Forest Fires and Related Regime Shifts in Ayora, Spain

An Assessment of Land Use, Land Degradation and Sustainable Land Management Practices

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submitted to the Faculty of Natural Sciences

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by Nina Juanita Lauterburg

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Cover photos: Forest fire in Ayora in July 2013 (SIGIF 2014)

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Preface

During my studies at the Institute of Geography of the University of Bern, I focused on integrative geography and sustainable land management (SLM). Furthermore, before starting my master thesis, I have been working for one year as a research assistant for WOCAT (World Overview of Conservation Approaches and Technologies), a programme which documents best practices of sustainable land management. I learned that SLM is an important asset for land users all over the world and crucial for ensuring ecosystem functioning in the future. It was clear to me that my master thesis should deal with SLM using the WOCAT tools.

When I was looking for a topic for my master thesis, I got interested in the EU-CASCADE project which focuses on sudden regime shifts in European drylands. In particular the study site Ayora in Spain, which is threatened by recurrent forest fires, attracted my attention. Regime shifts caused by forest fires may lead to irreversible changes, which can result in degradation and a loss of ecosystem services. Therefore, there is a need for sustainable management of fire-prone areas.

Although forest fires are threatening many regions and people all over the world, there is no major focus on this topic within CDE and WOCAT. Thus, addressing this issue was challenging. However, through this master thesis SLM practices related to forest fires could be added to the WOCAT database, contributing to the dissemination of the available knowledge to other land users. Furthermore, through the application of the WOCAT mapping methodology, the strength of maps in land management planning became apparent; maps may help to spatially understand regime shifts and indicate spots where urgent actions are needed.

Due to the fact that Spain has almost become my second home over the last years, I highly appreciated to conduct research in this country. Through participating in a bigger research project and especially through the 3-months field stay in spring 2013, I gained a lot of experience of life as well as practical skills which are useful both in my professional and private life.

Acknowledgment

I highly appreciated the support and contribution of numerous people who enabled this master thesis.

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A very special acknowledgement goes to the team of CEAM (Centro de Estudios Ambientales del Mediterráneo) in Alicante, especially Alejandro Valdecantos and Jaime Baeza who assisted me during my extremely enriching field stay and during the analysing phase of this thesis. Without their academic and moral support, guidance and extremely valuable inputs on the topic, connections and endless patience, it would not have been possible to write this thesis. Further, I would like to thank the staff of the University of Alicante for their support in administrative issues.

I am deeply grateful to all my interview partners who contributed to the success of this master thesis. A very special thank is devoted to Vicente Colomer, forest agent of Jarafuel, who enabled most of my field visits and stakeholder meetings, and who always assisted me with his knowledge on forest management.

Further, I would like to express my gratitude to the team of the EU-CASCADE project for giving me the opportunity to participate in the plenary meeting in Alicante and to be a part of a bigger research project.

Last but not least, I would like to thank my family and friends for their moral support and their interest in my thesis. A special thank goes to my parents, my brother, Edmilson de Lima, Claudia Mösching, Caroline Amsler and Christina Sieber. Without these irreplaceable persons, I would not have been able to write this thesis successfully.

Nina Lauterburg, 28.05.2014

Summary

Work package 7 of the EU-CASCADE project (**CA**tastrophic **S**hifts in Drylands: How **CA**n We Prevent Ecosystem **DE**gradation?) deals with the potential of sustainable land management (SLM) practices to prevent or reverse sudden regime shifts in European dryland ecosystems. This master thesis is embedded in WP 7 and focuses on forest fires in the Ayora study site (Valencia, Spain). In the Mediterranean region, fires are a natural element and Spain is one of the most affected countries due to adverse climatic conditions and socio-economic processes. Considering the projections on climate change, SLM strategies are a priority to increase the resilience of the vegetation to fires. To properly manage endangered areas, it is crucial to know where land degradation is taking place at what intensity and how land users are addressing these problems.

Therefore, the overall objective of this master thesis is to explain the causes and consequences of forest fires, and to assess the role of SLM strategies in controlling fires and preventing regime shifts in Ayora. Based on the negative regime shift concept and the SLM-DPSIR (Driver-Pressure-State-Impact-Response) framework, this thesis addresses four specific objectives. In a first step, regime shifts related to fires which already occurred in Ayora are identified and assessed. In a second step, the mapping of land use, land degradation and SLM practices provides an overview of state, responses and impacts. Finally, there is a documentation and impact assessment of local SLM technologies and approaches, which are related to fires and regime shifts.

The objectives have been achieved through the application of the WOCAT (World Overview of Conservation Approaches and Technologies) tools. While the mapping questionnaire allows categorizing the prevailing land use systems and mapping the spatial spread of land degradation and SLM practices, the questionnaires on SLM technologies and approaches rather focus on local details. Additionnally, literature review, interviews and field observations have been further applied methods.

Several results arise from this thesis which can be summarized through the following key messages:

Ayora, which is considered as a representative region for the western Mediterranean basin due to its history and climatic conditions, is threatened by both the impacts of past land use and recurrent wildfires. Most of the natural vegetation has been removed several centuries ago to convert the land to agriculture, whereas the remaining forest has been used for fuel wood or charcoal production. The removal of key species resulted in a first regime shift; the vegetation composition has been modified from more fire resistant holm oak (resprouters) to pine forest (seeders) which increased the vulnerability of the vegetation to fires. In the 1960s, most of the cultivated areas have been abandoned. The rural exodus was triggered by socio-economic changes when the use of fossil fuels started, which decreased the demand on firewood. Most of the present forests and shrublands developed on abandoned agricultural fields and today they are in different successional stages containing a high fuel load. Due to the lack of fuel management, several fires occurred (e.g. in 1979, 1984, 1991, 1994), resulting in a second regime shift from pine forest to seeder shrubland. Thus, both regime shifts originate from the combination of past land use, land abandonment, lack of management, and recurrent fires. To conclude it can be stated that natural forest fire dynamics and the resilience of the vegetation to fires have been modified by human activities.

Through the application of the WOCAT mapping questionnaire it has become obvious that around one fourth of Ayora's surface has been affected by fires. Vegetation degradation is of particular importance in this region and has increased over the last 34 years. At present, forests and shrublands (both unburnt and burnt) contain a considerable fire risk. This is due to the change in species composition and the huge fuel amount of fire-prone seeder species. A major problem is that the vegetation degradation may promote short-interval fire cycles and establish a positive feedback between fire risk and degradation. Considering the state of the burnt vegetation it can be concluded that the degree of vegetation degradation is increasing with the number of fires.

One main result of the WOCAT mapping is that regime shifts and the impacts of fires are also influenced by the slope aspect (north, south). North exposed forests and shrublands recover quite rapidly depending on the number of fires. However, due to their high amount and density of fire-prone seeder species further fires may be triggered. The highest degradation extent and degree can be found in south exposed shrublands which burnt twice. Additionally to severe vegetation degradation, further degradation may occur, such as erosion, crusting and aridification. In the worst case, a pattern of bare soil with little vegetation cover could arise which may accelerate desertification processes.

Through the WOCAT mapping it has become evident that the impacts of fires and the fire risk by itself are much lower if resprouter species are dominating. Thus, additionally to the influence of the aspect, it is actually the number of perturbations, namely the combination of past cultivations and recurrent fires, which determines the degradation degree, the impact of fires, the regeneration capacity and the probability of a regime shift.

As a consequence of several devastating fires and their negative impacts on productive, ecological and socio-economic ecosystem services, the government of Valencia introduced management interventions in order to improve fire prevention and extinction as well as to promote mature forests. Important SLM practices in Ayora include the establishment of a firebreak network, selective forest clearings and afforestations. These measures are mainly based on the forest law 3/1993 and on several management plans and have been documented using the WOCAT questionnaires on technologies and approaches.

The basic principle of a firebreak network is to split continuous forest areas into smaller forest patches separated by vegetation-free strips, in order to hinder the spread of the fire and to facilitate access for fire fighters. If firebreaks are well maintained and if fire fighting is well organized, they indeed contribute in limiting the burnt area and are therefore an effective tool in fire extinction.

Numerous Pinus halepensis afforestation projects, aiming in post-fire rehabilitation or restoration of abandoned fields, have been realized. However, these afforestations often experience a lack of maintenance which leads to an increased fire risk. Therefore, pine afforestations are not considered as an appropriate management practice.

Selective forest clearing, which is considered as the most sustainable land management practice in Ayora, includes activities such as thinning and pruning, aiming at fire prevention through the reduction of fuel and its continuity. The combination of fuel management and planting of resprouter species is considered to be even more effective because this may accelerate natural succession and promote resilience to fires. Due to the high costs, this practice is not yet applied on a larger scale but only tested and evaluated within an experiment.

Although there is still a high number of fires and fire prevention stays challenging, the implementation of a holistic approach in fire prevention and extinction through the government of Valencia resulted in a decrease of the burnt area since 1994. Nevertheless, it is crucial to further investigate on prevention measures to control fires and to decrease the probability of future regime shifts to reduce the adverse impacts on ecosystems and the livelihoods of local people. Unfortunately, there is a lack of financial resources invested in forest management due to the current economic crisis which hinders maintenance and decreases the effectivity of the above mentioned practices.

Resumen

Tarea 7 (WP 7) del proyecto EU-CASCADE (**CA**tastrophic **S**hifts in Drylands: How **CA**n We Prevent Ecosystem **DE**gradation?) trata el potencial de gestión sostenible de la tierra (MST) en prevenir o revertir cambios bruscos de régimen en las zonas áridas de Europa. Esta tesis de máster está incluído en el WP 7 y se centra en los incendios forestales en el área de estudio Ayora (Valencia, España).

En la región mediterránea, los incendios forestales son un elemento natural y España es uno de los países más afectados debido a las condiciones climáticas adversas y los procesos socio-económicos. Considerando las predicciones sobre el cambio climático, las estrategias del MST son una prioridad para aumentar la resiliencia de la vegetación a los incendios. Para poder gestionar adecuadamente las zonas de alto riesgo es fundamental saber dónde la degradación de la tierra se está produciendo a qué intensidad y cómo los usuarios de la tierra están abordando estos problemas.

Por eso, el objetivo general de esta tesis es explicar las causas y consecuencias de los incendios forestales, y evaluar las estrategias MST en el sentido de control de incendios y de la prevención de los cambios bruscos de los ecosistemas en Ayora. Basado en los conceptos “cambio brusco de régimen” y “SLM-DPSIR”, esta tesis aborda cuatro objetivos específicos. En un primer paso, se identifica y se evalúa los cambios bruscos del régimen que ya pasaron en Ayora. En un segundo paso, la cartografía del uso del suelo, de la degradación de la tierra y del MST proporciona una visión general del estado, de las respuestas y de los impactos. Por último hay una documentación y evaluación de los impactos de las tecnologías y los enfoques locales de MST, que están relacionados con los incendios forestales y los cambios de régimen.

Los objetivos se han conseguido a través de la aplicación de la metodología del WOCAT (World Overview of Conservation Approaches and Technologies). Mientras que el cuestionario de mapeo permite categorizar los sistemas de uso del suelo y la cartografía de la distribución espacial de la degradación de la tierra y prácticas de MST, los cuestionarios sobre las tecnologías y los enfoques más bien se centran en los detalles locales. Además, la revisión de la literatura, entrevistas y observaciones en el campo han sido otros métodos aplicados.

Varios resultados surgen de esta tesis, que se puede resumir a través de los siguientes mensajes claves:

Ayora, que es considerada como una región representativa de la cuenca occidental del Mediterráneo debido a su historia y las condiciones climáticas, se ve amenazada tanto por los impactos del uso de la tierra en el pasado y los incendios recurrentes. La mayor parte de la vegetación natural se ha eliminado hace varios siglos para convertir la tierra en cultivos, mientras que el bosque restante se ha utilizado para la producción de leña o de carbón vegetal. La eliminación de especies claves resultó en un primer cambio de régimen; se ha modificado la composición de la vegetación de encina que es más resistente al fuego (rebrotadoras) a Pinar (germinadoras) lo que aumentó la vulnerabilidad de la vegetación a los incendios. En la década de 1960, la mayoría de los cultivos han sido abandonados. El éxodo rural fue provocado por los cambios socio-económicos cuando se inició el uso de combustibles fósiles lo que disminuyó la demanda de leña. La mayoría de los bosques y matorrales han crecido en los cultivos abandonados y hoy se encuentran en diferentes estados de sucesión y contienen una alta carga de combustible. Debido a la falta de manejo de combustible se produjeron varios incendios (por ejemplo, en 1979, 1984, 1991, 1994), lo que resultó en un segundo cambio de régimen de bosque de pinos a matorral (germinadoras). Así, ambos cambios de régimen han sido causado por la combinación del uso de la tierra en el pasado, del abandono, por la falta de gestión, y por los incendios recurrentes. Para

concluir, se puede afirmar que la dinámica de los incendios forestales naturales y la resiliencia de la vegetación a los incendios han sido modificados por las actividades humanas.

A través de la aplicación del cuestionario de mapeo del WOCAT se ha hecho evidente que aproximadamente un cuarto de la superficie de Ayora ha sido afectada por incendios. La degradación de la vegetación es de mayor importancia en esta región y se ha aumentado en los últimos 34 años. En la actualidad, los bosques y matorrales (tanto no quemados y quemados) contienen un riesgo de incendio considerable. Esto se debe al cambio en la composición de las especies, la cantidad de combustible enorme de especies germinadoras y la falta de gestión. Un problema importante es que la degradación de la vegetación puede promover incendios de alta recurrencia y establecer una retroalimentación positiva entre el riesgo de incendios y la degradación. Teniendo en cuenta el estado de la vegetación quemada se puede concluir que el grado de degradación de la vegetación está aumentando con el número de incendios.

Un resultado principal de la cartografía WOCAT es que los cambios de régimen y los impactos de los incendios también están influenciados por la orientación (umbría, solana). Los bosques y matorrales se recuperan más rápidamente en la umbría. Sin embargo, debido a su gran cantidad y densidad de especies germinadoras propensas a incendios más fuegos se pueden formar. El grado más alto de degradación se puede encontrar en el matorral que se quemó dos veces en la solana. La degradación de la vegetación grave puede implicar más tipos de degradación, como la erosión, formación de costras y aridez. En el peor caso, un suelo desnudo con poca cobertura vegetal podría surgir lo que podría acelerar los procesos de desertificación.

A través de la aplicación del cuestionario de mapeo se ha hecho evidente que los impactos del fuego y el riesgo de incendio por sí son mucho más bajos si las especies rebrotadoras están dominando. Por eso, adicionalmente a la influencia de la orientación, es el número de perturbaciones, o sea la combinación de uso de la tierra en el pasado y los incendios recurrentes, que determina el grado de degradación, el impacto de los incendios, la capacidad de regeneración y la probabilidad de un cambio de régimen.

Como consecuencia de varios incendios graves y sus impactos negativos en los servicios de los ecosistemas, el gobierno de Valencia implementó intervenciones de gestión con el fin de mejorar la prevención y extinción de incendios, así como para fomentar bosques maduros. Prácticas importantes de MST en Ayora incluyen el establecimiento de una red de cortafuegos, los clareos selectivos del bosque y repoblaciones. Estas medidas se basan principalmente en la ley forestal 3/1993 y en varios planes de gestión y se han documentado usando los cuestionarios de tecnologías y enfoques del WOCAT.

El principio básico de una red de cortafuegos es dividir una área forestal continua en fragmentos más pequeños separadas por franjas sin vegetación, con el fin de impedir la propagación del fuego y para facilitar el acceso para los bomberos. Si los cortafuegos están bien mantenidos y si la lucha contra incendios está bien organizado, contribuyen a limitar la superficie quemada y por eso son una herramienta eficaz en la extinción de incendios.

Se han ejecutado varios proyectos de repoblaciones de Pinus halepensis con el objetivo de la rehabilitación después de un incendio o una restauración de cultivos abandonados. Sin embargo, una falta de mantenimiento en estos bosques repoblados aumenta el riesgo de incendio. Por eso, repoblaciones de pino no son considerados como una práctica adecuada en esta zona.

Clareo o desbroce selectivo incluye actividades tales como clareo y poda con el fin de prevención de incendios a través de la reducción del combustible y su continuidad. Está considerada como la práctica más sostenible en Ayora. La combinación de desbroce selectivo y plantación de especies rebrotadoras

está considerada más eficaz aún, ya que puede acelerar la sucesión natural y promover la resiliencia a los incendios. Debido a los altos costos, esta práctica todavía no se aplica en una escala más grande; sólo se ha evaluado en un experimento.

Aunque todavía hay un alto número de incendios y la prevención de incendios se mantiene desafiante, la implementación de un enfoque integral en la prevención y extinción de incendios por el gobierno de Valencia resultó en una disminución de la superficie quemada desde 1994. Es importante de seguir investigando sobre las medidas de prevención para controlar el fuego y para reducir la probabilidad de futuros cambios de régimen para reducir los impactos negativos a los ecosistemas y a la población local. Desgraciadamente, hay una falta de recursos financieros invertidos en la gestión forestal debido a la crisis económica que dificulta el mantenimiento y que disminuye la efectividad de las prácticas mencionadas.

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Abbreviations

a.s.l.	Above sea level
CASCADE	Catastrophic Shifts in Drylands – How can we prevent ecosystem degradation?
CDE	Centre for Development and Environment, University of Bern
CEAM	Centro de Estudios Ambientales del Mediterráneo (Centre of Environmental Studies of the Mediterranean)
CORINE	Coordination of information on the environment
DEM	Digital elevation model
DESIRE	Desertification Mitigation and Remediation of Land – a Global Approach for Local Solutions
EFFIS	European Forest Fire Information System
e.g.	Exempli gratia (latin), for example
ESS	Ecosystem Services
FAO	Food and Agriculture Organization of the United Nations
FRA	Forest Resources Assessment
GEORANGE	Geomatics in the assessment and sustainable management of Mediterranean rangeland
GIS	Geographical Information System
GLASOD	Global Assessment of Soil Degradation
GVA	Generalitat Valenciana (government of Valencia)
ha	Hectare(s)
i.e.	id est (latin), this means
JRC	Joint Resource Center
LADA	Land Degradation Assessment in Drylands
LUS	Land use system
LUT	Land use type
MEA	Millenium Ecosystem Assessment
OECD	Organisation for Economic Cooperation and Development
PATFOR	Plan de Acción Territorial Forestal de la Comunitat Valenciana (Forest Action Plan of Valencia)
PRACTICE	Prevention and Restoration Actions to Combat Desertification. An Integrated Assessment.
PSP	Plan de Selvicultura Preventiva de Incendios Forestales en la Comunidad Valenciana (Plan of fire preventive silviculture in the Forests of Valencia)
QA	WOCAT Questionnaire on Approaches
QM	WOCAT Mapping Questionnaire
QT	WOCAT Questionnaire on Technologies
SIGIF	Sistema Integrado de Gestión de Incendios Forestales (Integrated System on Forest Fire Management)
SLM	Sustainable Land Management
SIOSE	Sistema de Información sobre Ocupación del Suelo de España (Information System on land cover in Spain)
UNEP	United Nations Environment Programme
UNCCD	United Nations Convention to Combat Desertification
USGS	U.S. Geological Survey
WOCAT	World Overview of Conservation Approaches and Technologies
WP	Work Package

1. Introduction

This general introduction explains the initial conditions and provides an outline of the problem. Since this master thesis is conducted within the framework of EU-CASCADE, the project is presented briefly in the subsequent chapter. Furthermore, an introduction on forest resources and fires in Spain is provided, and related to that, the relevance of the research is elaborated. At the end of this chapter, the study site is presented.

1.1 EU-CASCADE Project

Understanding discontinuous or abrupt changes in ecosystems, termed as sudden regime shifts, catastrophic shifts or critical transitions, is a major challenge in ecology. Regime shifts can lead to irreversible changes, which may result in a loss of biological diversity and ecosystem services. The CASCADE project (**CA**tastrophic **S**hifts in Drylands: How **CA**n We Prevent Ecosystem **DE**gradation?) focuses on sudden regime shifts in European drylands, aiming at understanding the drivers and finding ways to prevent such shifts. Furthermore, ways to predict the proximity of dryland ecosystems to thresholds are developed in order to enable policymakers and land users to manage drylands more sustainably. Through the CASCADE project, which is realized between 2012 and 2017 and funded by the 7th Framework Programme of the European Commission, research is carried out in 6 study sites in southern Europe. The study sites are located in Portugal, Spain, Italy, Crete and Cyprus (figure 1). The study site addressed in this thesis is the Ayora mountain range in the province of Valencia (number 3), which will be presented in detail in chapter 1.5.

