case in Greece



The moderate juniper cover regime enhanced floristic diversity, but at the dense juniper cover regime biodiversity was reduced.

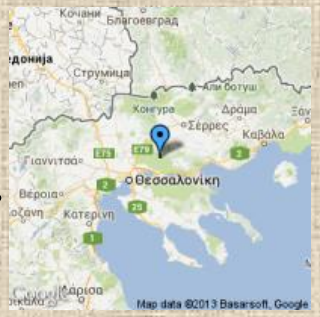




Kyriazopoulos et al., 2012

Study case in Greece

An area with semi-arid Mediterranean environment in Lagadas county, N. Greece. *(Papadimitriou et al. 2004)*



Compositional and functional diversity was studied: 1) abandoned arable field, 2) grassland, 3) open shrubland and 4) dense shrubland.

Grassland was the richest and the shrubland the poorest land use type in terms of number of species

Grasses and legumes were the most persistent groups while forbs and sub-shrubs the most sensitive ones along the land use types

Annual species and therophytes were decreased while perennials and hemicryptophytes were increased as the succession proceeded from the abandoned field to the dense shrubland

The different effect could be result of region-specific variation in:

Environmental conditions
Soil, climate

Disturbance,
Grazing, fire

Intensity of anthropogenic impacts

Key role:
Shrub density < 50% positive effect

Positive effect

Shrubs: act as nurse plants,
- ✓ improve microclimate
- ✓ increase diversity, biomass & stability of neighboring species

Competition with herbaceous species

Negative effect

1. Biodiversity and habitat value

Shrub encroachment also affect fauna

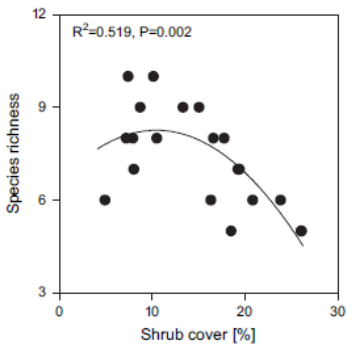


Fig. 2 – Effects of shrub encroachment on species richness of 10 small carnivore species in 20 southern Kalahari rangelands.

Overgrazed African Savanna: shrub cover ⟩20% reduced the species richness of small carnivores *(Blaum et al. 2007)*

Overgrazed African Savanna: shrub cover ⟩40% reduced the species richness of birds *(Simari et al. 2009)*

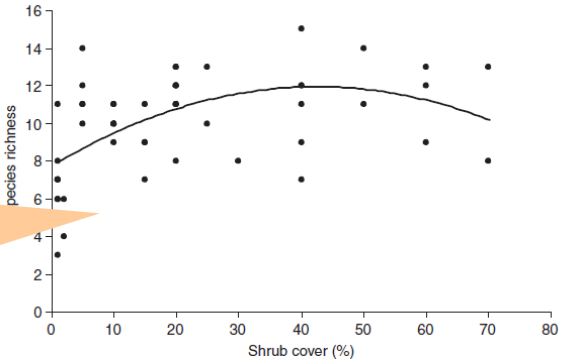


Figure 2 Species richness along the gradient of shrub encroachment. Symbols show observed species richness in the 50 plots plotted against the shrub cover (%). Line shows modelled species richness using equation in Table 2.

Supporting services

2. Soil function and properties

Australia :Positive effect on soil infiltration, stability and nutrient indices, SC(<50%) *(Eldridge et al 2013, Howard et al 2012)*

Grazing reduced it *(Eldridge et al 2013)* or did not affect it *(Howard et al 2012)*

America: Negative effect on soil moisture *(Darrouzet-Nardi et al. 2006)*, infiltration *(Parizak et al. 2002)* and nutrients *(Schlesinger et al. 1999)*

Mediterranean: Positive effect on biomass of fungi, actinomycetes, soil fertility and N mineralization rates *(Maestre et al 2009)*, activity of soil enzymes SC (26%)*(Maestre et al. 2011)*

Supporting services

3. Primary production

Herbaceous above-ground biomass and net productivity (ANPP) decreases in Mediterranean areas *(Karakosta and Papanastasis, 2007)*, but this may be balanced by shrub productivity, resulting in no change in ANPP, or in an increase in ANPP *(Reich et al., 2001; Huenneke et al., 2002; House et al., 2003).*

Cistus ladanifer, a pioneer species that colonises degraded areas and
forms one of the first stages of succession of woody communities contributed in increase of shrub ANPP .

