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
• 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).
Legend

- Grasslands
- Rest (shrublands, forests, agricultural lands, etc.)

Orientation map of central and north Greece

Chouvardas et al., 2012
Diachronic evolution of shrublands (Ha) in Kolchiko, Hortaitis, Askio and Portaikos-Pertouli pastoral landscapes of Greece

<table>
<thead>
<tr>
<th></th>
<th>Open shrubland</th>
<th>Medium shrubland</th>
<th>Dense shrubland</th>
</tr>
</thead>
<tbody>
<tr>
<td>1945</td>
<td>4215,30</td>
<td>1945</td>
<td>1945</td>
</tr>
<tr>
<td>Difference (%): 1945-1997</td>
<td>-25,06</td>
<td>50,12</td>
<td>94,07</td>
</tr>
</tbody>
</table>
Results

Kolchiko Site

Changes of land cover/use types between 1945 and 1993

Grasslands

Forests

Shrublands

Agricultural lands

Chouvardas et al., 2012
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; Schlesinger, 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 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
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 (Ratajzak et al. 2012)
- Positive or neutral (Eldridge et al. 2011)
Study case in Greece

- Altitude: 380 m
- Mean air temperature: 13.7°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:
  - 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


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

**Negative effect**
- Competition with herbaceous species
1. Biodiversity and habitat value

Shrub encroachment also affect fauna

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)
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)*

**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)*

**America:** Negative effect on soil moisture *(Darrouzet-Nardi et al. 2006)*, infiltration *(Parizak et al. 2002)* and nutrients *(Schlesinger et al. 1999)*
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.
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 production (ANPP) in grasslands (black bars) and former grassland sites now dominated by shrubs (open bars) for each of the study site (Table 1). Sites along the x-axis are ordered by increasing mean annual precipitation (MAP) and the largest responses in ANPP to shrub conversion occur in the most mesic sites. Inset: mean increase in ANPP over all sites with shrub encroachment into grasslands ($t = -2.42, df = 6, P = 0.05$). (b) The relationship between MAP and the change in ANPP for seven sites across North America where grassland has been converted to shrubland. Solid line indicates a significant positive relationship between MAP 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”.

Koniak et al., 2009
Provisioning services

- Fleshy fruits Production

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

*Koniak et al. (2009)*

![Graph showing energy density comparison](image)

**Fig. 5** Means of total fruits energy density (cal per m²) 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.
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).

<table>
<thead>
<tr>
<th>Response variable</th>
<th>Type</th>
<th>Number of cases</th>
<th>P-value</th>
<th>Trend</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Increasing</td>
<td>Declining</td>
<td>Unchanged</td>
</tr>
<tr>
<td>Plant tissue N</td>
<td>Functional</td>
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<td>0</td>
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<tr>
<td>Soil erosion</td>
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<td>1</td>
</tr>
<tr>
<td>Soil infiltration index a</td>
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<td>27</td>
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<tr>
<td>Soil nutrient index a</td>
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<td>2</td>
<td>26</td>
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<tr>
<td>Total soil S</td>
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<td>3</td>
<td>2</td>
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<tr>
<td>Tree richness</td>
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<td>0</td>
<td>9</td>
</tr>
</tbody>
</table>

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

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

Most of them reported in Israel

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