Figure 1: Study sites of the EU-CASCADE project (CASCADE Website 2014)

CASCADE is organized in 9 Work Packages (figure 2). This master thesis is embedded in work package 7, which is coordinated by the University of Bern and which focuses on the evaluation of land use and land management. Sustainable management of natural resources depends on appropriate technologies and related implementation approaches. Therefore, WP 7 aims to identify existing land management practices and to assess them using the methods of the WOCAT (World Overview of Conservation Approaches and Technologies) programme (www.wocat.net). There is a focus on the resilience of management practices towards shocks and shifts, and on their key role with respect to regime shifts. Furthermore, potential management practices for sustainable management of dryland ecosystems are evaluated and guidelines of best practices for natural resource managers are developed (CASCADE 2011).

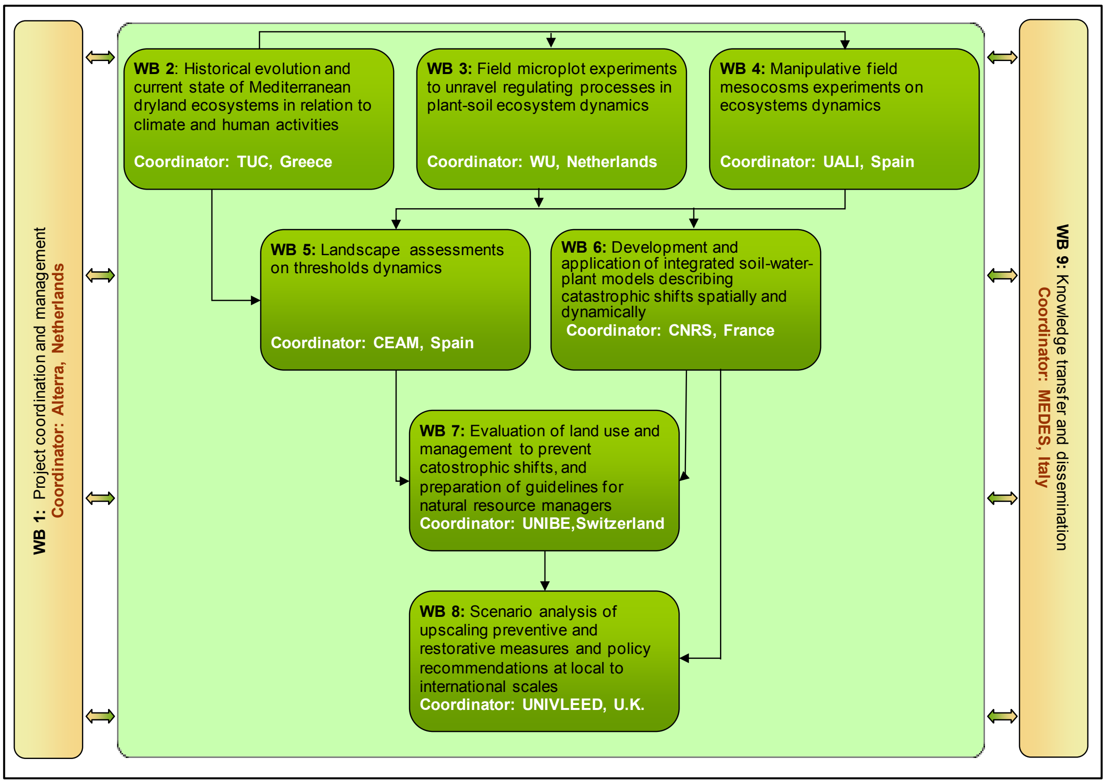


Figure 2: Work Packages of CASCADE (Source: CASCADE 2011)

1.2 Forest Resources and Forest Fires in Spain

Forest fires are the main degradation driver in the Ayora study site, causing regime shifts and losses of ecosystem functions and services. Therefore, this chapter provides a general overview of forest resources and forest fires in Spain.

In the province of Valencia, the main forest types are subtropical dry forests (below 800 m a.s.l.) and subtropical mountain forests (800 m - 2000 m). The original vegetation of the subtropical dry forests was evergreen sclerophyllous forest but the species composition has become rather monotonous through anthropogenic influences. In the subtropical mountain forest temperatures are lower (greater frequency of frost) and there is a higher amount of precipitation which sometimes also falls as snow. In contrast to the sclerophyllous forests, the vegetation of this zone is typically composed of deciduous oak species (FRA 2000: 187-188).

Today, many of the remaining forests in Spain are in poor conditions or reduced to shrubland with some scattered trees due to a long history of forest destruction (FRA 2000). During the Roman occupation, deforestation in Spain started and continued for the next 2000 years. The wood has been used as fuel, or to build houses or strategic material such as ships (FAO Forestry 2014). Furthermore, a large percentage of the forest was deforestated in order to convert it to cropland. Another important disturbance is fire (FRA 2000), which will be discussed later in this chapter.

Although large areas have been severly degraded through human land use over millennia, Spain is the fourth country in Europe in terms of forest resources. As shown in table 1, the forested area accounts to 14.4 million ha which is around 29% of the country's surface (FAO Forestry 2014). Furthermore, there are 12.5 million ha of other wooded land. Thus, 50% of Spain is covered by forest and other wooded land (FRA 2000).

Despite the occurrence of many forest fires, Spain’s forest is annually increasing by about 86’000 ha, thus showing the highest increase in forest area in southern Europe (FAO Forestry 2014). This increase is a result of forest regeneration on wooded land, natural recolonization on abandoned agricultural fields, and plantations (FRA 2000). There was a plantation programme (funded by the European Union) which lasted for more than 50 years aiming at soil stabilization and environmental protection (FAO Forestry 2014). Therefore, the largest areas covered by plantations in southern Europe are to be found in Spain (FRA 2000).

Country/area	Land area	Forest area 2000					Area change 1990-2000 (total forest)		Volume and above-ground biomass (total forest)		Forest under management plan	
		Natural forest	Forest plan-tation	Total forest								
	000 ha	000 ha	000 ha	000 ha	%	ha/capita	000 ha/year	%	m^3/ha	t/ha	000 ha	%
Albania	2 740	889	102	991	36.2	0.3	-8	-0.8	81	58	406	41
Andorra	45	-	-	-	-	-	-	-	0	0	n.a.	n.a.
Bosnia and Herzegovina	5 100	2 216	57	2 273	44.6	0.6	n.s.	n.s.	110	-	2 007	88
Bulgaria	11 055	2 722	969	3 690	33.4	0.4	20	0.6	130	76	3 690	100
Croatia	5 592	1 736	47	1 783	31.9	0.4	2	0.1	201	107	1 531	86
Greece	12 890	3 479	120	3 599	27.9	0.3	30	0.9	45	25	2 009	56
Italy	29 406	9 870	133	10 003	34.0	0.2	30	0.3	145	74	1 117	11
Malta	32	n.s.	0	n.s.	n.s.	-	n.s.	n.s.	232	-	n.s.	100
Portugal	9 150	2 832	834	3 666	40.1	0.4	57	1.7	82	33	1 201	33
Romania	23 034	6 357	91	6 448	28.0	0.3	15	0.2	213	124	6 448	100
San Marino	6	-	-	-	-	-	-	-	0	0	n.a.	n.a.
Slovenia	2 012	1 106	1	1 107	55.0	0.6	2	0.2	283	178	1 107	100
Spain	49 945	12 466	1 904	14 370	28.8	0.4	86	0.6	44	24	11 694	81
The Former Yugoslav Republic of Macedonia	2 543	876	30	906	35.6	0.5	n.s.	n.s.	70	-	906	100
Yugoslavia	10 200	2 848	39	2 887	28.3	0.3	-1	-0.1	111	23	2 723	94
Total Southern Europe	**163 750**	**47 397**	**4 327**	**51 723**	**31.6**	**0.3**	**233**	**0.5**	**112**	**60**	**34 839**	**67**
Total Europe	**2 259 957**	**1 007 236**	**32 015**	**1 039 251**	**46.0**	**1.4**	**881**	**0.1**	**112**	**59**	**954 707**	**92**
TOTAL WORLD	**13 063 900**	**3 682 722**	**186 733**	**3 869 455**	**29.6**	**0.6**	**-9 391**	**-0.2**	**100**	**109**	**-**	**-**

Table 1: Forest resources and forest management in southern Europe (FRA 2000: 212)

In Spain, 60% of the forest is owned by private individuals or by cooperatives, whereas 30% belongs to the municipalities and 4% to the autonomous communities. Only 6% is owned by the state. About 25% of the forests are designated as protected areas (FRA 2000, FAO Forestry 2014).

The main functions of forests in Spain are protection against soil erosion and desertification, and regulation of the hydrological cycle. Additionnally, there is an important productive function. However, many areas are not available for wood extraction because they are not accessible. Non-wood forest products such as cork, medicinal and aromatic plants, hunting, fodder, nuts, fruit and truffles have a high value as well (FAO Forestry 2014). Furthermore, forests are gaining an increasing importance for rural tourism in Spain due to their aesthetic, recreational and spiritual value (FRA 2000).

However, forests and woodland are threatened by fires which constitute a natural element in the Mediterranean region and which have always been a major factor in shaping rural landscapes. More trees are destroyed by fire than by any other threat such as pests, extreme wind, drought or frost. On average, every year a surface of about 500’000 ha is burnt in Europe, whereas the annual number of fires accounts to 50’000 (FRA 2000). In Spain, the high number of fires is a result of both adverse climatic conditions and sociological processes. There are prolonged hot and dry seasons which result in a low moisture content of the vegetation. Temperatures are often above 30°C, there is only little rainfall and high wind speed (FAO 2013: 48, Röder et al. 2008). Along with adverse climatic conditions, natural forest fire dynamics and the resilience of the vegetation to disturbances have been modified by human activities. Since prehistoric days, people used fire to clear the ground, for hunting, to stimulate regeneration of plants or to expand human habitat (Pausas et al. 2011). However, due to rural exodus which went along with urbanization and industrialization, many fields have been abandoned and colonized by shrubs which increased the fire risk (FAO 2013). Human-caused fuel changes are considered as an important driver for fire regime changes (Pausas et al. 2011). The lack of local rural population results in difficulties to detect fires and in an increase of fires due to a lack of management (FAO 2013).

In the Mediterranean basin, most of the fires are caused by humans, either accidentally or through negligence. Many fires start on agricultural land and spread into the forest (FRA 2000). A large number of fires are also started due to a variety of social, economic or political reasons (e.g. electrical power/high-tension lines, vehicles, weapons, vegetation management, recreation, fireworks, cigarettes, vandalism, etc.) (JRC 2013). Only a small percentage is triggered by natural causes (e.g. lightning) (FRA 2000).

Figure 3 and 4 indicate that mainly the western European countries are affected by a high number of fires resulting in a considerable burnt area (per year and 10 km^2). 81% of the fires between 2006 and 2010 occurred in this region and the fire density was highest in Portugal and Spain.

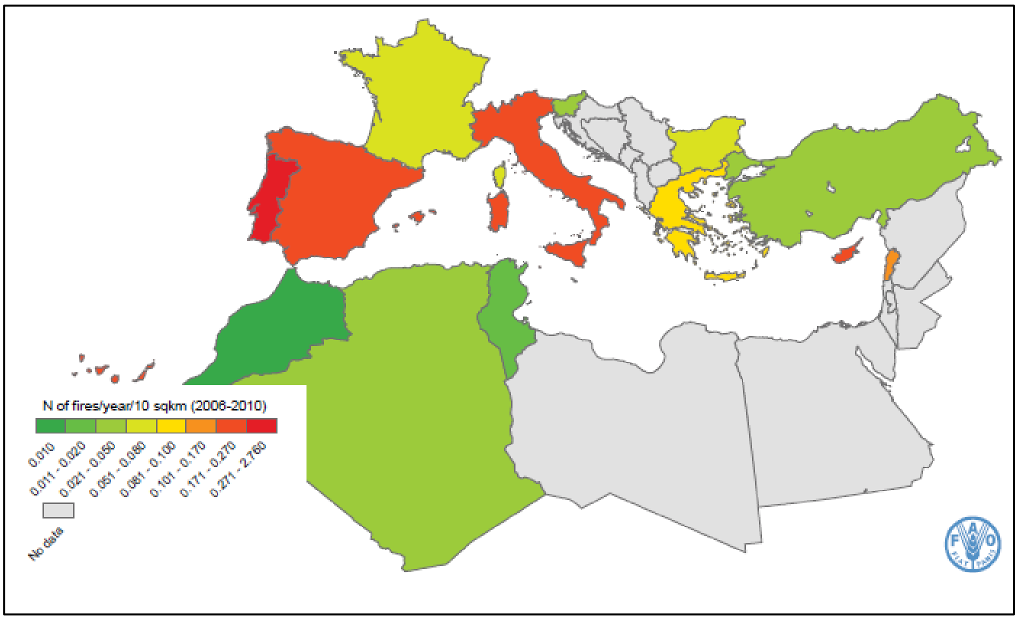


Figure 3: Number of fires per year and 10 km^2 in the Mediterranean region 2006-2010 (FAO 2013: 51)

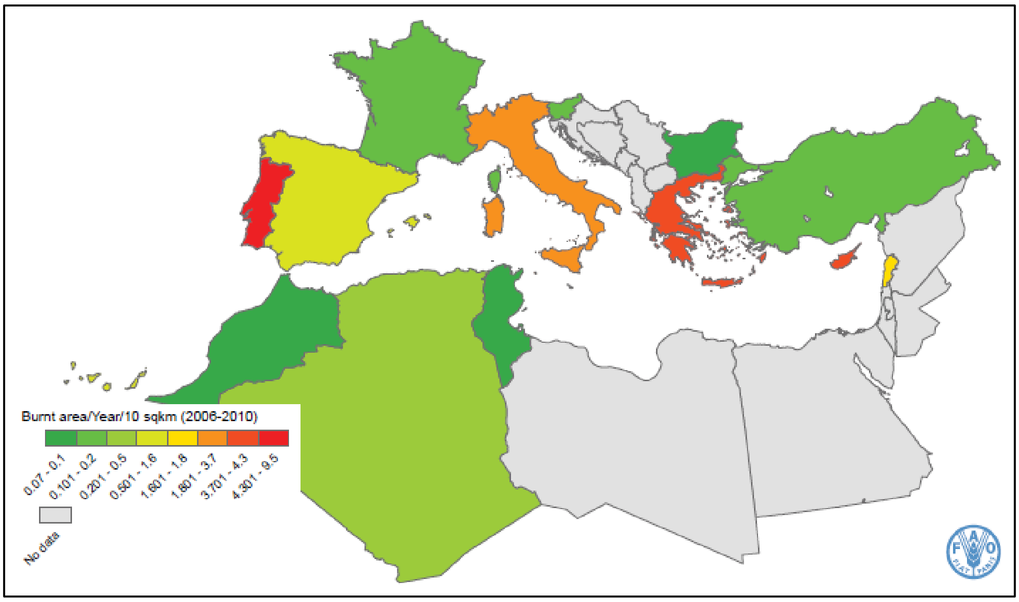


Figure 4: Burnt area per year and 10 km^2 in the Mediterranean region 2006-2010 (FAO 2013: 52)

Concerning the forest fires which occurred between 1980 and 2012, Spain is one of the most affected countries in Europe. The number of fires increased during the 1990s (this is also partly a result of the improvement of recording procedures), afterwards it was stable for a decade, and then in the last decade there was a decrease (figure 5). In the last five years, the trend of the number of fires again showed an increase (JRC 2013: 2). Figure 6 illustrates the recorded burnt area. After 1994, in general there is a downward trend of areas affected by fires which can be partly explained by improved fire fighting. This is further investigated in the results. In the year 2012, the burnt area in Spain accounted to 209’855 ha, which was 40% of the total burnt area recorded in Europe in 2012 (JRC 2013: 89).

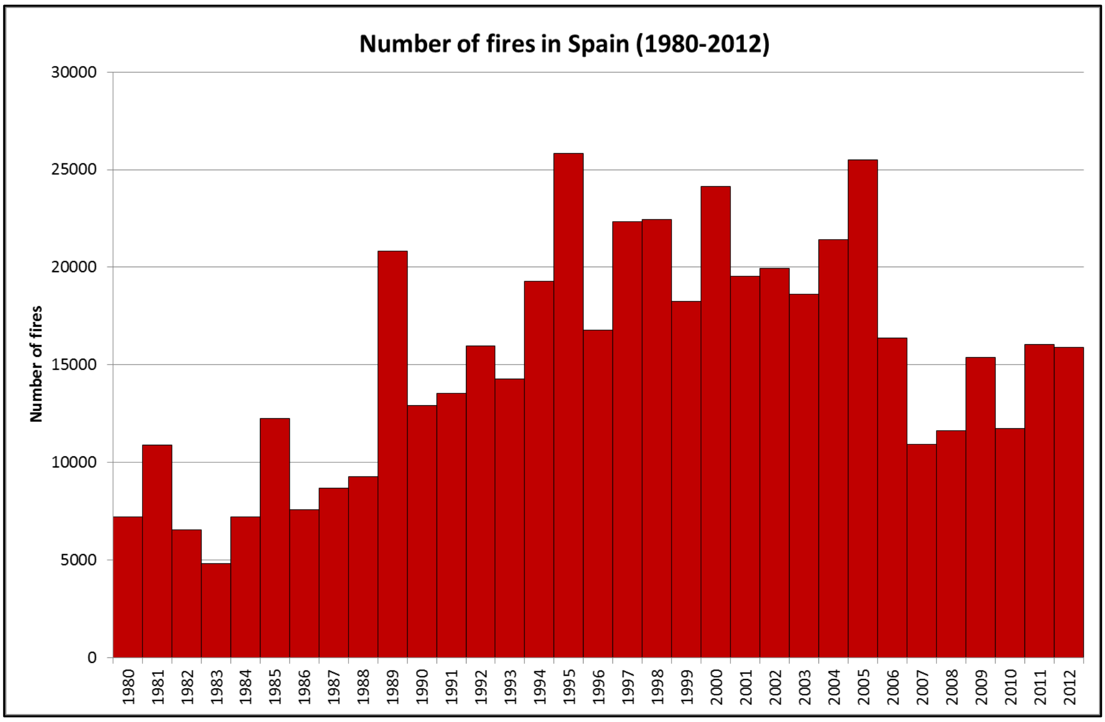


Figure 5: Number of fires in Spain 1980-2012 (Nina Lauterburg 2014, data source: JRC 2013: 105)

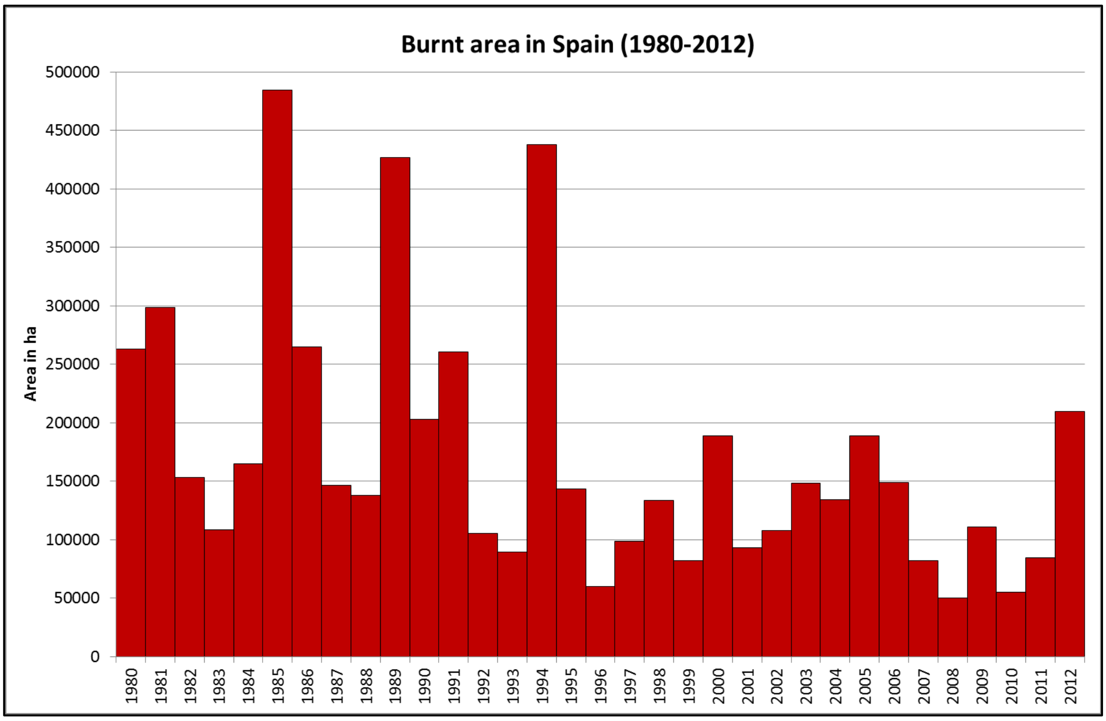


Figure 6: Burnt area (ha) in Spain 1980-2012 (Nina Lauterburg 2014, data source: JRC 2013: 106)

Table 2 also illustrates that Spain and Portugal were the most affected countries in terms of number of fires and burnt area since the year 1980.