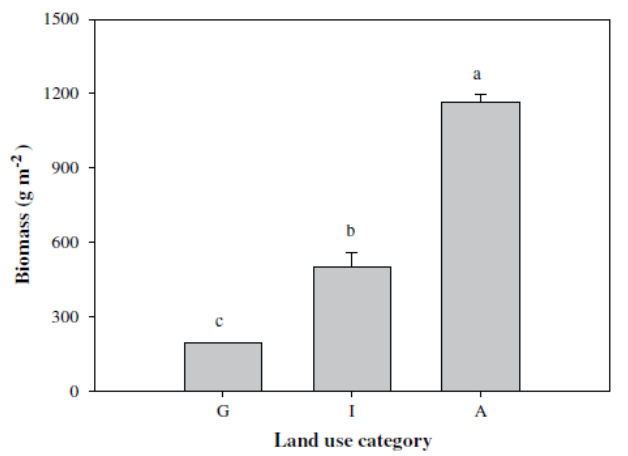


Fig. 1. Above-ground biomass in grazing (G) and intermediate (I) and advanced (A) succession land use categories ($F = 115.07$, $p < 0.0001$, $n = 9$). Values in intermediate succession represent the sum of plant biomass in the herbaceous and shrubs layers.

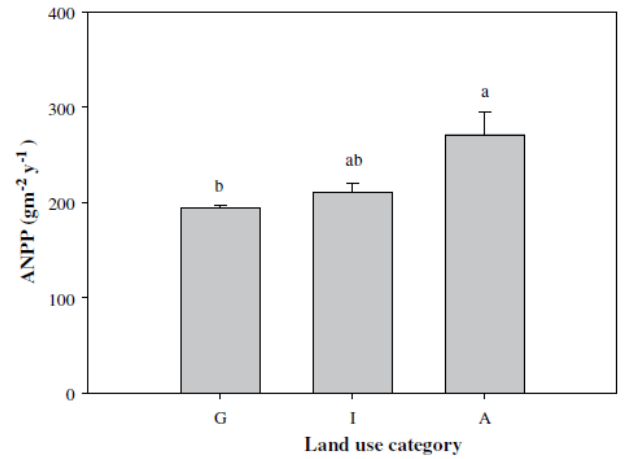


Fig. 2. Above-ground net primary productivity (ANPP) in grazing (G), intermediate (I), and advanced (A) succession land use categories ($F = 6.95$, $p < 0.05$, $n = 9$). Values in intermediate succession represent the sum of plant biomass in the herbaceous and shrub layers.

Castro and Freitas, 2009

Supporting services

3. Primary production

Shrub encroachment decreased ANPP in xeric sites but dramatically increased ANPP at sites with high mean annual precipitation, where shrub patches maintained extraordinarily high leaf area *(Knapp et al., 2008)*