Number of fires	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE[(*)]	TOTAL
2012	21 176	15 902	4 105	8 252	1 559	50 994
% of total in 2012	42%	31%	8%	16%	3%	100%
Average 1980-1989	7 381	9 515	4 910	11 575	1 264	34 645
Average 1990-1999	22 250	18 152	5 538	11 164	1 748	58 851
Average 2000-2009	24 949	18 337	4 406	7 259	1 695	56 645
Average 2010-2012	22 808	14 551	4 168	9 736	1 408	50 040
Average 1980-2012	18 613	15 263	4 880	9 736	1 554	50 046
TOTAL (1980-2012)	614 228	503 690	161 036	321 294	51 282	1 651 530
Burnt areas (ha)	PORTUGAL	SPAIN	FRANCE	ITALY	GREECE	TOTAL
2012	110 231	209 855	8 600	130 814	59 924	519 424
% of total in 2012	21%	40%	2%	25%	12%	100%
Average 1980-1989	73 484	244 788	39 157	147 150	52 417	556 995
Average 1990-1999	102 203	161 319	22 735	118 573	44 108	448 938
Average 2000-2009	150 101	125 239	22 342	83 878	49 238	430 798
Average 2010-2012	105 711	116 372	9 433	83 118	32 678	347 313
Average 1980-2012	108 334	171 593	26 383	113 496	47 141	466 947
TOTAL (1980-2012)	3 575 020	5 662 572	870 632	3 744 360	1 555 659	15 409 243

[(*)] Numbers of fires are incomplete since 2009

Table 2: Number of fires and burnt area in Portugal, Spain, France, Italy and Greece (JRC 2013: 4)

Wildfires have severe environmental and socio-economic impacts. Through recurrent fires, large areas of forests and woodland have been converted to shrubland and grassland. A return to tree cover is often prevented due to the fact that shrubland and grassland are much more prone to fire (FRA 2000). Wildfires also produce economic damages due to the vast amount of resources which are spent in fire prevention and extinction, the loss of commercial value of damaged wood products, or the costs which are related to the loss of non-market services (such as biodiversity protection, water cycle regulation, soil protection, carbon sequestration or supply of recreational areas) (Moreira et al. 2012: 1).

To reduce the adverse impacts on ecosystems and the livelihoods of local people, it is crucial to investigate on prevention measures to control these recurrent fires. There is a growing awareness from the public and policy-makers on the role of forests in providing environmental, economic and social benefits, and there is an agreement on the importance of forest protection measures. It is recognized that the resources are not infinite and that there is a need for sustainable management. However, often there is a lack of financial resources. It is a big task for forest managers to prevent or extinct fires but also to educate the public on fire prevention. Policy-makers agree on the fact that emergency preparedness and response programmes have to be combined with better land use policies and practices. Between 1998 and 2000, many international initiatives were launched related to sustainable development and fire prevention or fire management in order to improve the institutional capacity to prevent and combat forest fires. An important strategy is the application of sustainable forest management practices, involving the local population in forest fire management. Also the use of satellites to map active fires and burnt areas is quite effective and increasingly used (FRA 2000). As shown in figure 6, the realized measures seem to have a positive impact on the reduction of the burnt area.

1.3 Relevance of the Research

The Mediterranean basin is one of the world's 34 biodiversity hotspots (figure 7). A biodiversity hotspot is defined as an area with a high level of species diversity and a high amount of endemic species, but in most cases these hotspots are threatened by significant habitat losses (Conservation International 2014).

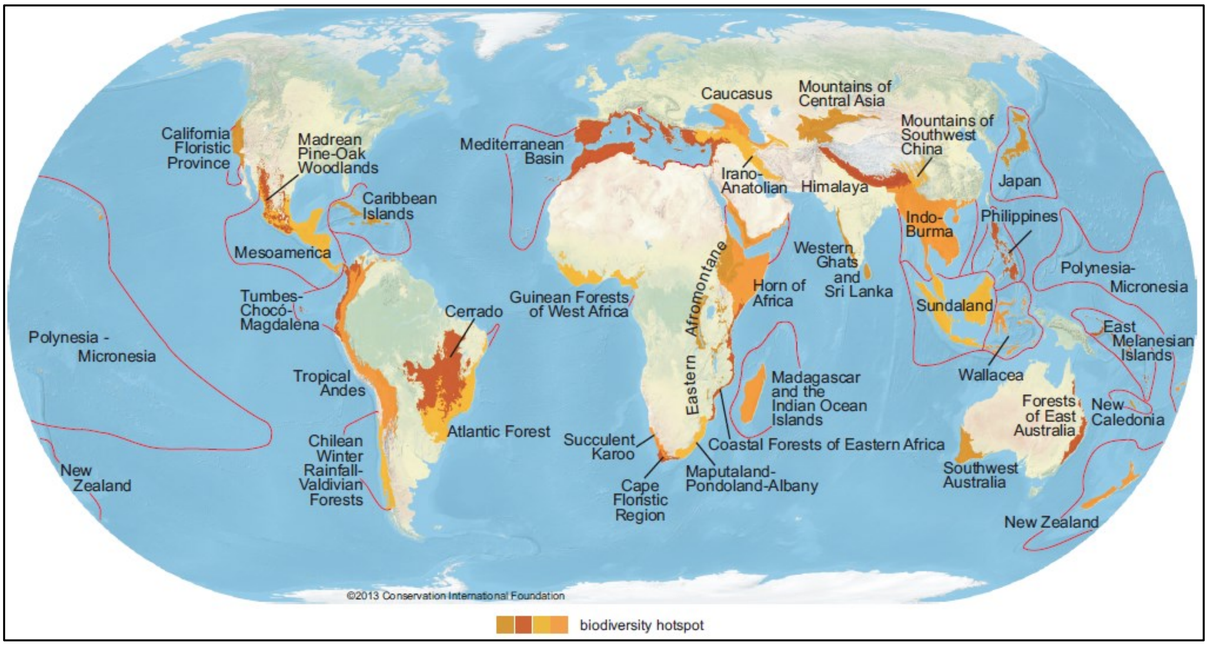


Figure 7: Biodiversity hotspots (Conservation International 2014)

The Mediterranean hotspot includes North Africa, Turkey, Greece, Malta, Cyprus, Montenegro, Albania, Croatia, Italy, some parts of France, Spain, Portugal and islands such as Cape Verde, the Azores, Madeira and Canaries (figure 8). Approximately 52% of the 22'500 species found in this area do exist nowhere else in the world (Moreira et al. 2012: 258).

A big area of this hotspot was once covered by evergreen oak forests, deciduous and conifer forests. However, 8000 years of human settlement have caused a shift to hard-leafed or sclerophyllous shrublands. There is no other hotspot in the world which experienced such a long lasting impact on its ecosystem. The Mediterranean basin is among the four most significantly altered hotspots of the world - only 5% of the original extent of the hotspot contains intact vegetation (Conservation international 2014).

Figure 8: Mediterranean hotspot (Conservation International 2014)

Fire constitutes a main degradation driver in the Mediterranean hotspot. Furthermore, several researchers concluded that climate change is likely to have a strong impact on fire activity and on the stability of the forest ecosystems (Moreira et al. 2012: 260).

Pausas (2004) states that in south-eastern Spain there is already evidence of the impact of climate change on the occurrence of fires. Especially heat waves in combination with droughts can result in severe fires (Moreira et al. 2012: 260).

In the frame of the course "Climate Risk Assessment" at the University of Bern, changes in heat wave occurrence for the periods 2001-2010 and 2041-2050 based on calculations of two different regional climate models (ETHZ and KNMI) have been analyzed. The output of the models (see Annex 1) and also various scientific papers show the vulnerability of Europe to extreme events and indicate a clear trend to an increased frequency, duration and intensity of heat waves due to regional surface warming and increased temperature variability (Beniston et al. 2007: 72, UNDP 2002: 5). Above all, both models indicate a strong increase in the number of heat waves in Spain and Portugal.

Until the end of the 21th century, the burnt area in the Mediterranean basin is expected to increase due to a significant increase of the fire frequency and severity, an enlargement of fire-prone areas and a lengthening of the fire season. As a result, a shift in the forest composition is likely to occur (Moreira et al. 2012: 260).

In the study site addressed in this master thesis, which is considered as a representative area for the western Mediterranean basin due to its history, climatic conditions, and numerous wildfires, this shift in the vegetation composition is already visible and the situation may become worse when considering the predictions discussed above. This is the reason why Ayora is included in the CASCADE project. There is a need to prevent fires in order to avoid irreversible regime shifts and positive feedbacks on degradation. This is not only the case for Ayora; forest fires are a global concern and endanger numerous biodiversity hotspots. Therefore, future conservation efforts will require to achieve sustainable management of forests and shrublands, and an appropriate fire management (Moreira et al. 2012: 259).

To properly manage endangered areas, it is crucial to know where land degradation is taking place at what intensity and how land users are addressing this problem (Liniger et al. 2008a). Through the WOCAT tools, fields and needs of action can be identified and the development of further management strategies can be supported (WOCAT Website 2014).

1.4 Objectives and Research Questions

This chapter presents the overall and the specific objectives and research questions of this master thesis.

Overall objective	Overall research question
Explaining the causes and consequences of forest fires, and assessing the role of SLM strategies in controlling fires and preventing regime shifts in Ayora.	Which causes and consequences do forest fires have and which SLM strategies are currently applied in Ayora? Do they contribute to the reduction of fires and to the prevention of regime shifts?

Based on the above highlighted overall research objective, the following specific objectives and research questions are addressed:

Specific objectives and research questions to achieve them	
Specific Objectives	**Specific research questions**
1. Assessing regime shifts related to fires in Ayora.	Which regime shifts already happened and why?
2. Mapping of land use, land degradation and SLM practices to provide an overview of state, responses and impacts.	Which types of land degradation and SLM practices occur on which land use systems? What are the spatially explicit impacts of degradation and SLM on the provision of ecosystem services and fire risk?
3. Documentation and impact assessment of local SLM technologies related to fires and regime shifts.	How can the local SLM technologies be characterized? What are benefits and disadvantages of SLM technologies and how do they function in view of preventing or triggering fires and regime shifts?
4. Documentation and impact assessment of approaches under which the local SLM technologies have been achieved.	Through which approaches were the technologies implemented, and which benefits and disadvantages do they have?

The thesis is structured by the four specific objectives. In chapter 5, the research questions will be answered through summarizing the main findings.

1.5 Study Site – Ayora (Province of Valencia, SE Spain)

This chapter presents the study site of this master thesis by providing general information on the ecological and socio-economic environment, on land use changes and on the main ecosystem services of the region.

Ayora is located in the interior of Valencia in the eastern Iberian Peninsula (figure 9).

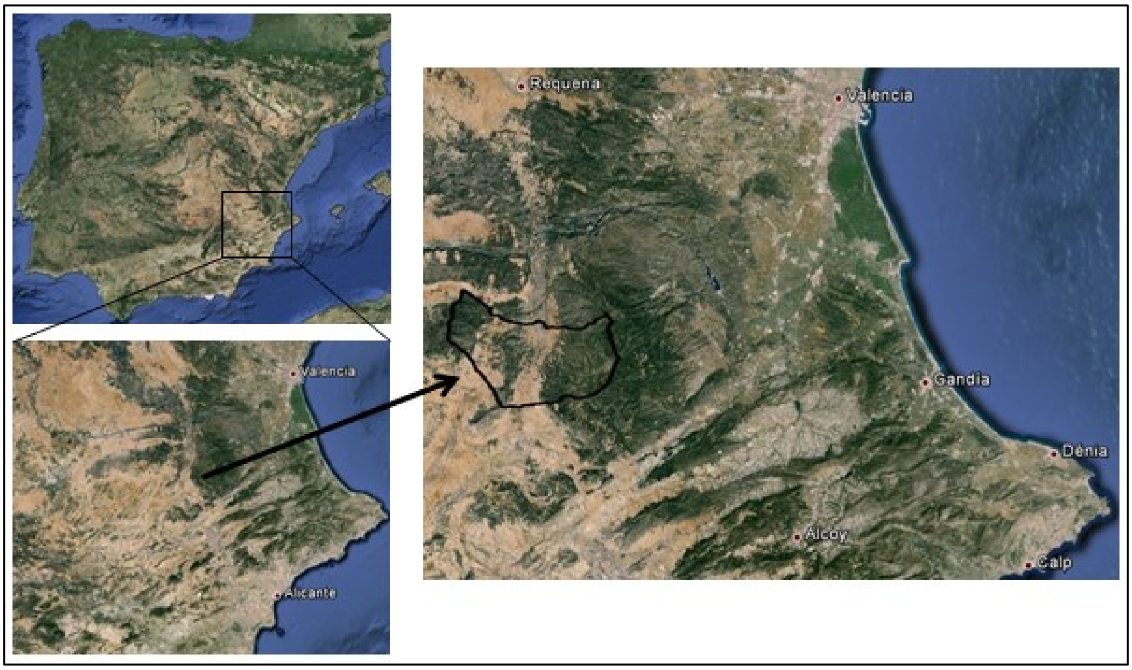


Figure 9: Location of study site Ayora (Nina Lauterburg 2014, adapted from CASCADE 2011, source of image: Google Earth)

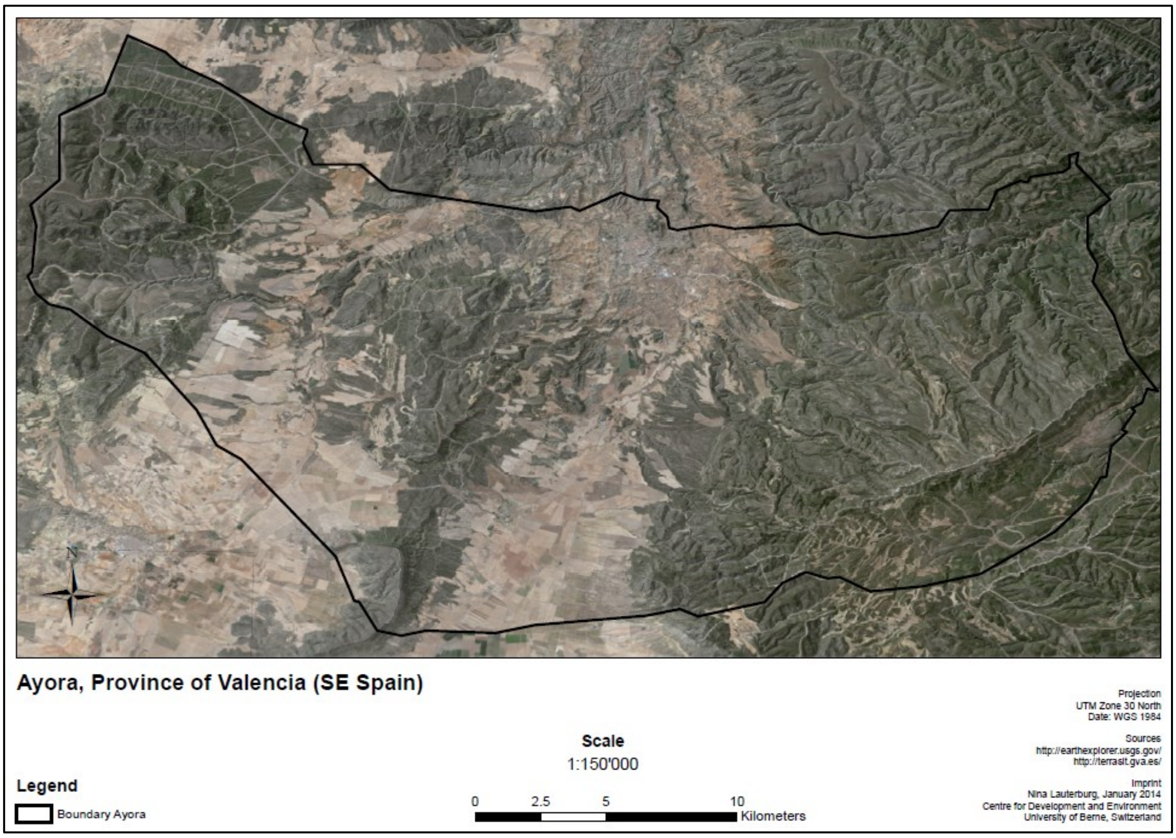


Figure 10: Study site Ayora (Nina Lauterburg 2014, data sources: USGS, Terrasit)

1.5.1 Ecological Environment

The landscape of Ayora is mountainous with altitudes ranging from 500m to 1128m and has moderate to steep slopes. The dominant soil types are Regosols (with low stoniness) which developed over marls, and shallow Leptosols and Luvisols which are found over limestones (CASCADE 2011).

At present, the vegetation is mainly composed of regenerating pine woodlands and shrublands at different successional stages (CASCADE 2011). If trees are present, the main species are Pinus halepensis and Pinus pinaster. The most abundant seeder shrubs are Rosmarinus officinalis (rosemary), Ulex parviflorus (gorse) and Cistus albidus (rockrose). Furthermore, there are still some resprouter shrubs such as Quercus coccifera (kermes oak), however in a lower proportion (Santana et al. 2013, Baeza et al. 2011).

The climate of Ayora is classified as dry Mesomediterranean (Rivas-Martinez 1987), or as BSk (semiarid) using the Köppen climate classification (Pidwirny 2012). The mean annual rainfall ranges from 350 to 700mm and mean annual temperatures are between 13 and 17°C (Baeza et al. 2007: 244). The highest temperatures are recorded in July and August, the lowest in January. The winters are relatively cold, therefore also snow is frequent. The driest months are July and August whereas the highest amount of precipitation is recorded in spring and autumn (figure 11).

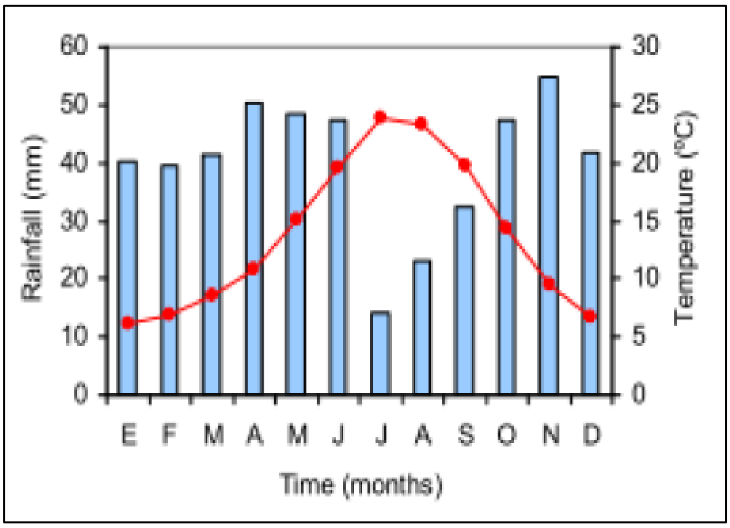


Figure 11: Mean monthly rainfall (mm) and temperature (°C) in Ayora for the period 1961-1990 at the Ayora CHJ weather station (641 m a.s.l.) (PRACTICE Deliverable D3.1b n.d.)