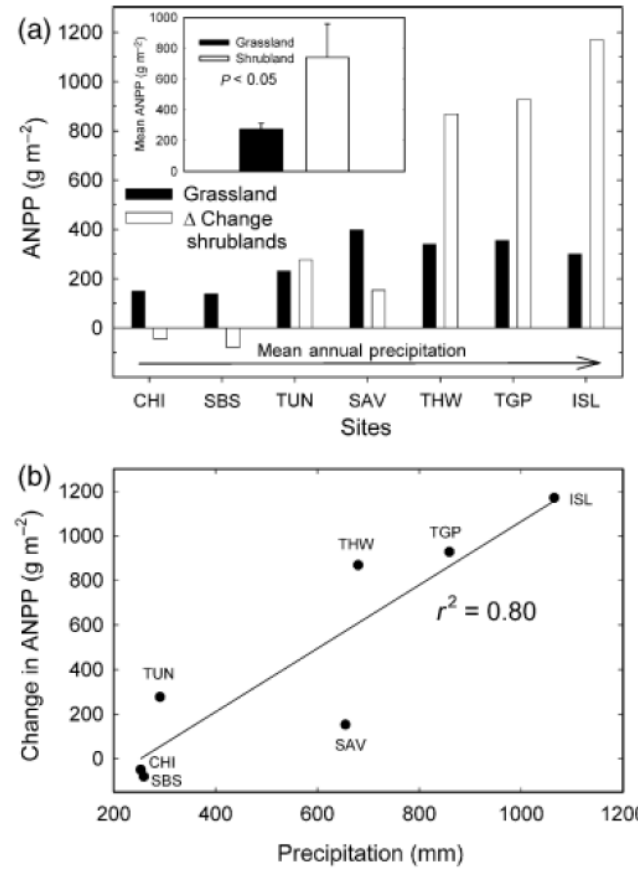


Fig. 1 (a) Patterns of aboveground net primary productio (ANPP) in grasslands (black bars) and former grassland site now dominated by shrubs (open bars) for each of the study site (Table 1). Sites along the *x*-axis are ordered by increasing mea annual precipitation (MAP) and the largest responses in ANP to shrub conversion occur in the most mesic sites. Inset: mea increase in ANPP over all sites with shrub encroachment int grasslands ($t = -2.42$, df = 6, $P = 0.05$). (b) The relationship be tween MAP and the change in ANPP for seven sites across Nort America where grassland has been converted to shrubland. Soli line indicates a significant positive relationship between MA and the change in ANPP ($F = 20.5$, df = 6, $P = 0.006$). See Table for three-letter site codes.