According to stakeholder interviews, there is a general trend observed of decreasing precipitation (snow and rainfall) and increasing aridity in the inland of Valencia. Forest fires constitute the main degradation driver in Ayora.

The risk of fire incidence is at its highest from June to September when there are adverse conditions such as drought, high temperatures and strong winds (mainly the winds coming from central Spain, called “poniente”). Ayora has been affected by several wildfires of which the fire of 1979 was the biggest and most devastating one, burning approximately 33’000 ha and 26% of the surface of Ayora. Following this large fire, several smaller fires occurred, for example in 1991 when 5’000 ha burnt (Baeza et al. 2007).

Image 1: General view of the Ayora valley, including the area burnt in 1979 in the front (Nina Lauterburg 2013)

1.5.2 Social and Economic Environment

The Ayora region, which covers an area of 446.6 km^2, is composed of a small village and its surrounding areas (mainly forests, shrublands and cropland). In the year 2013, most of the local people (total population: 5457) lived in the village of Ayora (Argos 2014).

As it is the case for almost the whole Mediterranean region, also in Ayora the land has been strongly used which resulted in a modification of the landscape and significant forest loss.

According to Baeza et al. (2007), forest exploitation was one of the most important economic resources in Ayora before the fire in 1979. The wood was used in several industries, e.g. for construction, packages, pallets, paper, furniture, fuel wood, energy production, etc.

However, triggered by the industrialisation and the large fire in 1979, Ayora has undergone a major socio-economic change which has resulted in a generalized abandonment of forest, traditional agricultural practices and grazing activities, and a decrease in the rural population density. This is especially the case in mountainous areas. This trend also partly roots in the restrictions which have been introduced by the government after the fire in 1979; the state bought major parts of the burnt area and limited exploitation through grazing or agriculture to ensure regeneration.

Nowadays, the cultivated area is mainly located in the valleys, where mechanisation is possible. Due to the high costs of wood extraction and low economic profitability, wood extraction lost its importance.

According to stakeholder interviews, local people work for example in agriculture, honey production, construction, artesanry, restaurants, shops, transport, or forest management.

In the 1970s, a nuclear power plant was constructed near to Ayora (image 2) and the production of electricity started in 1984, therefore many local people started to work in the construction of the power plant. Until the present day, the power plant has always been an important source of jobs (PRACTICE Deliverable D3.1b n.d., Llovet López et al. 2012, GEORANGE Website n.d.).

Image 2: Nuclear power plant near to Ayora (Nina Lauterburg 2013)

Although there are only few job opportunities in Ayora, it seems that rural people are less affected by the current economic crisis than urban dwellers due to lower living costs in the countryside.

Table 3 summarizes important facts of the study site.

Area	Yearly rainfall	Elevation range	Total pop.	Pop. density	Main ecosystems	Indications for irreversible change	Drivers of change
446.6 km^2	350-700 mm	500m-1128 m a.s.l.	5457	12.2 persons/ km^2	Shrubland, pine woodland, abandoned cropland	Changed vegetation composition, decreased ecosystem resilience towards fire	Increased fire incidence

Table 3: Characterisation of the study site Ayora (Nina Lauterburg 2014, data sources: CASCADE 2011, Argos 2014)

1.5.3 Main ecosystem services (ESS)

In order to faciliate the understanding of the results of this master thesis, important ESS of forests and shrublands are presented in table 4. The definition of ESS is provided in chapter 2.1.5.

At present, traditional practices such as agriculture and grazing are only marginal activities whereas hunting and honey production are main activities in Ayora. Furthermore, forests and shrublands provide numerous ecological services, amongst others soil and water conservation, photosynthesis, habitat, and carbon sequestration. Notably, rural tourism (ecotourism) gained importance in the area which results in a considerable number of forest visitors (PATFOR 2011).

Productive services	Ecological services (regulating/supporting)	Socio-cultural services/human well-being
Wood/timber	Biodiversity	Recreation
Fuel wood	Habitat	Hiking
Honey production	Carbon sequestration	Ecotourism
Game	Climate regulation	Aesthetic value
Pastures, marginal grazing	Plant composition and cover	Food and livelihood security (e.g. jobs in forest management)
Forage	Photosynthesis	Hunting
Agricultural products (wheat, olives, almond, fruits)	Nutrient cycling	
Aromatic and medical plants	Soil formation	
Mushrooms	Soil and water conservation	
Forest fruits (e.g. berries)	Regulation of fires	
Seeds	Pest control	

Table 4: Important ecosystem services in Ayora (Nina Lauterburg 2014, data sources: CASCADE 2011, CASCADE Website 2014, PATFOR 2011, interviews with stakeholders)

2. Theoretical Background

2.1 Definitions

In order to facilitate the understanding, the subsequent chapter provides definitions of the most important terms or concepts which are used in this thesis.

2.1.1 Regime shifts, thresholds and tipping points

Regime shifts are at the center of the CASCADE project and within this thesis, regime shifts in Ayora are assessed. Since chapter 2.3.1 will further elaborate this issue, only a brief explanation will be provided here.

Various years of research showed that ecosystems can suddenly shift to a new state, which is characterized by a different structure, species composition and functioning. Such abrupt regime shifts from one state to a degraded state, separated by a tipping point, can have severe economic and ecological consequences.

The term ecological threshold is defined as a

> *"limit or amount of external pressure/change at which there is an abrupt change in an ecosystem property, or phenomenon. At this point small changes in one or more external conditions produce large and persistent responses in an ecosystem. A threshold is not necessarily associated with a tipping point, and thresholds can be passed without feedback or hysteresis" (CASCADE glossary n.d.).*

2.1.2 Land Degradation

As mentioned above, regime shifts may have severe consequences and may cause land degradation. In the glossary of the CASCADE project, three different definitions of land degradation are provided:

> *"the reduction of resource potential by one or a combination of processes acting on the land. These processes include water erosion, wind erosion and sedimentation by those agents, long term reduction in the amount or diversity of natural vegetation, where relevant, and salinization and sodication" (UNEP).*

> *"the reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rainfed cropland, irrigated cropland, or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns" (UNCCD 1994).*

> *"the reduction in the capacity of the land to provide ecosystem goods and services and to assure its functions over a period of time for its beneficiaries" (LADA 2009).*

Ponce-Hernandez and Koohafkan (2004: 8) have developed a further definition of land degradation which is also important for this master thesis. Land degradation is understood as a

> *"complex set of processes of impoverishment of terrestrial ecosystems under the impact of human activities. Land degradation can be understood as the gradual or permanent loss of productivity of the land resulting from human activities, mainly from the mismatch between land quality and the intensity of activities as part of the actual land use".*

To draw a conclusion, in most cases land degradation has negative impacts on natural resources resulting from unsustainable land management.

According to Liniger et al. (2008a: E6-E8), the following degradation types exist:

Main degradation type	Examples
Soil erosion by water	loss of topsoil, gully erosion, mass movements, riverbank erosion, coastal erosion, off-site degradation effects
Soil erosion by wind	loss of topsoil, deflation and deposition, off-site degradation effects
Chemical soil deterioration	fertility decline, reduced organic matter content, acidification, soil pollution, salinisation
Physical soil deterioration	compaction, sealing and crusting, waterlogging, subsidence of organic soils, loss of bio-productive function
Water degradation	aridification, change in quantity of surface water or aquifer level, decline of surface water/groundwater quality, reduction of the buffering capacity of wetland areas
Biological degradation	reduction of vegetation cover, loss of habitats, quantity/biomass decline, detrimental effects of fires, quality and species composition/diversity decline, loss of soil life, increase of pests

Table 5: Main degradation types (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E6-E8)

It should be noted that this master thesis does only assess the major degradation types occurring in Ayora, which includes mainly degradation of vegetation.

2.1.3 Sustainable Land Management (SLM)

Sustainable land management (SLM) is considered as the key to avoid or reverse land degradation and is required to achieve a sustainable development. WOCAT uses the following definition of SLM:

> *"The use of land resources, including soils, water, animals and plants, for the production of goods to meet changing human needs, while simultaneously ensuring the long-term productive potential of these resources and the maintenance of their environmental functions" (WOCAT 2007: 10)*

As stated by Liniger et al. (2008a: iii)

> *"the main objective of SLM is to promote long-lasting human coexistence with nature so that the provisioning, regulating, cultural and supporting services of ecosystems are ensured for future generations".*

2.1.4 SLM Technology and SLM Approach

SLM technologies can be understood as the physical practices in the field and are defined by WOCAT as

> *"agronomic, vegetative, structural and/or management measures that prevent and control land degradation and enhance productivity in the field" (WOCAT 2007: 10).*

In contrast, SLM approaches are "the ways and means of support that help introduce, implement, adapt and apply SLM technologies on the ground" (WOCAT 2007: 10).

The combination of a SLM technology with a corresponding approach is defined as a sustainable land management strategy within a selected area (Schwilch et al. 2012: 15).

Thus, SLM strategies aim to address and reduce land degradation in a specific context. Since this research project focuses on vegetation degradation, the documented SLM practices are classified as vegetative measures.

2.1.5 Ecosystem Services (ESS)

If assessing regime shifts, land degradation and sustainable land management, the term ecosystem services is of major importance and is therefore used frequently in this thesis.

The Millenium Ecosystem Assessment (MEA) focuses on the linkages between ecosytems and human well-being and defines ecosystem as "a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit" (MEA 2005: V). As stated in the MEA people are an integral part of the ecosystem and there is a dynamic interaction between them and other parts of the ecosystem.

Through the increasing complexity of human societies one seems to gain the impression that humans do not longer depend on the natural system. However, we still rely completely on the services it delivers. Ecosystem services are defined as "the benefits people obtain from ecosystems. These include provisioning services such as food, water, timber, and fiber; regulating services that affect climate, floods, disease, wastes, and water quality; cultural services that provide recreational, aesthetic, and spiritual benefits; and supporting services such as soil formation, photosynthesis, and nutrient cycling" (MEA 2005: V).

Derived from the MEA, Liniger et al. (2008a: E14) terms provisioning services as productive services, and regulating and supporting services are listed as ecological services. Table 6 provides an overview of ecosystem services as defined in the WOCAT mapping questionnaire.

Productive services	Ecological services	Cultural services
Production of animal/ plant quantity and quality including biomass for energy Water quantity and quality for human, animal and plant consumption Land availability	Water services (e.g. regulation of scarce or excessive water) Soil services (e.g. soil formation, nutrient cycling, soil cover) Biodiversity Climate services (e.g. microclimate, greenhouse gas emissions)	Spiritual, aesthetic, cultural landscape and heritage values, recreation and tourism Education and knowledge Conflict transformation Food & livelihood security and poverty Health Net income Protection / damage of private and public infrastructure Marketing opportunities

Table 6: Ecosystem services defined in the WOCAT mapping questionnaire (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E14)

2.1.6 Ecological succession

To understand the processes occurring in Ayora, knowledge on ecological succession is crucial. Therefore, a short explanation is provided here.

Ecological succession can be understood as

> *"the gradual and orderly process of change in an ecosystem brought about by the progressive replacement of one community by another until a stable climax is established" (CASCADE Glossary n.d.).*

Luken (1990) describes the process of succession as the tendency of plant communities to change through time as they age. The changes can be shifts in population structure, species replacements and changes in resource availability, e.g. light and nutrients. This process was first reviewed by Clements in 1916. He proposed six basic processes which occur during succession: nudation, migration, ecesis, competition, reaction, and stabilization. In summary, these terms describe the process from a patch of bare soil where succession starts after being colonized by plants, until the establishment of certain plant communities. Through competition on limiting resources, some species will be eliminated, whereas other species will be in favour (Luken 1990).

It should be noted that there is primary (figure 12) and secondary succession (figure 13). Primary succession describes the establishment of plants on land that has not been previously vegetated. It starts with colonization and establishment of pioneer species (physicalgeography.net n.d.).

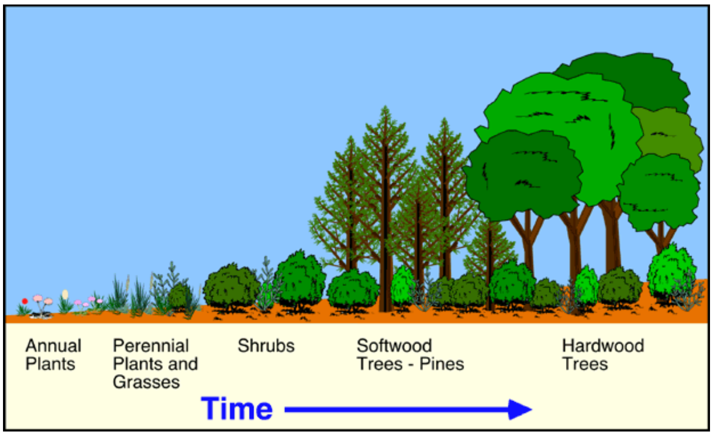


Figure 12: Primary succession (physicalgeography.net n.d.)

However, landscape transformations caused by humans often resulted in the disturbance of natural succession (Luken 1990). Therefore, in contrary to primary succession, secondary succession is described as the establishment of plants in areas which were previously vegetated and where the vegetation was removed by disturbances such as fire or cultivation (abandoned fields) (physicalgeography.net n.d.).

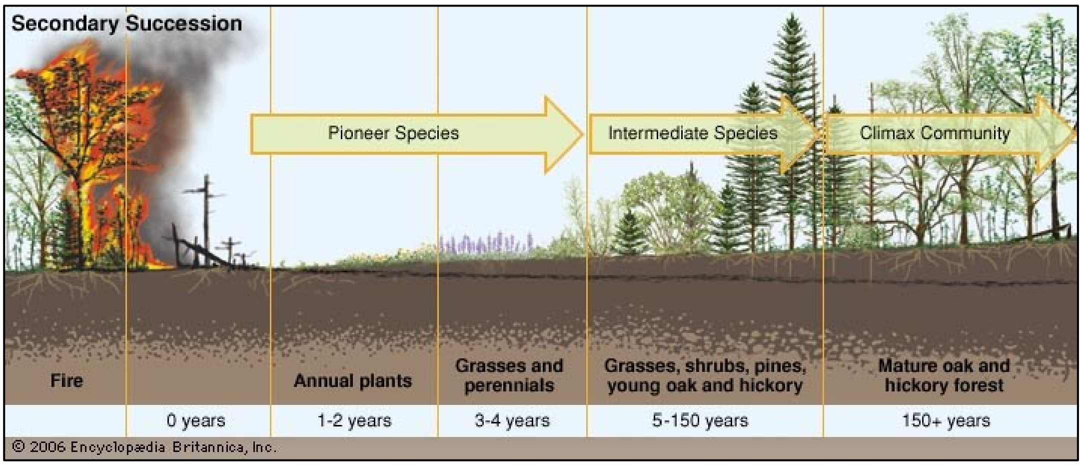


Figure 13: Secondary succession after a fire (Encyclopedia Britannica 2006)

Early-successional species such as Cistus albidus, Ulex parviflorus and Pinus halepensis, develop in the early stage of the ecological succession. Early-successional species accumulate huge amounts of dead standing biomass and may therefore promote fires. In contrast, late-successional species such as Juniperus oxycedrus, Quercus coccifera and Quercus ilex contain a lower amount of fuel and therefore a lower fire risk (Baeza et al. 2011).

2.2 State of the art

This chapter presents where and how far research has already been conducted concerning the relevant issues of this master thesis. Thereby, research gaps are identified. In a first step, the state of the art on regime shifts is presented briefly. In a second step, the research on fires in the Mediterranean basin with a focus on Spain is discussed. Ultimately, prior WOCAT research in Spain and on forest fires is presented.

2.2.1 Research on regime shifts

The state of the art presented here is mainly based on the information provided on the CASCADE website. The state of the art will be further investigated through the PhD thesis of Matteo Jucker Riva and through the research conducted by the different WPs within the CASCADE project.

Although the research of ecological thresholds has increased over the last few decades, it is still difficult to understand and predict regime shifts and thresholds. Models show that thresholds exist, however it is a challenge to find evidence in the real landscape. Therefore it has become obvious that there is still a lot to be done in order to improve the knowledge on ecological changes before, during and after thresholds.

This huge challenge is addressed by the CASCADE project in an integrated way. The main objective of CASCADE is to find effective strategies to predict and prevent such regime shifts. CASCADE focuses on drylands based on the general agreement that these regions are among the most threatened ecosystems in Europe, experiencing regime shifts from one state to another. The project aims at developping an approach which will serve as the base for sustainable management of these ecosystems. For drylands in Europe, such detailed and integrated modelling and participatory evaluation does still not exist. Thus, natural resource managers will directly benefit from the results of the project (CASCADE Website, MEA 2005).

Apart from the research conducted through CASCADE, it should be noted that there is a database on regime shifts which can be accessed through the following link: http://www.regimeshifts.org/

2.2.2 Research on forest fires in the Mediterranean basin

As stated in the introduction, fires are a major natural threat and a main degradation driver in many regions in the Mediterranean basin. Thus, research on drivers, impacts and management of fires is crucial.
In the following, a general overview of relevant research activities and past or on-going projects related to wildfires in the Mediterranean region is provided. It should be noted that this list is incomplete, however it provides information on some important activities.

2.2.2.1 Global Forest Resources Assessment (FRA)

Since 1946, the Food and Agriculture Organisation (FAO) has been monitoring the world's forests. The findings are published in the report "Global Forest Resources Assessment (FRA)" with an interval of 5 to 10 years, in order to decribe the forests and their dynamics in a consistent way (the most recent report was published in 2010). It is based on country reports and on remote sensing data. Forest fires constitute a relevant issue of the report as well. However, Europe is treated as one region and there is no division between different European countries.

FRA on the FAO website: http://www.fao.org/forestry/fra/en/

2.2.2.2 European Forest Fire Information System (EFFIS)

The Joint Research Centre (JRC) and the Directorate General for Environment of the European Commission jointly established the European Forest Fire Information System (EFFIS) where harmonized data on forest fires is collected aiming to support fire management in Europe. The research activities for the development of the system started in 1998, whereas in the year 2000 the first EFFIS operations were carried out. Since then, EFFIS has provided a platform to share good practices on fire prevention, fire fighting, restoration practices and other activities related to fire management. Long-time series of forest fire data are mainly available for France, Greece, Italy, Portugal and Spain. Notably, since the year 2011, the European Commission prepared the base to involve Middle East and North African (MENA) countries in the activities of EFFIS and to include them as members of its Expert Group on Forest Fires (EGFF). This was supported by Silva Mediterranea (FAO) and GIZ and represents a first step to expand the EFFIS system to other countries.

There are currently 38 countries which are part of the EGFF: Austria, Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, the Netherlands, the United Kingdom, Albania, Bosnia & Herzegovina, FYROM, Kosovo, Montenegro, Norway, Russia, Serbia, Switzerland, Turkey, Algeria, Lebanon, Morocco and Tunisia.

EFFIS publishes annual reports on forest fires. The 13th report, which is the most recent one, is titled as "Forest Fires in Europe, Middle East and North Africa 2012". These reports are now highly appreciated because they document the previous year's forest fires and contain information on the fire risk evolution, fire danger forecast, fire damage assessments and fire statistics based on data provided by the national experts. There are also chapters which provide insights about efforts on the national or regional level. A web mapping interface has been established which provides EU wide data on forest fires. Information about the on-going fire season is updated daily, providing maps on fire danger up to six days in advance or fire perimeters of active fires (FAO 2013, JRC 2013).

EFFIS is accessible through the following link: http://forest.jrc.ec.europa.eu/effis/

2.2.2.3 Integrated System on Forest Fire Management (SIGIF) in Valencia

There also exists a database on forest fires of the government of Valencia (Generalitat Valenciana). The Integrated System on Forest Fire Management (SIGIF) was established within the fire prevention plan of Valencia. Amongst others, information on meteorological conditions, prevention infrastructures, water deposits, forest observatories and fire risk is provided. It shoud be noted that Geographical Information Systems and the application of remote sensing has a huge potential for sustainable management of fire threatened regions. This system will be presented more in detail in the results.