Knapp et al., 2008

Provisioning services

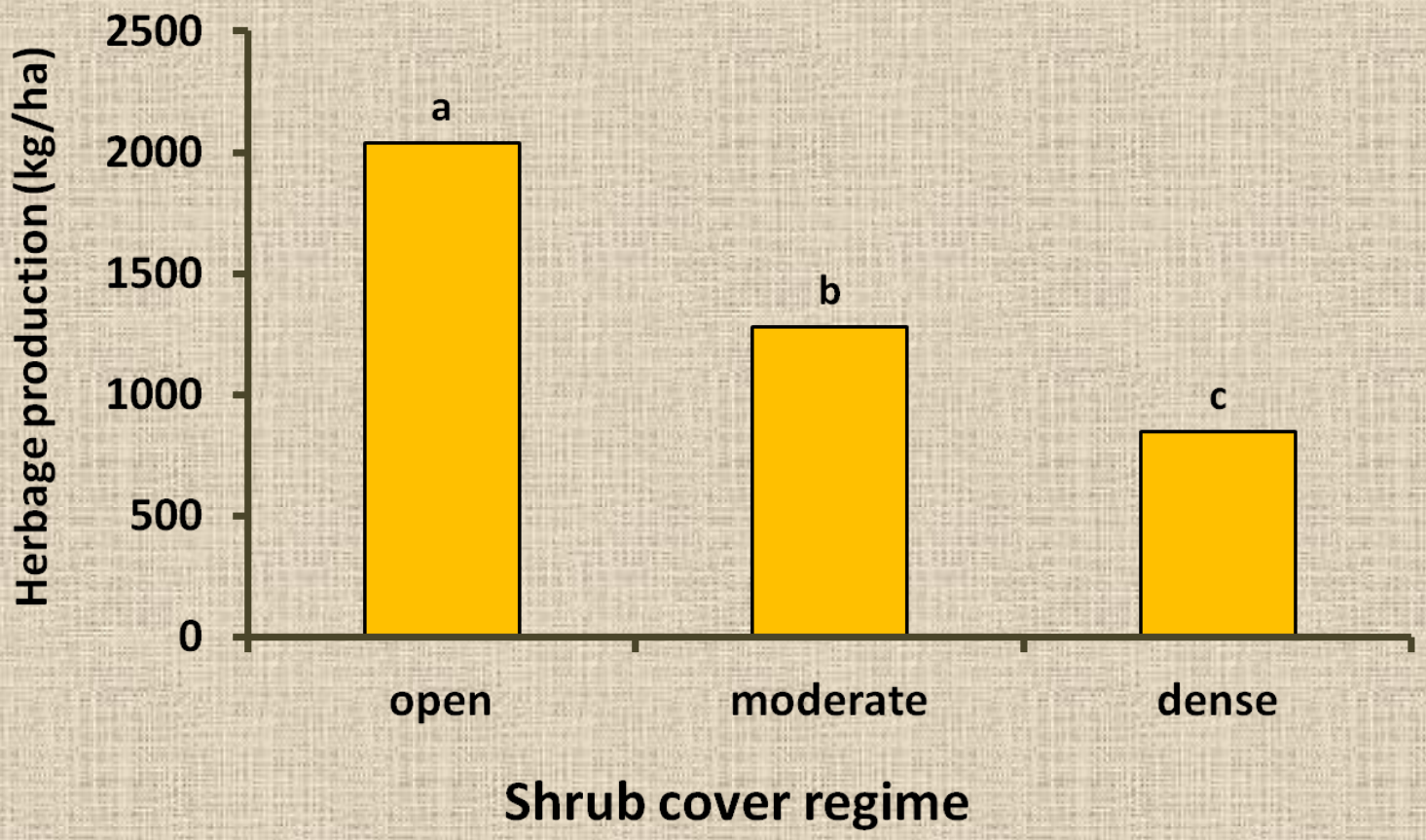
- Forage Production and Quality

Shrub encroachment:

- ✓ The suppression of grasses and other herbaceous species
- ✓ The dominance of unpalatable species even to browsers
- ✓ The reduction of carrying capacity for livestock
- ✓ Nutritive value may reduced, but there are contrasting results (Kesting et al., 2009)

Study case in Evros, Greece

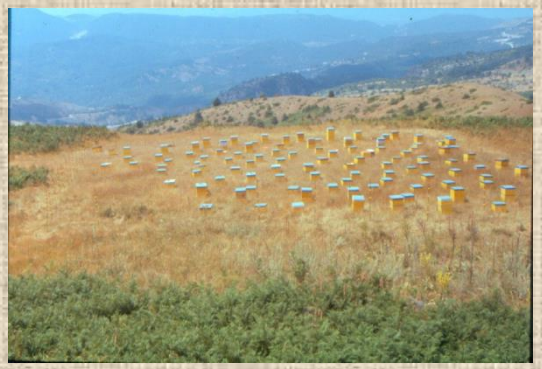
Herbage production for the three shrub cover regimes



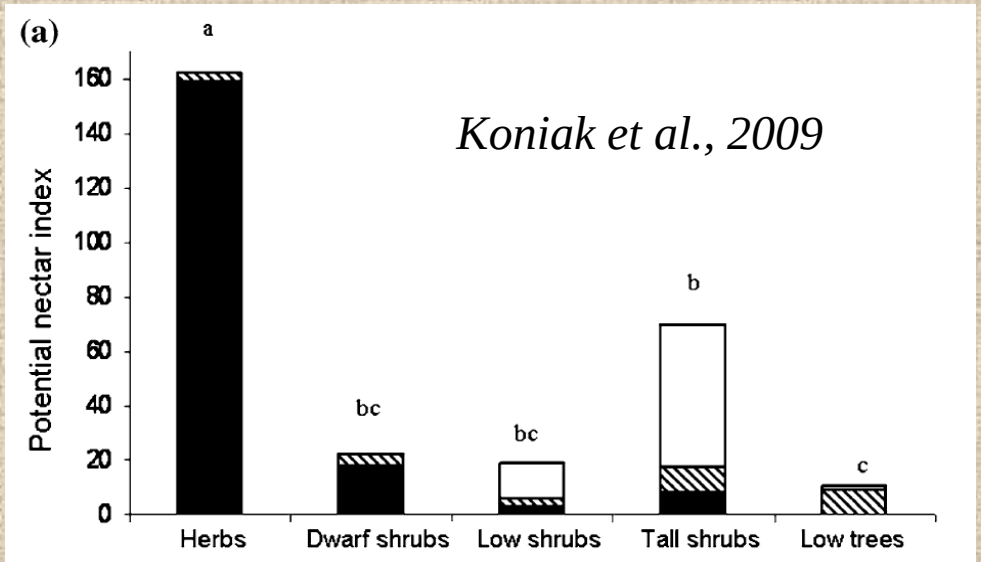
Kyriazopoulos et al., 2012

Provisioning services

- Honey Production



Honey flowers had their highest values in patches dominated by herbaceous plants with medium or low values in patches of woody vegetation with a positive impact on honey production



Vulliamy et al. (2006) concluded: "*the best management to maintain the diversity and abundance of bees and flowers in phrygana would be to allow a moderate level of grazing, which would preserve the mosaic structure of shrubland and open patches*".

Provisioning services

- Fleshy fruits Production

Fleshy fruits energy is contributed mainly by patches dominated by woody vegetation. However, this result is species dependent.

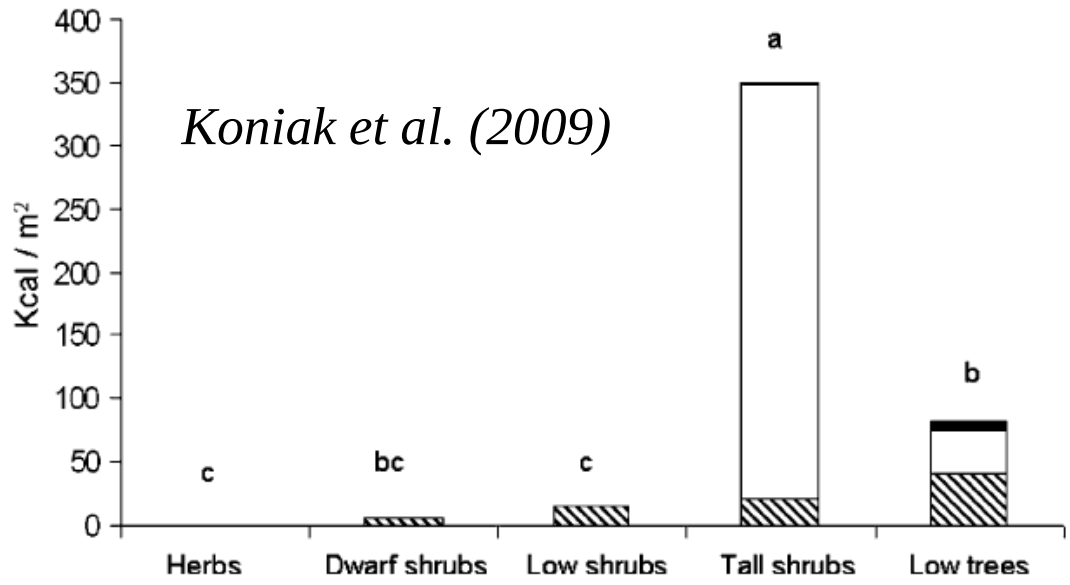


Fig. 5 Means of total fruits energy density (cal per m^2) by dominant PFTs, subdivided by growth forms: *white*—woody plants, striped—climbers, *black*—geophytes. Different *letters* indicate significantly different values ($P < 0.005$)

Regulating services

- Carbon sequestration

Woody encroachment is likely to cause substantial alterations in the sequestration and cycling of carbon (Briggs et al., 2005; Hughes et al., 2006) as grasslands generally have moderate capacity for carbon sequestration in biomass in comparison to woody communities (Gill and Burke, 1999). Thus, increases in above-ground carbon storage have been reported by some authors (Asner et al., 2003; Hughes et al., 2006).

However, Bai et al. (2009) reported no differences in SOC among woody, ecotone and grassland communities. They related the lack of correspondence between aboveground phytomass and SOC to the poor quality and slow decomposition rate of shrub litter, and they conclude that soil texture plays a role in the C budget by regulating C efflux from soil.

Table 3
Soil organic carbon ($kg\,m^{-2}$) in grassland, ecotone, and western snowberry shrub communities in central and southern Saskatchewan, Canada.

Community/soil texture	Soil depth (cm)						
	0–50	0–3	3–10	10–20	20–30	30–40	40–50
Snowberry	8.3 a (0.7)	5.7 a (1.26)	2.8 a (0.55)	1.6 a (0.25)	0.9 a (0.14)	0.7 a (0.17)	0.5 a (0.14)
Ecotone	7.9 a (1.0)	6.3 a (1.10)	2.7 a (0.49)	1.5 a (0.31)	0.9 a (0.20)	0.7 a (0.12)	0.5 a (0.09)
Grassland	7.9 a (0.7)	6.7 a (1.28)	3.0 a (0.62)	1.7 a (0.35)	1.2 a (0.28)	0.8 a (0.19)	0.6 a (0.15)
Coarse	6.2 b (0.4)	4.2 b (0.52)	1.8 b (0.21)	1.1 a (0.11)	0.6 b (0.05)	0.4 b (0.03)	0.3 b (0.03)
Fine	10.4 a (0.6)	8.8 a (0.97)	4.1 a (0.39)	2.2 a (0.26)	1.4 a (0.20)	1.2 a (0.11)	0.9 a (0.10)