SIGIF is accessible through the following link, however you need to ask for access:
http://www.vaersa.org/prevencion/

2.2.2.4 Important past and on-going projects

Table 7 presents an overview of important European projects concerning forest fires. All of these projects included Spain or in some cases even Ayora as a study site.

Project	Description
COST Action (ES1104) Arid Lands Restoration and Combat of Desertification 2012-2016.	This COST Action aims to create an "Arid Lands Restoration Hub" to provide guidance for dryland restoration and combat of desertification. An integrated database will deliver information of current and new methods of restoration, field studies, assessment indicators, academic and practical publications, and tools to support restoration projects and decision-makers in planning and restoring drylands. Project website: http://desertrestorationhub.com
FUME 2010-2013: Forest fires under climate, social and economic changes in Europe, the Mediterranean and other fire-affected areas of the world [GA243888].	This project was funded by the 7th Framework Programme of the European Union and aimed to document and evaluate land use changes and other factors (such as climate, socio-economic factors) which influence forest fires in Europe. A further objective was to conduct a review of current practices of fire prevention and management of fire-prone areas. Project website: http://www.fumeproject.eu/
PRACTICE 2009-2012: Prevention and Restoration Actions to Combat Desertification. An Integrated Assessment [FP7-ENV-2008-1 nr. 226818].	The main objective of the PRACTICE Project, which was funded by the European Commission, was to link science and society in order to share best practices to combat desertification. Ayora was a study site in this project and the effectiveness of prevention and restoration practices such as "afforestation" and "forest thinning" was assessed in collaboration with important stakeholders. Project website: http://80.24.165.149/drupal/
COST Action (FP0701) on Post-Fire Forest Management in Southern Europe 2008-2012.	This COST Action, which was realized between 2008 and 2012, focused on the restoration of burnt areas and on the opportunity to establish more resilient forests. The main research question was how to manage 500'000 ha of burnt forests in Europe every year. The main objective was to develop and disseminate scientifically-based decision criteria for post-fire management. There was a focus on fire hazard and resilience, fire effects and severity, global warming impacts, economic assessment of damage and current practices in post-fire management, forest conversion and post-fire management techniques, and knowledge transfer. Within this action, they reviewed the current scientific knowledge on post-fire management in Europe. Afterwards, the knowledge was transferred to technical recommendations and disseminated to important stakeholders. The results are published in the book "Post-Fire Management and Restoration of Southern European Forests". Project website: http://www.cost.eu/domains_actions/fps/Actions/FP0701

Project	Description
FIREMED 2009-2011: Fire recurrence in Mediterranean ecosystems: consequences for regressive or progressive successional trajectories in a global change scenario [AGL 2008-04522/FOR].	It is acknowledged that fire recurrence can lead to regressive successions towards shrublands. This project was funded by the Spanish government and aimed to increase the knowledge on the effects of recurrent fires on the persistence mechanisms of germinating species and on the successional dynamics of ecosystems in the Mediterranean region. There is no project website.
SPREAD Project [EVG1-2001-0027].	The SPREAD project, which was funded by the European Commission, aimed to increase the knowledge of the phenomena that influence forest fires at all stages in order to support the policy and decision making process for the institutions and individuals involved in the management of fires in European countries. Project website: http://www.algosystems.gr/spread/ The experiment on selective clearing and planting which is documented in this master thesis was conducted within the SPREAD project.
FireParadox 2006-2008: An Innovative Approach of Integrated Wildland Fire Management Regulating the Wildfire Problem by the Wise Use of Fire: Solving the Fire Paradox.	The main objective of this project was to create a scientific and technical base in order to define which new practices and integrated management policies will ensure Europe's ability to prevent and fight fires most effectively. The strategical use of fire such as prescribed burning is assessed. The Fire Paradox is a European project of the 6th Development Research programme. Project website: http://www.fireparadox.org
GEORANGE 2001-2003: Geomatics in the assessment and sustainable management of Mediterranean rangelands [EVK2-CT-2000-00091].	This project was funded by the European Union and included experts in range ecology and management, ecosystem conservation and restoration, remote sensing and spatial information systems. It defined optimised management strategies for multi-functional rangelands, involving land managers. Project website: http://fern39.uni-trier.de/georange/start.html Ayora was a study site in this project.
LUCIFER 1997-2000: Land use change interactions with fire in Mediterranean landscapes [ENV 4-CT96-0320].	Objectives of this project were to determine the change of landscapes of fire-prone areas in the last decades of all the Mediterranean countries of the European Union, how fires themselves have contributed to such change, and which role landscape changes have played in promoting fire. An assessment was carried out on whether fires induce a further homogenization of the burnt area, thus increasing the fire risk. Furthermore, there was a focus on postfire species dynamics. The project was funded by the European Commission. Project website: http://pendientedemigracion.ucm.es/info/lucifer/

Table 7: Overview of important European projects on forest fires (Nina Lauterburg 2014, data source: CASCADE Website 2014)

Although there have been carried out many projects and a lot of research is going on, fire prevention is still a major challenge and Europe continues to be threatened by a high fire risk. To reduce the adverse impacts on ecosystems and the livelihoods of local people, it is crucial to investigate on prevention measures to control the recurrent wildfires. Thus, assessing fire prevention practices and post-fire management is still a relevant issue. Furthermore it is crucial to disseminate the existing knowledge on sustainable management measures in order to support other countries. The detailed documentation of SLM practices related to forest fires or particularly the public access to these documentations is still weak. Using the WOCAT tools allows to assess the measures in a standardized way and to disseminate the knowledge to a broad audience.

2.2.3 Importance of WOCAT to assess land degradation and conservation

According to Schwilch et al. (2011), sustainable land management is promoted to prevent and mitigate land degradation, but assessment has usually been focused more on land degradation than on the sustainable management of land resources.

The first global map of soil degradation was produced by the Global Assessment of Soil Degradation (GLASOD) in the 1980s. However, this map had some limitations, for example the assessment was conducted at a coarse scale (1:15 million) and it was based on expert opinions focusing on soils.

Based on GLASOD and some additional data, two higher resoluted editions of a desertification world atlas were published in 1992 and 1997. However, these were single exercises at the continental and global scales.

Notably, SLM has now been recognized as the key to combat degradation and there is wide agreement that SLM has global benefits. There are many SLM technologies and approaches but the documentation of traditional land use systems, local land management and the assessment of their cost-effectiveness, impacts on ecosystem services, and on the economy is still weak (Schwilch et al. 2011). According to Hurni et al. (2006) science can contribute to SLM by producing evidence of the impacts of SLM on natural resources and by assessing the implications from these impacts on society, economy and policy.

In order to collect information on the application of SLM worldwide, the World Overview of Conservation Approaches and Technologies (WOCAT) was founded in 1992. Today, the WOCAT programme is an established global network of mainly soil and water conservation specialists. "WOCAT's vision is that existing knowledge of sustainable land management is shared and used globally to improve livelihoods and the environment. WOCAT's mission is to support decision-making and innovation in sustainable land management by connecting stakeholders, enhancing capacity, developing and applying standardised tools for the documentation, evaluation, monitoring and exchange of soil and water conservation knowledge." (WOCAT 2007: 10).

Notably, through the application of the mapping questionnaire, which is currently the only standardized method to map land degradation and conservation, it is possible to evaluate what type of land degradation is actually occurring where and why and what is done in terms of SLM. The mapping database and the created maps provide a powerful tool to obtain an overview of land degradation and conservation in a specific area (Liniger et al. 2008a: E1).

The knowledge is collected in a database which serves as a basis to share the diverse options or ideas (best practices) from all over the world with other land users or land managers (Schwilch et al. 2012).

Thus, the aim of WOCAT is "to unite the efforts in knowledge management and decision support for up-scaling SLM among all stakeholders including national governmental and non-governmental institutions, international and regional organizations" (WOCAT Website 2014).

2.2.4 WOCAT research in Spain and on forest fires

The application of the WOCAT tools in Spain is still very limited. Currently, there are no Spanish documentations available on forest management or fire management. However, through the DESIRE project (2007-2012) and the COST Action ES1104 (2012-2016), some case studies of Spain were added to the database:

- Reduced contour tillage of cereals in semi-arid environments (Murcia)
- Vegetated earth-banked terraces (Murcia)
- Organic mulch under almond trees (Murcia)
- Water harvesting from concentrated runoff for irrigation purposes (Murcia)
- Ecological production of almonds and olives using green manure (Murcia)
- Cover crops in organic vineyards (Madrid)
- Cover crops in olive orchards (Madrid)

These examples show that the documented measures are mainly dealing with degradation problems on agricultural land. Up to now, WOCAT heavily focused on SLM practices related to agriculture or grazing land, implemented by small-scale land users in developing countries, whereas forest management is only addressed in few cases. Thus, the CASCADE project and particularly the Ayora study site is a special task for WOCAT due to the different context of SLM (forest fires, management conducted through the government).

Notably, Portugal documented some technologies and approaches related to forest fires during the projects DESIRE and CASCADE:

- Primary strip network system for fuel management (firebreaks)
- Prescribed fire
- Post-fire forest residue mulch
- Forest intervention area (approach)

Due to the rare application of the WOCAT tools on forest issues in the European context, some parts of the questionnaires were not applicable and some sections even had to be further developed.

2.3 Conceptual Framework

In order to understand the conceptual framework in which this thesis is embedded, two important concepts are briefly presented in the subsequent chapter.

To assess regime shifts in Ayora and thus to achieve the first objective of this thesis, the negative regime shift concept provides the theoretical background and links this master thesis to the CASCADE project. To achieve objectives 2-4 this concept is combined with the SLM-DPSIR framework.

2.3.1 Negative regime shift concept

According to Crépin et al. (2012), the dynamics of human activities and ecosystems are tightly interlinked and there is an increase in the occurrence of regime shifts in social-ecological systems. Regime shifts can be understood as substantial reorganizations in the functions and feedbacks of a system. Such shifts can therefore have significant impacts on ESS and human well-being.

As stated by Ravi et al. (2010), drylands are experiencing rapid land degradation and shifts in the vegetation composition in response to climate change and anthropogenic disturbances. This may affect the productivity of the land and result in environmental, socio-economic and political implications.

According to Crépin et al. (2012: 17) "different regimes can be mathematically represented by a stability landscape with different domains of attraction (valleys). A regime shift entails a shift in the current system state (represented as a ball) from one domain of attraction to another. Regime shifts are usually due to a combination of a shock (e.g. drought or flood), and slow changes in external drivers and/or internal feedbacks that change the domains of attraction (or resilience) of the different regimes" (figure 14). It should be noted that this concept illustrates a negative regime shift, where recovery to the previous state seems not to be possible.

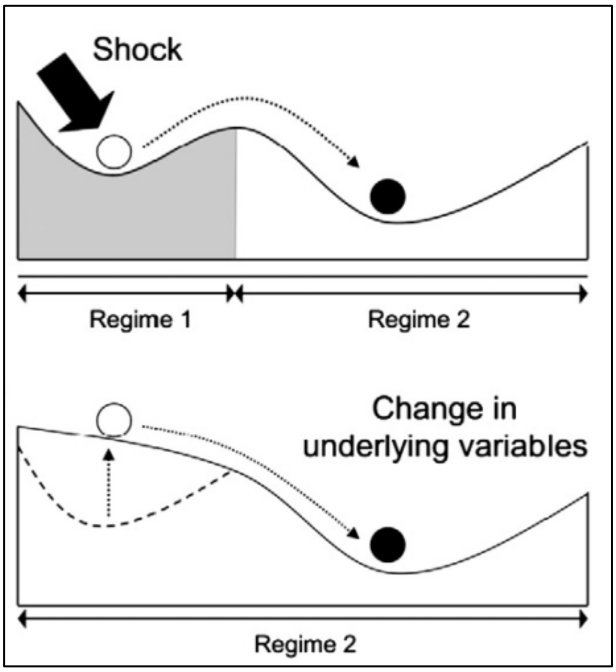


Figure 14: Negative regime shift concept (Crépin et al. 2012: 17)

Fires have already been assessed using threshold concepts. However, most examples are on the transition from Savannah to a shrub-encroached woodland state, which is a different situation than the one in Ayora (where the natural state would be a forest). According to Scheffer et al. (2001: 593) many studies showed that woodlands and grassy open landscapes can be alternative stable states. The natural state in Savannahs consists of sparse trees combined with a grass layer. From the combination of a change in fire and grazing regimes, the result could be a dense woody state through bush encroachment. Usually, natural fires can reduce the woody plant cover and thus enhance the growth of the grass layer. Scheffer et al. (2001: 593) further explains that "excessive grazing by livestock reduces grass and hence fuel for fire. In the absence of fire, cohorts of shrubs establish during wet years and can suppress grass cover, thereby inhibiting the spread of fire".

In contrast to this example, this master thesis applies the negative regime shift concept on the shift from forest to shrubland (and probably to grassland), caused by anthropogenic disturbances and forest fires.

Bestelmeyer (2006) argues that the recognition of states and thresholds has been very useful to prioritize management efforts. However, regime shifts are challenging for management. Even if the input which caused the shift is reduced or removed, in many cases the system tends to remain in this particular regime. The dynamics and feedbacks may keep the system locked which makes it very difficult or even impossible to reverse regime shifts once a threshold has been passed. Therefore, one objective of management should be to reduce the probability of regime shifts (Crépin et al. 2012).

2.3.2 Overall Framework of Sustainable Land Management (SLM-DPSIR)

The second theory, on which this master thesis is based on, is the overall conceptual framework of SLM. Mainly the objectives 2 to 4 are referring to this concept, however always combined with or related to the first theory. The link between these concepts will be discussed in chapter 2.3.3.

This framework provides an overview of the cause-effect interactions of degradation and sustainable land management on the environment and human well-being. It combines elements of two conceptual frameworks which are widely known. First, the framework of drivers, pressures, states, impacts, responses, the so-called DPSIR framework (Smeets and Weterings 1999), and second the perspective of ecosystem services which is used in the Millenium Ecosystem Assessment (MEA 2005). In order to understand the dynamics between humans and the environment, this framework has been used by several scientists (Schwilch et al. 2011).

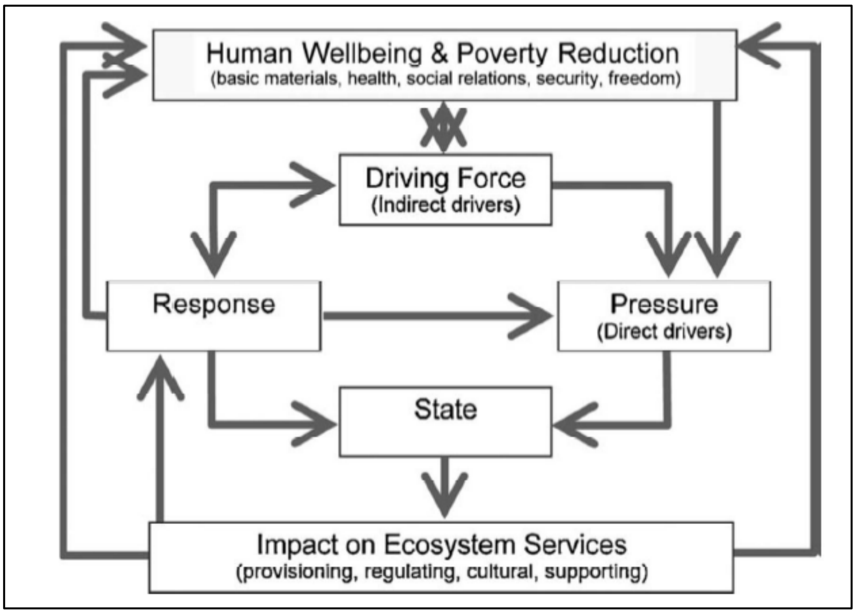


Figure 15: Conceptual framework of SLM (SLM-DPSIR) (Schwilch et al. 2011: 216)

Campuzano and Mateus (2008: 31) state that the idea of the DPSIR concept is that “human activities i.e. the drivers exert a certain pressure on a particular part of the natural environment causing a change in its components and/or in its overall state. The outcome of this process is an environmental impact which usually results in certain response by the society. The response can run across different segments of society, from the political arena, to socio-economic and purely economic sectors. Eventually, responses can modify the nature of the driving forces (thus mitigating or enhancing the actual pressure) and/or compensate for the impact. Finally, the driving forces may also be altered directly by the impact.”

WOCAT uses the SLM-DPSIR model as a central theoretical framework. Therefore, this concept was selected to facilitate the analysis of regime shifts occurring in Ayora. In order to illustrate the theoretical background of WOCAT's methods and thus also the one of this thesis, the SLM-DPSIR model will be explained in detail in the following section.

The framework contains five permanently interacting variables: Drivers, pressures, state, impact and responses. During my field stay and writing process, all these elements have been analysed and will be presented in the results.

Drivers:

According to Kristensen (2004: 2) a driving force represents a human need. He distinguishes between primary needs such as shelter, food and water, and secondary needs such as mobility, entertainment and culture. Human activities are the result of these driving forces. Within the SLM-DPSIR framework, driving forces are termed as indirect drivers and can be understood as indirect causes of land degradation. Examples of driving forces mentioned in Liniger et al. (2008a) are incidence of poverty/wealth, access rights/land tenure, population density, labour availability, inputs and infrastructure, occurrence of conflicts, education, knowledge and access to support service, and protected areas.

Pressures:

Kristensen (2004:2) states that the human activities, resulting from the driving forces (to meet a need), "exert pressures on the environment". He distinguishes three types of pressures: excessive use of environmental resources, land use changes, and emissions to water, soil and air (e.g. chemicals, waste). Within WOCAT, pressures are seen as direct drivers of degradation which have an influence on the state of land degradation.

Indicators of pressures mentioned in Liniger et al. (2008a) are land use area trend, land use intensity trend, soil management level, crop management level, deforestation, over-exploitation of vegetation, overgrazing, industrial activities, urbanization, discharge of effluents, washing out of pollutants, disturbance of the water cycle, and natural causes.

To measure the effectiveness of responses, pressure indicators are essential (FAO LADA 2007).

State:

As claimed above, pressures directly or indirectly affect the state of the environment. Kristensen (2004: 2) argues that the pressures affect "the quality of the various environmental compartments (air, water, soil, etc.) in relation to the functions that these compartments fulfil". He concludes that "the state of the environment is thus the combination of the physical, chemical and biological conditions".

Hence, state indicators show the current conditions of the environment and mirror the effects of the pressures which are put on a specific area. In general, state indicators are slow in responding to changes in environmental pressures. However, in the long-term, the effectiveness of adopted responses is measured on the state of the ecosystem (FAO LADA 2007).

According to Liniger et al. (2008a), state indicators are for example the type, the degree and the rate of land degradation (soil, biological, water).

The state component is often used "as a proxy for changes in ecosystem services and subsequently human well-being" (Schwilch et al. 2011: 215).

Impact:

Impact indicators describe the effect of changes in the state (FAO LADA 2007). Kristensen (2004: 3) further explains that "the changes in the physical, chemical or biological state of the environment determine the quality of ecosystems and the welfare of human beings. In other words changes in the state may have environmental or economic impacts on the functioning of ecosystems, their lifesupporting abilities, and ultimately on human health and on the economic and social performance of society". Thus, each state can have either positive or negative impacts on ecosystem services.

According to Liniger et al. (2008a), impacts on ecosystem services are assessed for productive, ecological and sociological services.

Response:

A response by society, researchers or policy makers is understood as "a result of an undesired impact and can affect any part of the chain between driving forces and impacts" (Kristensen 2004: 3). Through direct or indirect actions, the impacts caused by state, pressures and driving forces are addressed. Thus, the efforts of a society to solve a problem are demonstrated by response indicators (FAO LADA 2007).

According to Schwilch et al. (2011: 215) SLM can be understood as the response to the drivers, pressures and states of land degradation, which improves the provision of ecosystem services and thus leads to human well-being and poverty reduction. SLM practices are documented through this master thesis.

Reponse indicators listed in Liniger et al. (2008a) are macro economic policies, land policies and policy instruments, conservation and rehabilitation, monitoring and early warning systems, commitment to international conventions, and s in land and water resources.