Means within soil depth and plant community or soil depth and soil texture class followed by the same letters are not significantly different ($P > 0.05$).
Plant community values are means and SE (in parentheses) of nine study sites and soil texture values are means of five coarse-textured soils or four fine-textured soils.

Bai et al., 2009

Regulating services

- Soil erosion

Soil erosion has been reported to be increased with shrub encroachment in many studies *(Parizek et al., 2002; Baez & Collins 2008, Manjoro et al., 2012)*. This trend is related to the spatial patterning of woody shrub vegetation that increases bare soil patches, fact that leads to runoff connectivity and concentration of overland flow.

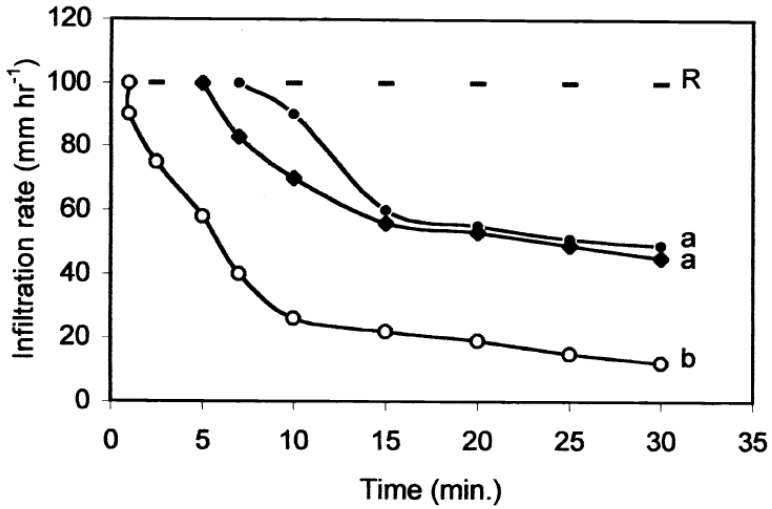


Fig. 2. Average infiltration rate across the 30 minute simulated rainfall for the soils of the shrub-grass (●), grass (◆), and shrub (○) steppes at Punta Ninfas range site, Patagonia. R is applied rainfall intensity. Plant community means with the same letter are not significantly different (P ≥ 0.05).

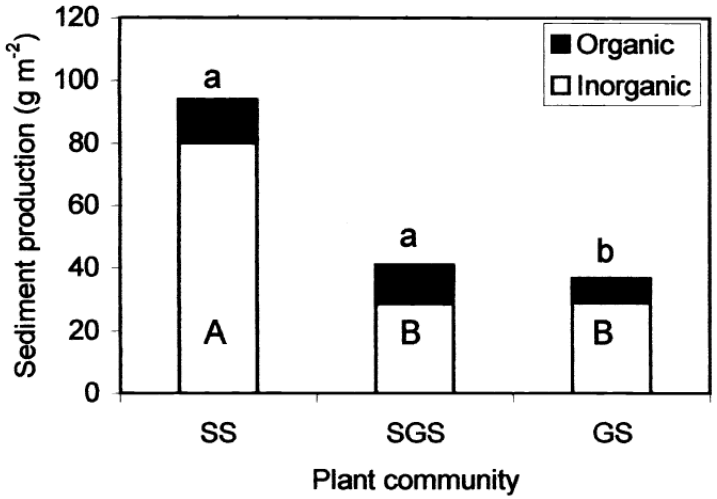


Fig. 3. Inorganic and organic sediment production for the shrub, shrub-grass, and grass steppes at the Punta Ninfas range site, Patagonia. Plant community means with the same lowercase and uppercase letters are not significantly different (P ≥ 0.05) for the organic and inorganic sediment production, respectively.

Parizek et al., 2002

Regulating services

- Soil erosion

Other studies however, have shown that shrub encroachment can reduce erosion and nutrient loss *(Maestre et al. 2009)*.

Response variable	Type	Number of cases				*P*-value	Trend
		Increasing	Declining	Unchanged	Total		
Plant tissue N	Functional	2	0	0	2	1	no change
Soil erosion	Functional	2	2	1	5	1	no change
Soil infiltration index [a]	Functional	1	2	27	30	1	no change
Soil nutrient index [a]	Functional	2	2	26	30	1	no change
Total soil S	Functional	3	2	9	14	1	no change
Tree richness	Structural	0	0	9	9	1	no change

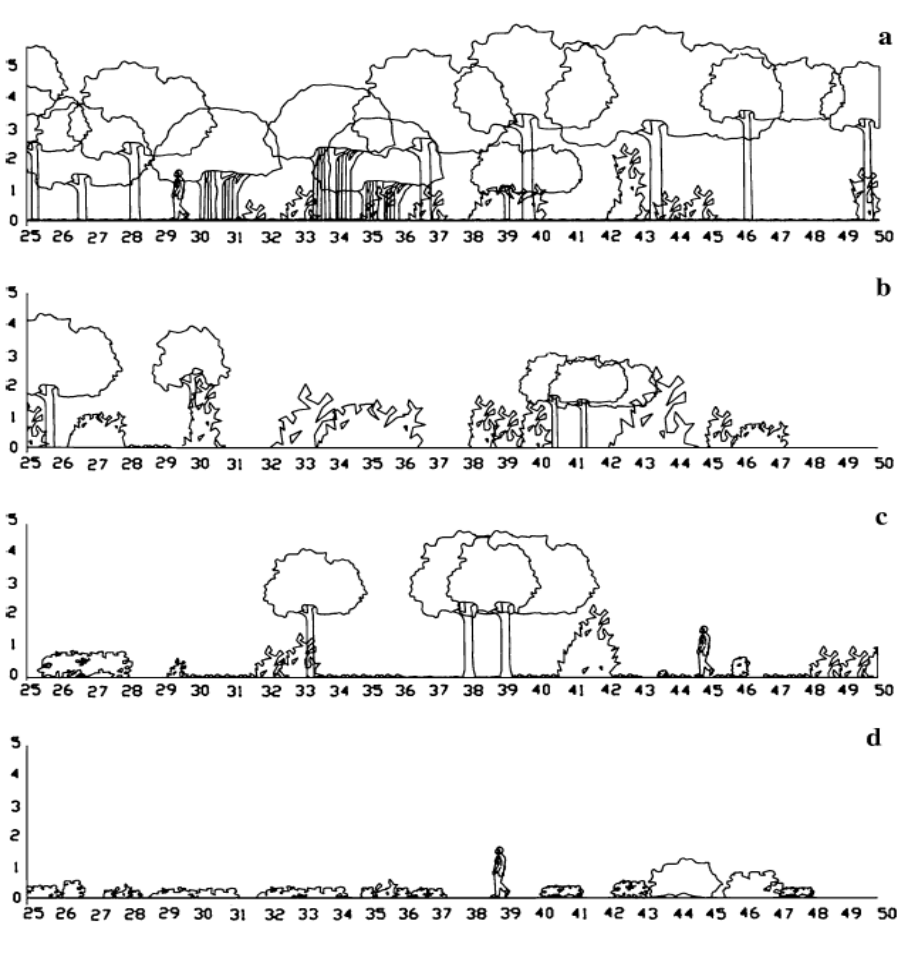
Eldridge et al., 2011

Cultural services

Limited knowledge is available

A complex, mixed, open landscape was preferred by more than 80% of the local population in Israel. Thus, an open, patchy landscape has greater amenity value than the dense Mediterranean woodland or shrubland *(Fleischer and Tsur, 2000).*

A mixed landscape with open spaces and scattered trees was preferred in a survey in Israel *(Henkin et al. 2004, 2007)*



Source: Henkin et al., 2007

Questionnaire (1/5)

1) Is shrub encroachment occurs in your country?
2) Please give a short description of the area (e.g. elevation, vegetation, soil, climatic data) that shrub encroachment is present.
3) Which are the dominant shrub species in this area? (Please provide the scientific names)
4) Is shrub encroachment related to climatic changes in your region? Which?
5) Is shrub encroachment related to land use changes in your region? Which?
6) Do you believe that shrub encroachment has some positive impacts on ecosystem services? Please name the most important of them.
7) Do you believe that shrub encroachment has some negative impacts on ecosystem services? Please name the most important of them.
8) What are the restoration practices to combat shrub encroachment, if any, at work in the area you assessed?
9) Are there any mitigation measures, strategies, programmes, agendas particularly targeting threats related to shrub encroachment?