In summary, the main questions which are addressed through the application of the DPSIR framework are (FAO LADA 2007):

- What is happening to the state of the environment?
- Why is it happening?
- What is being done about it?

Furthermore, the conceptual framework also asks for the impacts of degradation and conservation on ESS and human well-being.

According to FAO LADA (2007) the framework helps to keep the focus on important issues, process links and interrelationships, and enables the integration of biophysical, social, economic, cultural and policy factors of land degradation and conservation.

2.3.3 Linking negative regime shift concept with the overall framework of sustainable land management

The regime shift concept is the base to analyse the regime shifts which already happened in Ayora. Focusing on the change in the vegetation composition, the regime shift concept illustrates the shift from one state to another (degraded) state. While the regime shift concept does only ask in a limited way for the causes of this shift, the SLM-DPSIR concept provides a framework to analyse this "state" component through the assessment of the other components such as drivers, pressures, impacts and responses. The combination of these concepts allows assessing the causes and consequences of regime shifts in terms of land use, land degradation and sustainable land management.

2.4 Contribution of this master thesis

This master thesis, which is providing a broad overview of causes and consequences of forest fires, regime shifts, and SLM practices currently applied in Ayora, is conducted in close collaboration with the CASCADE PhD Student of CDE, Matteo Jucker Riva. Within WP7, Matteo evaluates land management practices of all study sites and assesses the role of SLM in preventing regime shifts. The output will be a simple tool to support land managers and land users to assess the resilience of land management practices. Since all study sites have to apply the WOCAT tools to document local SLM practices, both the Spanish partner CEAM as well as Matteo will benefit from the assessment of SLM measures documented in my thesis.

There are many different projects which already focused on fire prevention or post-fire measures in Spain, but these measures have never been assessed in a standardized way. Through the documentation of SLM practices using the WOCAT tools, it will be possible to share the knowledge with other countries which are facing the same problems. Furthermore, forest fires have hardly been assessed by WOCAT so far and therefore this thesis contributed to further improve and adapt the WOCAT tools and to add new records to the database.

Furthermore, the mapping of land degradation and conservation practices provides an overview where the various degradation types occur to what extent, and where sustainable land management (SLM) is implemented. Maps are considered as a high priority requirement for the planning and implementation of sustainable land management strategies. As stated in the FRA report (2000), many countries have well developed systems for documenting, reporting and evaluating wildfire statistics, but many statistics do not provide sufficient information on the damaging effects of fires and the benefits of SLM. Thus, the impact assessment of degradation and conservation on ESS is a major contribution of the WOCAT mapping.

During my field stay and collaboration with CEAM, the need to do further mapping using remote sensing and GIS has become evident. Another CDE student (Camille Flückiger) conducts her master thesis on this issue, which in turn also supports the research of CEAM and contributes to the thesis of Matteo.

3. Methodology

The subsequent chapter explains the methods used in this master thesis. First, an overview of the methods is presented, and in a second step, each method is addressed in detail.

3.1 Overview of methods

As mentioned in the introduction, the main objective of WP7 of the CASCADE project is the evaluation of land use and management which help to prevent regime shifts. Sustainable natural resource management depends on SLM technologies and associated implementation approaches. Thus, all study sites have to identify, to document and to assess existing management practices and their appreciation by the stakeholders using the standard WOCAT format (questionnaire on technologies and questionnaire on approaches) (CASCADE 2011). This fact justifies the choice of the methods used in this thesis and it will enable the comparison of the documented management measures with other practices applied in the same context.

The WOCAT programme provides a range of questionnaires and modules:

- Questionnaire on Technologies (QT)
- Questionnaire on Approaches (QA)
- Mapping Questionnaire (QM)
- Watershed module
- Climate change module

Additionally to the Questionnaires on Technologies and Approaches, the Mapping Questionnaire was used in this master thesis in order to understand the spatial spread and interaction of land degradation and conservation. Other applied methods have been literature review, interviews (with a range of stakeholders), and field observations.

Methods for each of the specific objectives	
Specific Objectives	**Methods**
1. Assessing regime shifts related to fires in Ayora.	Literature review, semi-structured interviews (knowledge of resource persons), field observations
2. Mapping of land use, land degradation and SLM practices to provide an overview of state, responses and impacts.	**WOCAT Mapping Questionnaire (QM)**, literature review, semi-structured interviews (knowledge of resource persons), field observations
3. Documentation and impact assessment of local SLM technologies related to fires and regime shifts.	**WOCAT Questionnaire on Technologies (QT)**, literature review, semi-structured interviews (knowledge of resource persons), field observations
4. Documentation and impact assessment of approaches under which the local SLM technologies have been achieved.	**WOCAT Questionnaire on Approaches (QA)**, literature review, semi-structured interviews (knowledge of resource persons), field observations

According to Liniger et al. (2008a: E16) the mapping questionnaire “is intended to provide the information necessary to obtain a geographical display of some important conservation data”, whereas the questionnaires on SLM Technologies and on SLM Approaches “collect detailed information on conservation activities”.

Following a structured and standardized process, the use of questionnaires helps to better understand the reasons of sustainable land management strategies. The questionnaires are filled by researchers and specialists, together with land users. By collecting knowledge from several sources and by filling in the questionnaires the contributor does also review and evaluate the SLM practice. The data is collected in a database (Schwilch et al. 2012, WOCAT Website 2014).

3.2 Field work

To achieve the objectives and to answer the research questions of this master thesis, I conducted field work from March to end of June 2013. The start of my field stay was the CASCADE plenary meeting in Alicante in March 2013. Through the participation in the meeting, I gained highly valuable insights into the project and could already visit the study site. During and directly after the meeting the assessment of natural resource management has been initiated, in collaboration with my supervisors Hanspeter Liniger and Gudrun Schwilch, PhD student Matteo Jucker Riva, Alejandro Valdecantos from CEAM, and forest agent Vicente Colomer.

Image 3: Assessment of natural resource management in Ayora (Hanspeter Liniger 2013)

Image 4: Group picture including supervisors, forest agent and scientist from CEAM (Matteo Jucker Riva 2013)

Due to the collaboration with CEAM which is located at the University of Alicante, I lived in Alicante and went to the field by car (1.5 driving hours). The frequency of my field visits depended on several issues, e.g. access to the car of the university, or availability of the forest agent or researchers. Whenever I could go to the field, I talked to different stakeholders in order to fill the WOCAT questionnaires. However, since Ayora is located in an abandoned region with very few land users, I could not get all the required information from stakeholders in Ayora. Therefore, additional literature review and consultation of official project documents was required.

3.3 Literature review, semi-structured interviews, field observations

As mentioned above, important methods to gain further knowledge on forest management and the problems related to forest fires have been literature review, consultation of official project documents (in Spanish), field observations, and semi-structured interviews (informal and formal). CEAM already has a long tradition of research in Ayora, therefore they could provide a lot of scientific papers and were an important source of information. However, they have less information on SLM than on topics related to regime shifts and degradation resulting from fires. Informal semi-structured interviews were conducted for example with researchers from CEAM or with stakeholders I met in the field. Furthermore, formal semi-structured interviews were conducted with the head of extinction and prevention service, and with the municipal councillor of Ayora.

3.4 WOCAT Mapping Questionnaire (QM)

To understand the spatial coverage of degradation and conservation, the WOCAT mapping methodology was applied.

Through the application of the mapping questionnaire, it is possible to evaluate what type of land degradation is actually occurring where and why and what is done in terms of SLM. The information is collected using the questionnaire, which is available for anyone and filled by a team of local experts who are familiar with the area. The collected information is gathered in the database, which is linked to a Geographical Information System (GIS). This enables the production of a series of maps as well as area calculations on various aspects of land degradation and conservation. The mapping database and the created maps provide a powerful tool to obtain an overview of land degradation and conservation in a specific area (Liniger et al. 2008a: E1). Up to the present day, the WOCAT mapping methodology seems to be the only standardized method to map land degradation and conservation.

According to Schwilch et al. (2012: 12) the mapping process consists of the following steps. First, the area which will be assessed is divided into different land use systems (LUS). In a second step, the team collects the required data on land degradation and conservation for each LUS. After having collected the data, they can be added to the mapping database and various maps can be generated.

The steps of the mapping exercise are now explained more precisely.

3.4.1 Base map, land use systems (LUS) and mapping units

Before starting the degradation and conservation mapping exercise, there is a need to create a comprehensive base map, which is composed of base units to be evaluated. These units are defined by land use systems which can be found in the region. If there is no existing land use map available, the base map has to be created using satellite images and digitizing tools in a GIS. Land use is the starting point for mapping degradation and conservation because it is one of the main drivers of degradation and conservation. Furthermore, subdivisions have to be included in order to reduce the size of the LUS polygons (e.g. forest within one specific administrative boundary).

WOCAT therefore proposes a hierarchical system to define LUS mapping units, for which e.g. trends and changes of land degradation and SLM technologies can be evaluated (WOCAT Website 2014):

1. Land use type: Cropland, Grazing land, Forest/woodland, Mixed, Other
2. Subcategories of land use types
3. Further subdivisions: physiographic /geomorphologic criteria (e.g. slope type), watersheds, administrative units (e.g. districts, village), access (e.g. land proximity to water points or villages)

In my case, the base map was prepared in collaboration with PhD student Matteo Jucker Riva. We used the land use map SIOSE 2009, which is available for whole Spain (Sistema de Información sobre Ocupación del Suelo de España). The main land use types in Ayora are forest, shrubland, cropland, water and urban areas. Since the high fire recurrence is a main degradation driver in Ayora, the land use map was combined with the number of forest fires. The GIS layer on forest fires was obtained through the GEORANGE project. Furthermore, the aspect of the slope (north, south) was included. Thus, the LUS of the base map are a combination of land use type, number of fires and slope aspect. We further divided the terrain in Ayora East and Ayora West in order to add the required subdivisions to the base map. However, stakeholders told me in the field that there is no need to distinguish these areas with respect to degradation and conservation. Therefore, this base map does actually not have any administrative subdivisions. In order to make it compatible with the database, we slightly changed the LUS, e.g. LUS = unburnt forest north exposed was modified to LUS = forest, with subdivision 1 = north exposed, and subdivision 2 = unburnt. The LUS will be presented in the results of the mapping.

3.4.2 LUS: Area trend of LUS and land use intensity trend

After having created the base map, the mapping exercise is conducted in the field in collaboration with local stakeholders. In my case, the mapping exercise was executed as a combination of office and field work. Before going to the field, all steps of the questionnaire have been discussed intensively with researchers from CEAM. Thus, some uncertainties about the method could already be eliminated and the amount of various degradation types and drivers were reduced to the potentially available ones. The mapping was conducted almost at the end of my field stay, therefore after several weeks of field experience through the documentation of SLM technologies and approaches, I already had a broad knowledge on problems and conservation measures. The experts who contributed to fill the questionnaire in the field were two scientists from CEAM (Alejandro Valdecantos, Jaime Baeza), the forest agent of Ayora, and an ecologist.

In a first step, the increase or decrease of the LUS within a specific subdivision has to be estimated. If the area of one LUS is increasing, the area of another LUS will show a decreasing area trend. Changes in land use may be an important factor in soil degradation assessment and evaluation of conservation activities. Usually, the last 10 years are considered to estimate changes and trends. However, in my case, a time span of the last 34 years (1979-2013, starting from the first forest fire) was included due to the fact that forest dynamics are slower than dynamics on cropland. In a second step, the intensity of land use within a specific LUS and subdivision (=mapping unit) has to be assessed. A change in the intensity of land use often leads to land degradation or conservation and is therefore a significant indicator. Due to a lack of knowledge of stakeholders, I combined their indications with the analysis of CORINE land cover maps (1990, 2000, 2006) and literature review.

Linking QM with the SLM-DPSIR model, these categories are also termed as direct drivers (of degradation and conservation).

The area trend and land use intensity trend are ranked according to table 8:

Area trend of LUS	Land use intensity trend
2: area coverage is rapidly increasing in size; i.e. > 10% of the LUS area/34 years	**2**: Major increase: e.g. from manual labour to mechanisation, from low external inputs to high external inputs, etc.
1: area coverage is slowly increasing in size, i.e. < 10% of the LUS area/34 years	**1**: Moderate increase, e.g. a switch from no or low external inputs to some fertilizers/ pesticides; switch from manual labour to animal traction.
0: area coverage remains stable	**0**: No major changes in inputs, management level, etc
-1: area coverage is slowly decreasing in size, i.e. < 10% of the LUS area/34 years	**-1**: A moderate decrease in land use intensity, e.g. a slight reduction of external inputs.
-2: area coverage is rapidly decreasing in size, i.e. > 10% of that specific LUS area/34 years	**-2**: A major decrease in land use intensity, e.g. from mechanisation to manual labour, or a large reduction of external inputs.

Table 8: Area trend and land use intensity trend (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E4)

Table 9 has to be filled for each mapping unit using the categories indicated above.

Land Use System (Step 2)		
a) LUS area trend	b) LUS intensity trend	c) Remarks (e.g. reasons for trend)

Table 9: Data entry table LUS (Liniger et al. 2008a: Q2)

3.4.3 Land degradation per LUS

The next step of the mapping exercise is dealing with land degradation. It is important to have an impression of the current land degradation. The following facts have to be assessed for each LUS: major types, extent, degree, rate, direct and indirect causes of land degradation, and its impact on ecosystem services (table 10). However, only the major degradation types should be addressed.

Type and Extent in %	Degree	Rate	Direct causes	Indirect causes	Impacts on ESS	Level of impact
Soil erosion by water: - Loss of topsoil - Gully erosion - Mass movements - Riverbank erosion - Coastal erosion - Off-site degradation effects **Soil erosion by wind** - Loss of topsoil - Deflation, deposition - Offsite degradation effects **Chemical soil deterioration** - Fertility decline, reduced organic matter content - Acidification - Soil pollution - Salinisation **Physical soil Deterioration** - Compaction - Sealing, crusting - Waterlogging - Subsidence of soils **Water degradation** - Aridification - Change in quantity and quality of surface water - Change in quantity and quality of groundwater - Reduction of buffering capacity of wetland areas **Biological degradation** - Reduction of vegetation cover - Loss of habitat - Quantity/biomass decline - Detrimental effects of fires - Quality and species composition - Loss of soil life - Increase of pests	**1** light **2** moderate **3** strong **4** extreme	**3** rapidly increasing **2** moderately increasing **1** slowly increasing **0** no change **-1** slowly decreasing **-2** moderately decreasing **-3** rapidly decreasing	- Soil management - Crop and rangeland management - Deforestation and removal of natural vegetation - Over-exploitation of vegetation for domestic use - Overgrazing - Industrial activities and mining - Urbanisation and infrastructure development - Discharges - Release of airborne pollutants - Disturbances of water cycle - Over-abstraction of water - Natural causes	- Population pressure - Consumption pattern - Land Tenure - Poverty - Labor availability - Inputs and infrastruct-ure - Education and awareness raising - War and conflict - Governance, institutions and politics	**Productive services:** - Production and risk - Water quantity and quality - Land availability **Ecological services:** - Regulations of excessive or scarce water - Organic matter status - Soil cover - Soil structure - Nutrient cycle - Soil formation - Biodiversity - Greenhouse gas emission - Micro climate **Socio-cultural services:** - Aesthetic, recreation - Education and knowledge - Conflict transformation - Livelihood security and poverty - Health - Net income - Protection or damage of infrastructure - Marketing opportunities	**-3** high negative **-2** negative **-1** low negative **1** low positive **2** positive **3** high positive

Table 10: Land degradation (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E6-E15)

Table 11 has to be filled for each mapping unit using the categories indicated above.

Land degradation (Step 3)									
a) Type			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services	h) Remarks
i	ii	iii							

Table 11: Data entry table land degradation (Liniger et al. 2008a: Q2)

In Ayora, mainly vegetative degradation was identified, but also some soil erosion by water (loss of topsoil), physical soil deterioration (crusting), and water degradation (aridification).

Linking QM and SLM-DPSIR, the type, extent, degree and rate of land degradation are indicators for the state, whereas direct and indirect drivers are termed as indicators for pressure (Liniger et al. 2008a: E6-E15).

3.4.4 Conservation per LUS

After the assessment of land degradation, conservation measures (responses) are analyzed. The following facts have to be assessed for each LUS (table 12): name, conservation group, type of measure (agronomic, vegetative, structural, management), purpose (prevention, mitigation, rehabilitation), extent, degradation which is addressed, effectiveness, effectiveness trend, and its impacts on ecosystem services (Liniger et al. 2008a: E16-E24).

Group/Extent in %	Measure	Purpose	Effectiveness	Effectiveness trend	Impact on ESS	Level of impact
- Conservation agriculture - Manuring - Rotational system - Vegetative strips - Agroforestry - Afforestation, forest protection - Gully control - Terraces - Grazing land management - Water harvesting - Groundwater, salinity regulation, water use efficiency - Water quality - Sand dune stabilization - Coastal bank protection - Protection against natural hazards - Storm water control - Waste management - Conservation of natural biodiversity	**Agronomic:** - Vegetation/ soil cover - Organic matter/soil fertility - Soil surface treatment - Subsurface treatment **Vegetative:** - Tree and shrub cover - Grasses and perennial herbaceous plants - Clearing of vegetation **Structural:** - Bench terraces - Forward sloping terraces - Bunds / banks - Graded ditches / waterways - Level ditches / pits - Dams / pans - Reshaping surface - Walls / barriers **Management:** - Change of land use type - Change of management / intensity level - Layout according to natural and human environment - Change in timing of activities - Control / change of species composition - Waste management	Prevention Mitigation Rehabilitation	**4** very high **3** high **2** moderate **1** low	**1** increase in effectiveness **0** no change in effectiveness **-1** decrease in effectiveness	**Productive services:** - Production and risk - Water quantity and quality - Land availability **Ecological services:** - Regulations of excessive or scarce water - Organic matter status - Soil cover - Soil structure - Nutrient cycle - Soil formation - Biodiversity - Greenhouse gas emission - Micro climate **Socio-cultural services:** - Aesthetic, recreation - Education and knowledge - Conflict transformation - Livelihood security and poverty - Health - Net income - Protection or damage of infrastructure - Marketing opportunities	**-3** high negative **-2** negative **-1** low negative **1** low positive **2** positive **3** high positive

Table 12: Land conservation (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E16-E24)

Table 13 has to be filled for each mapping unit using the categories indicated above.

Conservation (Step 4)											
a) Name	b) Group	c) Measure	d) Pur-pose	e) % of area	f) Degradation addressed	g) Effec-tiveness	h) Effect. Trend	i) Impact on ESS	j) Period	k)Ref to QT	l) Remarks

Table 13: Data entry table land conservation (Liniger et al. 2008a: Q3)

In Ayora, only vegetative conservation measures have been identified. It should be noted that this questionnaire obtains a geographical display of some important conservation data. Detailed information on conservation measures will be provided using the questionnaires on technologies and approaches.

3.4.5 Expert recommendation

The last part of the questionnaire addresses expert recommendation concerning interventions on how to address degradation, which should be provided for each mapping unit (table 14).

Expert recommendation	
Adaptation to the problem: the degradation is either too serious to deal with and is accepted as a fact of life, or it is not worthwhile the effort to invest in.	**Prevention** implies the use of conservation measures that maintain natural resources and their environmental and productive function on land that may be prone to further degradation, where some has already occurred. The implication is that good land management practice is already in place: it is effectively the antithesis of human-induced land degradation.
Mitigation is intervention intended to reduce ongoing degradation. This comes in at a stage when degradation has already begun. The main aim here is to halt further degradation and to start improving resources and their functions. Mitigation impacts tend to be noticeable in the short to medium term: this then provides a strong incentive for further efforts. The word ‘mitigation’ is also sometimes used to describe reducing the impacts of degradation.	**Rehabilitation** is intervention when the land is already degraded to such an extent that the original use is only possible with extreme efforts as land has become practically unproductive. Here longer-term and more costly investments are needed to show any impact.

Table 14: Expert recommendation (Nina Lauterburg 2014, data source: Liniger et al. 2008a: E25)

Table 15 has to be filled for each mapping unit using the categories indicated above.