Questionnaire (2/5)

RESPONSES
Israel
Italy
Spain
Portugal
Greece

DESCRIPTION OF THE AREAS
CLIMATE: Mediterranean semi-arid - Mediterranean-Humid
ELEVATION: 0-1000 m
SOIL: various
VEGETATION: Mediterranean evergreen woodlands, shrublands (maquis and phrygana), grasslands, *Eucalyptus* or *Pinus* plantations
GRAZER: sheep, goats, beef cows

DOMINANT SPECIES
Cistus spp.
Sarcopoterium spinosum
Pistacia lentiscus
Quercus coccifera
Juniperus oxycedrus
Genista triacanthus

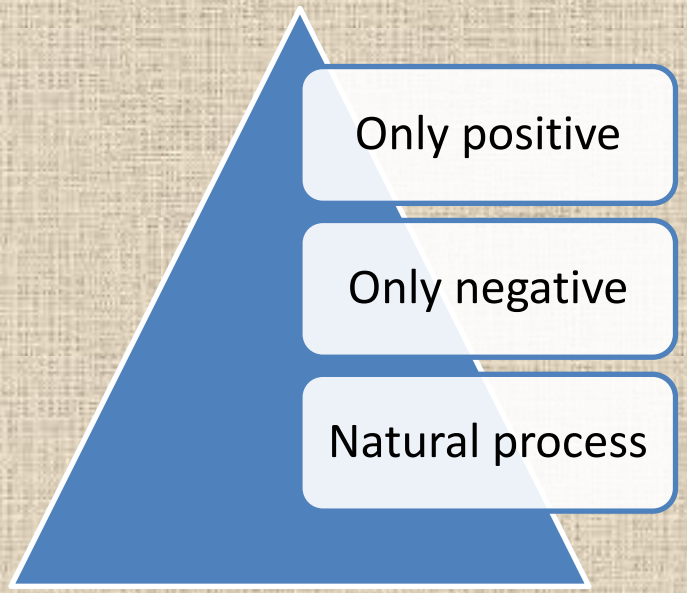
Questionnaire (3/5)

DRIVER – Climate change (Limited, mainly indirect)
Drought favours woody species
Drought increases fires which favours some species

DRIVER – Land use changes (MAIN DRIVER)
Agricultural / Grazing abandonment
Soil degradation / overexploitation of water and nutrients
Wildfire
Afforestation of marginal land
Overgrazing

Questionnaire (4/5)

PRONS
Beneficial for faunistic diversity
Increase biomass production
Protecting soil from erosion
Creating organic matter
Retaining water
Carbon dioxide (CO_2) capture



CONS
Lost pasture
Increase or introduction of unpalatable species for grazing
Reduction of plant biodiversity
Decrease biodiversity and habitats for wildlife
Increase of biomass for fires
Decrease aesthetic value of landscape and potential recreation

Questionnaire (5/5)

COMBAT
No action
Management of grazing
Removal by mechanical means
Selective herbicide application
Controlled burning
Enhancing growth of herbaceous vegetation by fertilizer application

Most of them reported in Israel

MEASURES - STRATEGIES
No formal national measures
Afforestation of marginal lands
Clearing of shrubs at cork harvesting (every 10 years)
Frequent Grazing on anti-fire belt areas

Reported in Southern Portugal

Conclusions

- **Shrub encroachment affects positively or negatively a number of ecosystem services.**
- **This effect is not consistent in all cases and is not net globally.**
- **Environmental factors, shrub species and land uses contributed to the differentiation of this effect.**
- **It is essential to include the degree of encroachment and grazing pressure when studying the effects of shrubs encroachment**

Shrub encroachment ?

What is this ?

Thank you