Expert recommendation (Step 5)	
Expert recommendation	Remarks and additional information

Table 15: Data entry table expert recommendation (Liniger et al. 2008a: Q4)

3.4.6 Analysis of the mapping questionnaire: Maps and charts

After having added all the required data to the mapping database, several maps and charts were produced using ArcGIS and Excel. In the results chapter, the most important values are displayed and analyzed.

3.5 WOCAT Questionnaire on Technologies (QT)

According to Schwilch et al. (2011: 217) "SLM technologies are the physical practices in the field, which are agronomic (e.g. intercropping, contour cultivation, mulching), vegetative (e.g. tree planting, hedge barriers, grass strips), structural (e.g. graded banks or bunds, level bench terrace, dams) or management measures (e.g. land use change, area closure, rotational grazing) that control land degradation and enhance productivity in the field". The identified technologies are documented and evaluated using the questionnaire on technologies. The questionnaire allows to assess the specifications of the technology (e.g. purpose, classification, design, costs), where it is used (the natural and human environment), benefits, disadvantages, economic impacts or adoption of the technology (Schwilch et al. 2011).

According to Liniger et al. (2008b) the questionnaire consists of three main parts:

1. General information
2. Specification of technology
3. Analysis of technology

Since forest fires are the main degradation driver in the study site of Ayora, the major concern is the documentation and evaluation of forest management practices to prevent fires which were detected during field visits. In order to fill the questionnaire on technologies, the knowledge of different stakeholders had to be collected. Although it was challenging to find stakeholders with a broad knowledge on the management practices, the local forest agent was a major source of information. Furthermore, he knew where to find important stakeholders (e.g. shepherd, hunter, farmer). The scientific and local knowledge of scientists from CEAM, who work in this region since a long time, was also highly valuable to complete the questionnaires. The combination of scientific and local knowledge allowed to document forest management practices in an integrative and holistic way.

The most important stakeholders who contributed in completing the questionnaires are mentioned in table 16. I highly appreciated the collaboration (some of them do not want to be mentioned by name).

Description Stakeholders	Name
Policy-makers, government	
Regional ministry of infrastructure, territory and environment of Valencia	José Antonio Rueda
Head of the forestry department in the regional ministry of infrastructure, territory and environment Valencia	Javier Hermoso
Head of the Prevention and Extinction Service, Regional Ministry of Governance Valencia	Luis Velasco García
Municipal councillor of Ayora	Ferreol Aparicio Camara
Researchers CEAM and University of Alicante	
Biologist	Jaime Baeza
Biologist	Alejandro Valdecantos
GIS	José Antonio Alloza Millán
Biologist	Joan Llovet Lopez
Biologist	Alberto Vilagrosa
PhD student, GIS	Sara Michelle Catalán
Forest agents	
Forest agent of Jarafuel (in the Ayora region)	Vicente Colomer
Forest agent of Ayora	Baltasar
Local land users/workers	
Farmer	
Shepherd	
Hunter	

Honey production	Manuel Valles Alejo
Ecologist	Gustavo Adolfo Sanchez
Biologist of the wind mill company	
Technician of the wind mill company	
Worker of VAERSA (supports companies in environmental issues)	
Workers of three forest brigades (firebreak maintenance, selective forest clearing, pest management)	
“Fire observer“	
Retired villager of Jarafuel who receives fuel wood	
Different villagers of Ayora	

Table 16: Overview of stakeholders who contributed to document and evaluate SLM in Ayora (Nina Lauterburg 2014)

3.6 WOCAT Questionnaire on Approaches (QA)

The questionnaire on SLM Approaches addresses the question of how implementation was achieved and who achieved it. According to Schwilch et al. (2012: 16), “SLM Approaches are the ways and means of support that help to introduce, implement, adapt and promote those technologies on the ground”.

An approach refers to a particular land conservation activity, e.g. an official project, or changes in a farming system towards more sustainable soil and water use (Liniger et al. 2008c). Schwilch et al. (2011: 217) state that an SLM approach “involves all participants (policy makers, administrators, experts, technicians, land users, etc; actors at all levels), inputs and means (financial, material, legislative, etc) and know-how (technical, scientific, practical)”.

The questionnaire focuses on the objectives of the approach, operations, participation by land users, financing and subsidies. The part of the analysis includes monitoring and evaluation methods as well as an impact analysis. It is claimed that successful approaches are the key to upscale SLM technologies.

Similar to QT, it also consists of three main parts:

1. General information
2. Specification of SLM Approach
3. Analysis of SLM Approach

In my case, only one QA was filled out, based on project documents which I consulted in the forestry department in the regional ministry of infrastructure, territory and environment in Valencia. Forest management is mainly ruled by laws which are not suitable to be documented in the format of the questionnaire. However, the important laws and management plans will be mentioned in the results.

4. Results and discussion

In the subsequent chapters, the results of this master thesis are presented and discussed. The results allow to explain causes and consequences of forest fires, and to draw a conclusion on the role of SLM strategies in controlling fires and preventing regime shifts in Ayora.

4.1 Assessment of regime shifts related to fires in Ayora

This chapter presents what is known about negative regime shifts occurring in Ayora. First, important background knowledge on past land use, land abandonment and fires is provided. In a second step, the observed regime shifts are discussed.

4.1.1 Past land use and fires

In Ayora, similar to the whole Mediterranean basin, there is a long history of deforestation. Most of the natural vegetation has been removed several centuries ago to convert the land to agriculture or to use the wood as fuel wood or for charcoal production (Santana et al. 2010). Through these disturbances and the removal of key species the vegetation is not in its climax but in a semi-natural state (Röder et al. 2005).

In the 1960s, most of the cultivated areas have been abandoned (Santana et al. 2010). The rural exodus was triggered by socio-economic changes when the use of fossil fuels started, which decreased the demand on firewood for cooking and heating. Therefore, profits from forests started to decrease and thus also activities such as shrub clearing and charcoaling lost their importance. The change in the energy source led to the abandonment of rural areas, which also resulted in a lack of management (Otero et al. 2013). Image 5 illustrates early abandoned terraces (1916) and the situation today.

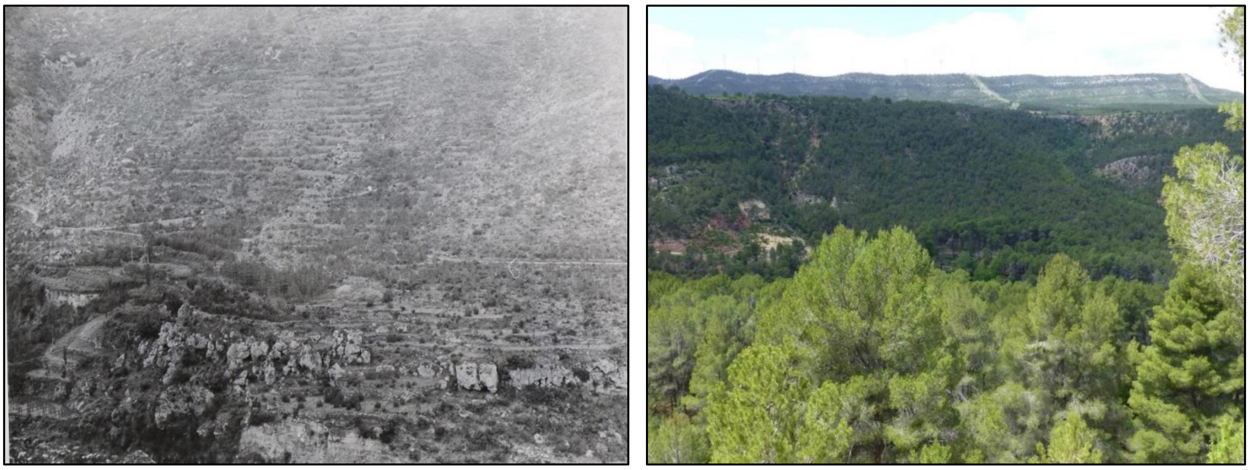


Image 5: Early abandoned terraces near Ayora in 1916 (left) and the situation today (right) (Vicente Colomer, Nina Lauterburg 2013)

After land abandonment, natural regeneration (secondary succession) was initiated (Röder et al. 2005). Most of the present forests and shrublands developed on abandoned agricultural fields and today they are in different successional stages containing a high fuel load (Santana et al. 2010). This is illustrated in image 6. Pausas et al. (2011) conclude that this increase in the amount and continuity of the fuel, which is related to land use changes (land abandonment and the associated lack of management), is the main reason for the increase in both fire frequency and burnt areas in the 1970s (figure 16). As mentioned previously, the increase in fires is also partly a result of the improvement of recording procedures.

Image 6: **Natural secondary succession on abandoned fields; the high fuel load increases the fire risk (Nina Lauterburg 2013)**

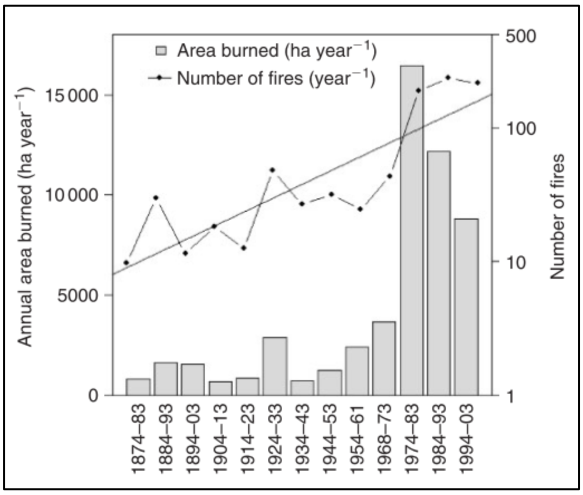


Figure 16: Increase in burnt area and fire frequency in the 1970s in the Valencia region (Pausas et al. 2008: 714)

Figure 17 illustrates the relationship between the decrease of the rural population density since the 1940s and the increasing burnt area in the Valencia province. Similar to these dynamics, the demographic trends in Ayora indicate a decrease of the rural population from 6870 to 5691 people between 1950 and 1970 (figure 18). The rural depopulation in Ayora is less evident than observed for the Valencia province in general. Nevertheless, it went along with a decrease of the population working in agriculture and forestry which supports the conclusion of Pausas et al. (2011) that the main driver of forest fires at that time was the dense growth of fire-prone vegetation as a consequence of land abandonment and lack of management.

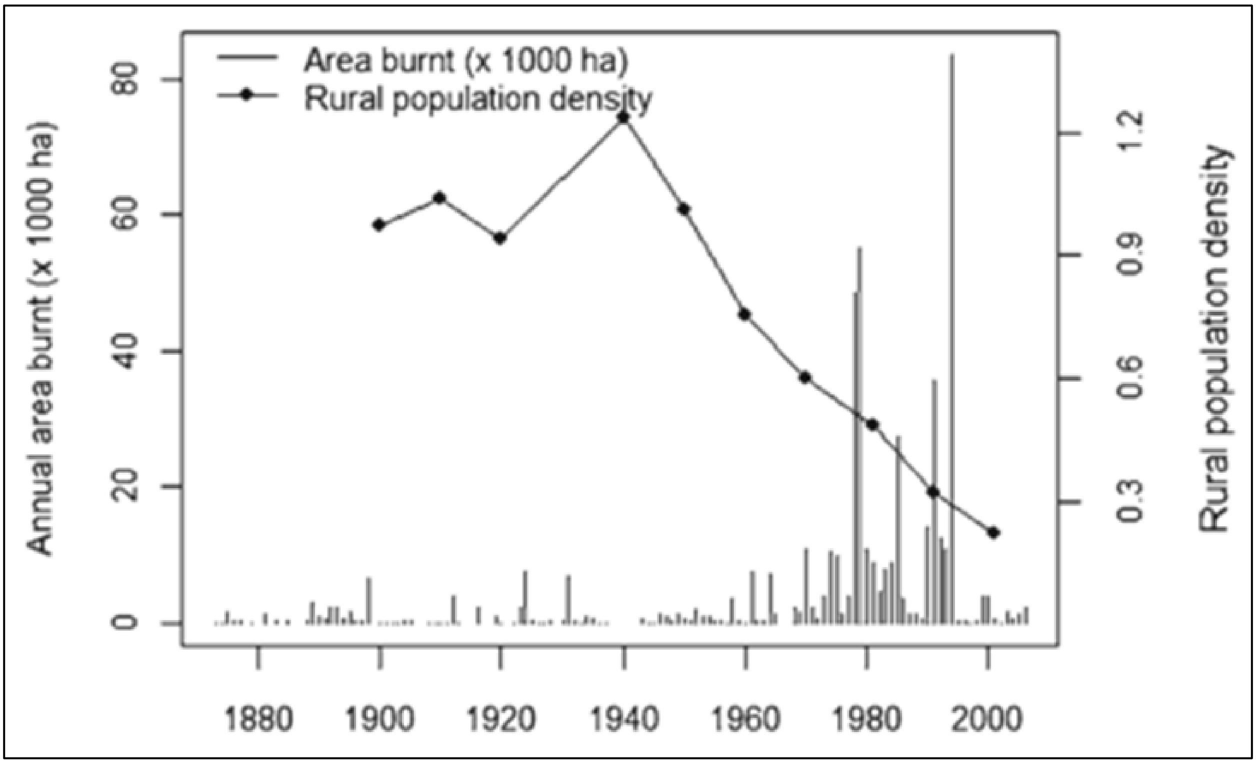


Figure 17: Increase in annual burnt area and decrease of rural population density in the Valencia province 1873-2006 (Pausas et al. 2011: 220)

As illustrated in figure 20, Ayora was affected by several fires, the most devastating one occurred in 1979 which coincides with the above presented findings. It should be noted that the map only displays the most important fires. However, it is actually the high fire recurrence which is the main degradation driver, thus the number of fires occurring in the same spot within a short time interval. As illustrated in figure 21, eastern Ayora suffered from three fires in the same spot; two of them affected big areas. Most fires in Ayora were triggered by lightning and burnings of agricultural residues, whereas in the whole Valencia province the main causes have been accidents (44%), arson (30%), and lightning (23%) (figure 19).

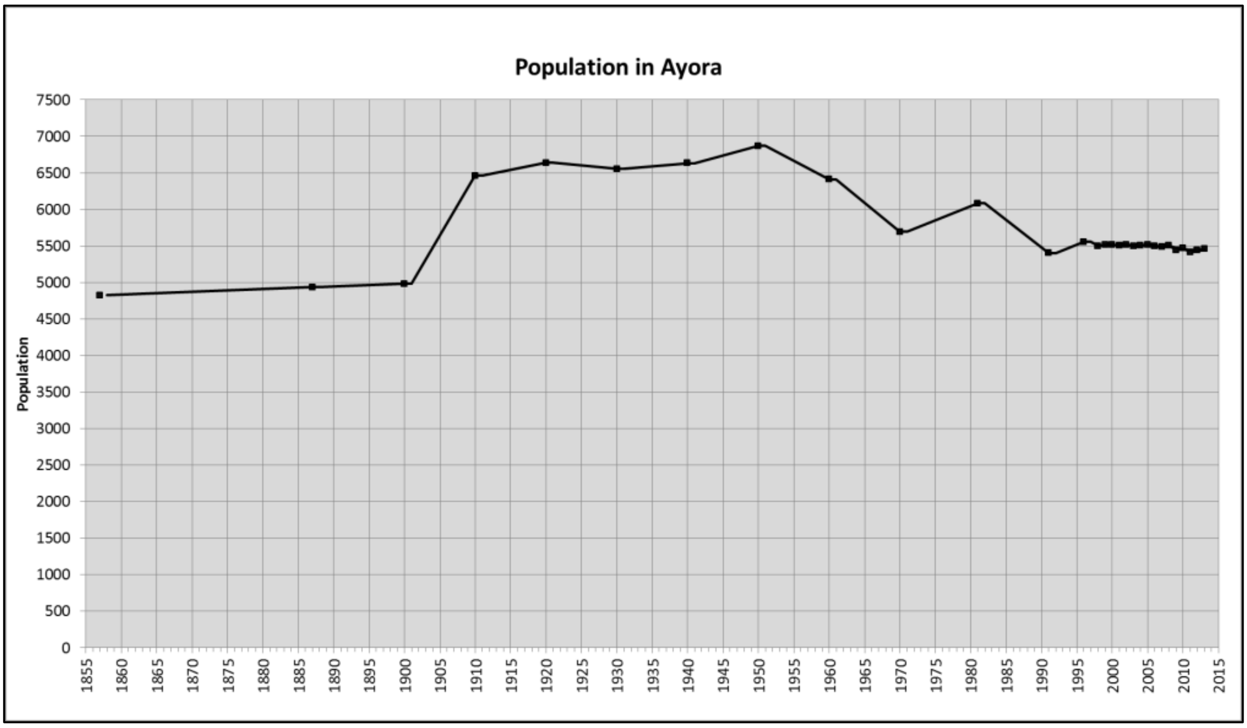


Figure 18: Decrease of rural population in Ayora since the 1950s resulted in a decrease of people working in agriculture and forestry (Nina Lauterburg 2014, data sources: INE 2014, Argos 2014)

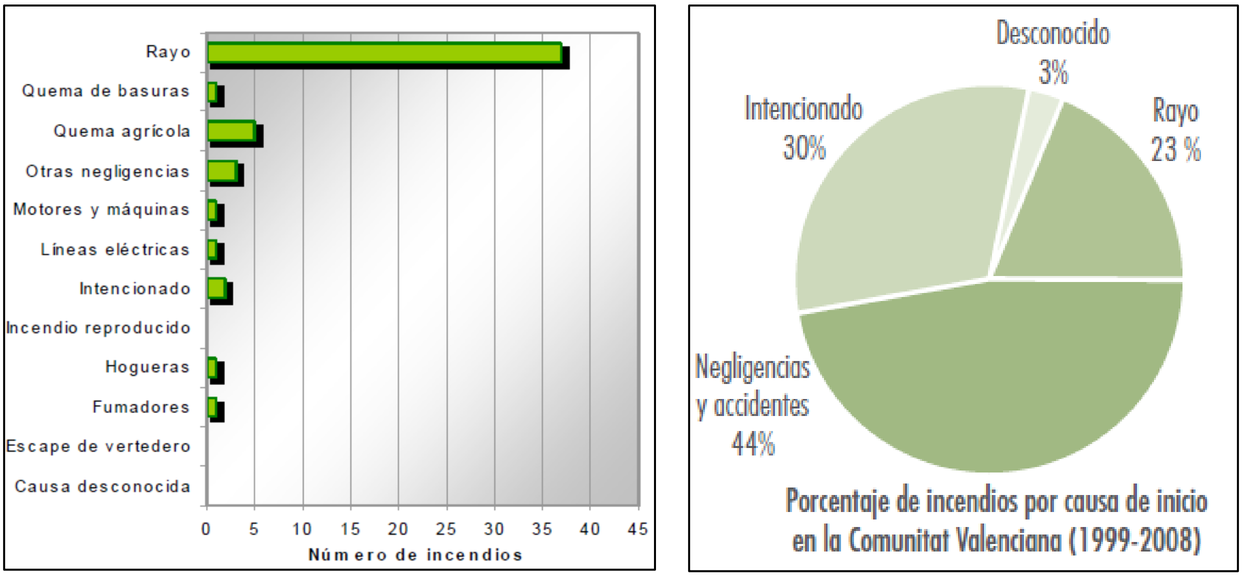


Figure 19: Main causes of fires in Ayora (left) and Valencia (right) between 1999 and 2008: In Ayora, most fires were triggered by lightning and burnings of agricultural residues, whereas in the whole Valencia province the main causes have been accidents (44%), arson (30%), and lightning (23%). (Rayo=lightning, quema de basura=burning of rubbish, quema agrícola=burning of agricultural residues, otras negligencias=other negligence, motores y máquinas=engines and machines, líneas eléctricas=power lines, intencionado=intentional, incendio reproducido=reproduced fire, hogueras=campfires, fumadores=smokers, escape de vertedero=waste deposits, causa desconocida=unknown causes) (GVA 2011, GVA 2012)

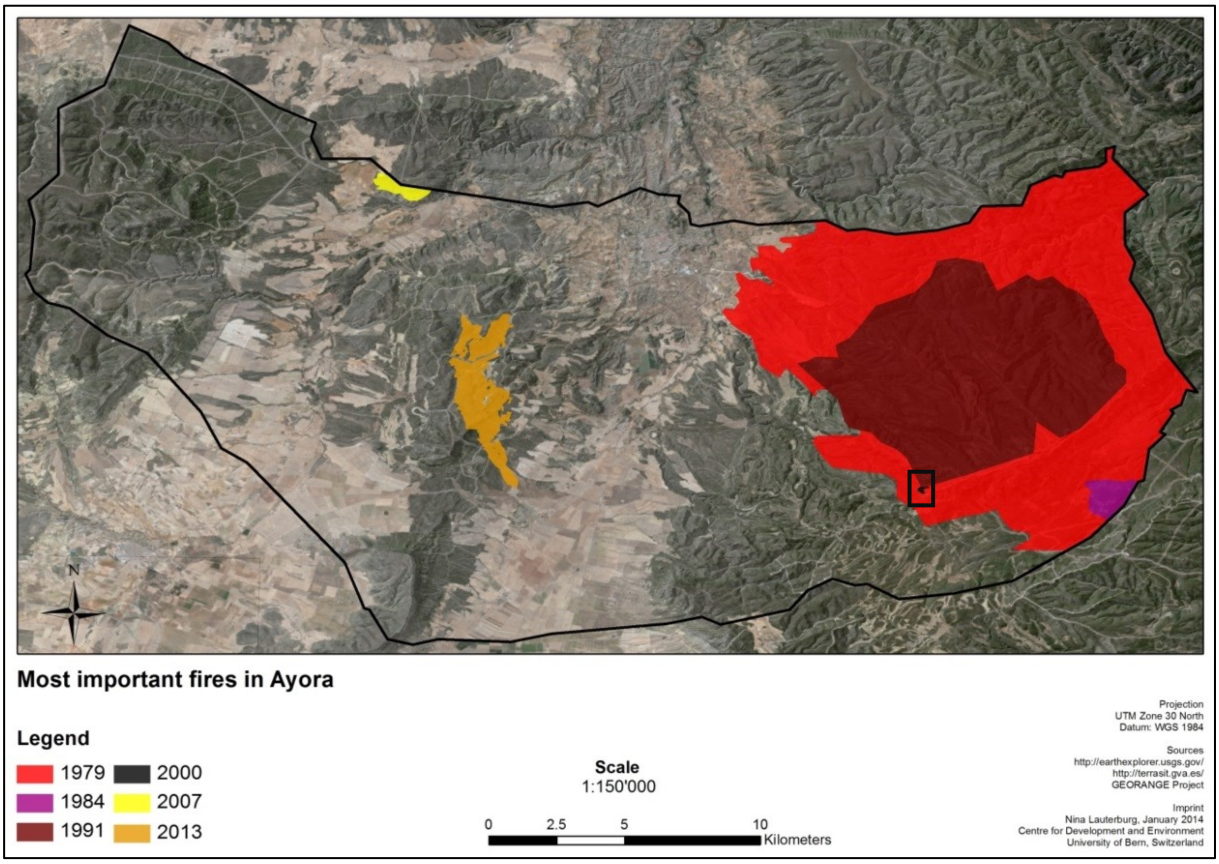


Figure 20: Most important fires in Ayora. The small fire of the year 2000 is located in the black box (Nina Lauterburg 2014, data sources: USGS, Terrasit, GEORANGE)

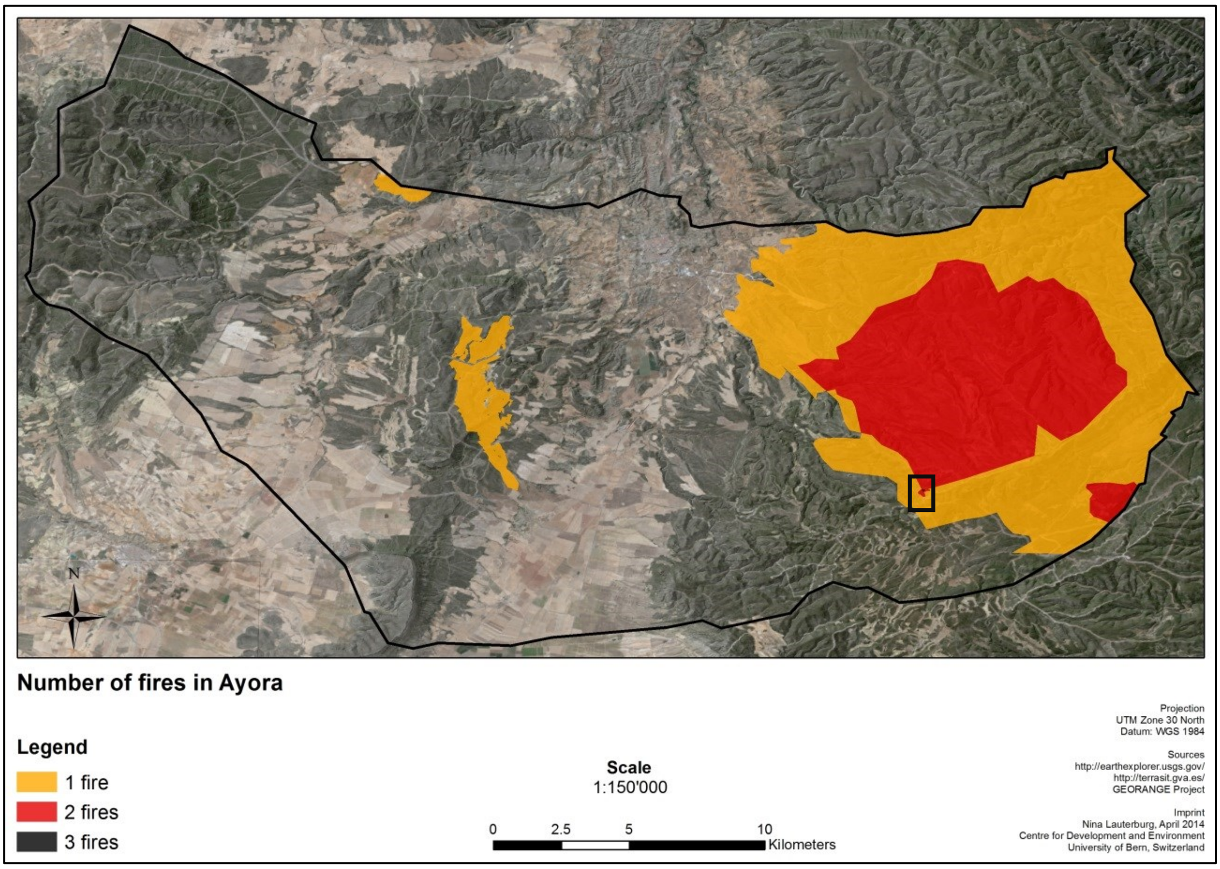


Figure 21: Fire recurrence in Ayora. The small area burnt three times is located in the black box (Nina Lauterburg 2014, data sources: USGS, Terrasit, GEORANGE)

4.1.2 Regime shifts in Ayora

After having presented important background knowledge on the past land use, land abandonment, and fires, the observed regime shifts are discussed in the following.

The potential vegetation of Ayora is a sclerophyllous oak forest of Quercus ilex. However, this forest is currently extremely degraded (Baeza et al. 2007, Valdecantos et al. 2009). As illustrated in figure 22, Ayora has experienced two main shifts.

The first regime shift was caused by past land use (anthropogenic deforestation for charcoaling, wood gathering, agriculture), which modified the holm oak woodland (Quercus ilex, resprouter species) to a pine forest - oaks largely disappeared. After land abandonment, secondary succession was initiated on old fields. Furthermore, several afforestation projects have been realized and mainly Pinus halepensis was planted.

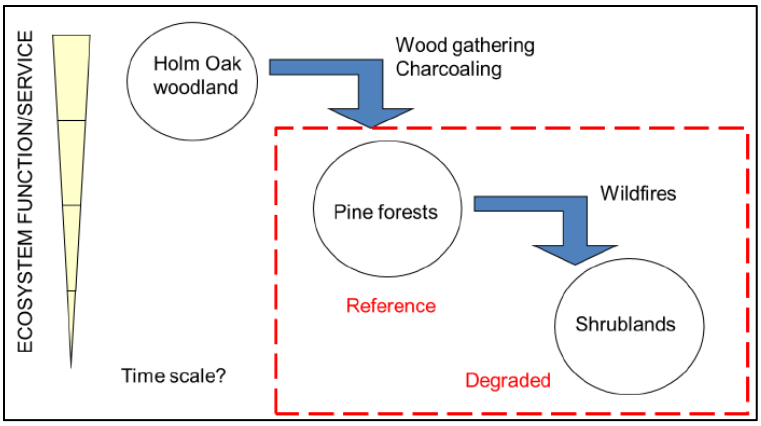


Figure 22: Regime shifts from holm oak woodland to pine forests to shrublands (CASCADE Website 2014)

The shift in the vegetation composition from oaks to pines, combined with land abandonment and lack of management, resulted in an increase of the fuel load and a reduction of the resilience to fires. This situation increased the occurrence and recurrence of fires in Ayora (Santana et al. 2010). However, it should be noted that fires are not only driven by fuel availability, but also by adverse climatic conditions such as droughts (Pausas et al. 2011). The high fire recurrence is currently considered as the main degradation driver and caused another shift from pine forest to shrubland. At present, a vast area is covered by shrubland, so-called matorral (Baeza et al. 2007). Thus, the landscape in Ayora can be characterized as “a mosaic of agricultural land and abandoned fields covered by post-fire regenerating pine woodlands and shrublands” at different successional stages (CASCADE 2011: 58).

Figure 23 illustrates the shifts explained above with pictures taken in the field. Furthermore, it includes the question on a possible shift towards grassland in case the disturbances such as the high fire recurrence will persist.

As a result of these shifts in the vegetation composition, a change in ecosystem functioning and ecosystem services has occurred (CASCADE Website 2014).

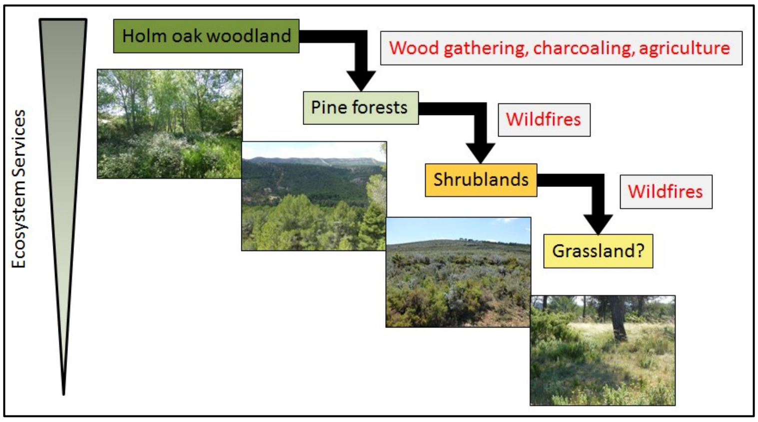


Figure 23: Regime shifts in Ayora (Nina Lauterburg 2013, data source: CASCADE Website 2014)

Since researchers from CEAM and CASCADE mainly focus on the shift from mature Pinus halepensis and Pinus pinaster forest (reference) to shrubland caused by wildfires, this master thesis will also further investigate on this specific regime shift.

The following conceptual model (figure 24) shows the vegetation dynamics after fires in Ayora. According to Santana et al. (2010) and Baeza et al. (2007), different successional pathways exist after fires, depending on the soil type, the vegetation type (seeder or resprouter), the previous land use, the occurrence, recurrence, and intensity of the fire, and on the climate before, during and after the fire. The starting point of the conceptual model is in the 1970s, where mainly pine forest was present. If a fire occurs in pine forest, the succession is interrupted and the system returns to an earlier state, but the vegetation is able to recover to the same state which existed before the disturbance if the seeds in the soil are not harmed (Baeza et al. 2007). However, one fire can be enough to divert the succession and change a pine forest to an alternative stable state (e.g. Rosmarinus officinalis), where the colonisation of later-successional species can be hindered. Especially in areas with a high fire recurrence over short time periods, the expected successional pathways may be diverted (Santana et al. 2010). It is crucial to understand the successional trajectories after fires, because this knowledge can contribute to effective management planning of fire-prone areas and post-fire management (Baeza et al. 2007).

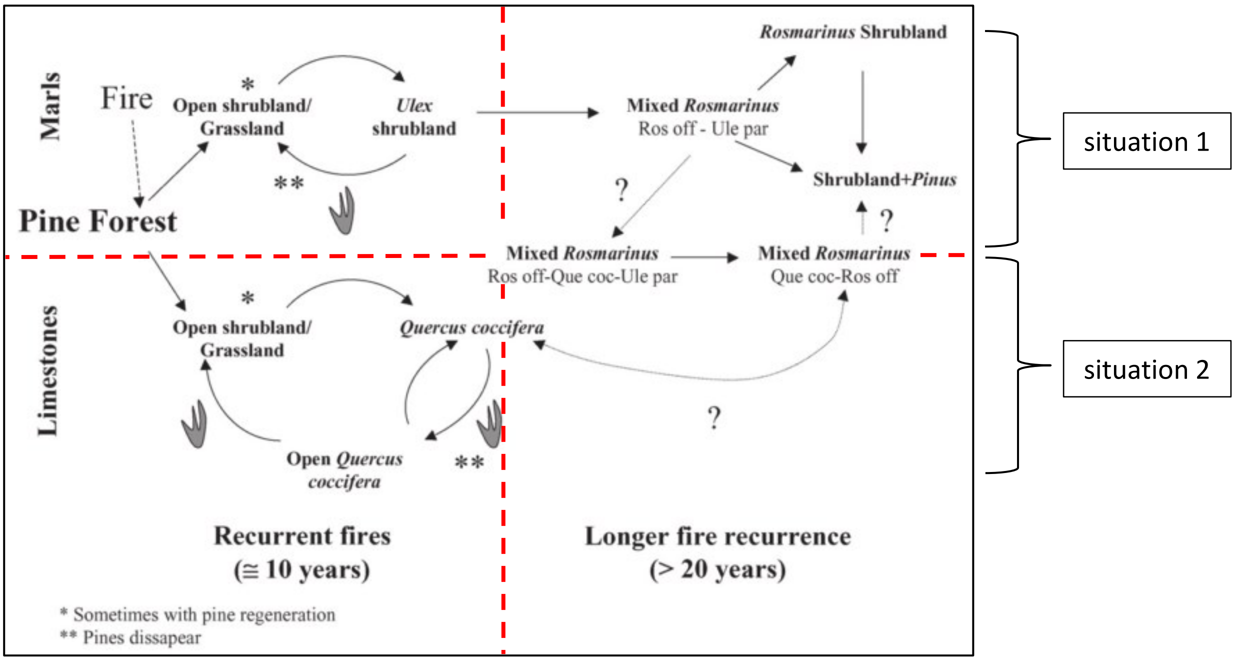


Figure 24: Conceptual model on different vegetation dynamics after fire in Ayora, depending on fire recurrence (left 10 years, right more than 20 years) and cultivations in the past. Cultivated areas were most prevalent on marls (situation 1) (Baeza et al. 2007: 250)

In order to understand the dynamics after fires as presented in the conceptual model (figure 24), it is crucial to add some explanations, especially on the difference between seeder and resprouter species. Baeza et al. (2007) state that areas which experienced land use and land abandonment in the past are likely to be dominated by seeder species (situation 1, fire causes shift from pine forest to grassland to Ulex shrubland to Rosemary shrubland), whereas in uncultivated areas resprouters are still present to a large proportion (situation 2, Quercus coccifera). The main difference between seeder and resprouter species is their regeneration strategy after a disturbance such as land abandonment or fires (Valdecantos et al. 2009).

Situation 2 on figure 24 illustrates the post-fire dynamics of areas which were not cultivated in the past and which are mainly composed of resprouter species (Quercus coccifera) growing on unaltered limestone soils. These shrublands are quite resilient to fire and recover rapidly in the same spot from belowground organs (image 7), thus they also protect the soil from erosion (Pausas et al. 2008). Even after two fires, this shrubland type does recover rapidly (Baeza et al. 2007).

However, resprouter species are usually very scarce or even absent resulting from the removal of these species in the past. Their colonization is quite slow and depends on the presence of nearby preserved natural ecosystems (seed sources) and animals that disperse the seeds (Valdecantos et al. 2009). According to Baeza et al. (2007) the main resprouter species in Ayora are Quercus coccifera, Quercus ilex and Pistacia lentiscus (image 8).


Image 7: Regeneration of resprouter species one year after a fire (left) and after the two fires in 1979 and 1991 (right) (Nina Lauterburg 2013)


Image 8: Resprouter species Quercus coccifera (left) and Quercus ilex (right) (Nina Lauterburg 2013)

In Ayora, situation 1 on figure 24 is more important, illustrating the shift on abandoned agricultural areas which are dominated by seeder species. Although these species are highly fire-prone and less resilient to fires than ecosystems dominated by resprouters, they may regenerate well after a fire (Valdecantos et al. 2009). The regeneration depends on the weather conditions after a fire and on the community age. Seeders establish a seed bank in the soil which persists after a fire and enables post-fire regeneration. Pines do not establish their seed bank in the soil but store their seeds within the cones (image 9). Stimulated by the heat of the fire, the cones open and seeds are dispersed (Pausas et al. 2008, Maestre et al. 2004).


Image 9: Burnt open cone of Pinus halepensis (left) and regeneration of Pinus halepensis one year after a fire (Nina Lauterburg 2013)

The age of the species determines the size of the seed bank and thus the regeneration capacity. Therefore, knowledge on the life cycle of plants is crucial. If plants burn before having reached maturity, not enough seeds have been produced to ensure post-fire regeneration. For example, local extinction of pines may occur if the fire recurrence is shorter than 10-15 years, the period which is needed to reach their mature state and to produce a significant seedbank. Several researchers concluded that the regeneration of pines depends mainly on seed-bank availability, fire severity and climatic conditions. However, in areas with a low fire recurrence, Rosmarinus officinalis and Pinus halepensis can be found (image 10) (Baeza et al. 2011, Maestre et al. 2004, Pausas 1999). Areas affected by two fires within a short time interval (10-15 years) are dominated by open shrubland (Ulex parviflorus, Cistus albidus, image 11) or even grassland, but there are no pines. This abundance can be explained by the short maturation time of these species (table 17).

Image 10: Seeder species Rosmarinus officinalis (left) and Pinus halepensis (right) (Nina Lauterburg 2013)

Image 11: Seeder species Ulex parviflorus (left) and Cistus albidus (right) (Nina Lauterburg 2013)

Furthermore, it is also important to consider the life span of different plants. Species with a short life span are Cistus albidus and Ulex parviflorus. After 10-20 years they die and accumulate dry biomass, thus promoting again a higher fire recurrence. Hence, it can be concluded that the high fire recurrence (short fire intervals e.g. less than 20 years) observed in Ayora endangers plant regeneration (Baeza et al. 2011).

	Life form	Persistence strategy after fire	Life span (years)	Dispersal	Maturation time (years)
C. albidus	Dwarf shrub	Seeder	Short (10–15)	Myrmecochory	Short (2)
E. multiflora	Shrub	Resprouter	Medium (30–40)	Anemochory	Short (3–4)
J. oxycedrus	Large shrub	Resprouter	Long (> 50)	Endo-zoochory	Medium (5–10)
P. halepensis	Tree	Seeder	Very long (> 200)	Anemochory	Long (10–15)
Q. coccifera	Shrub	Resprouter	Long (> 50)	Endo-zoochory	Medium (5–10)
Q. ilex	Tree	Resprouter	Very long (> 200)	Endo-zoochory	Long (15–20)
R. officinalis	Shrub	Seeder	Medium (30–40)	Myrmecochory	Short (2–3)
U. parviflorus	Shrub	Seeder	Short (15–20)	Myrmecochory	Short (2–3)

Table 17: Life span and maturation time of typical species in Ayora, influencing fire recurrence and regeneration. C=Cistus, E=Erica, J=Juniperus, P=Pinus, Q=Quercus, R=Rosmarinus, U=Ulex (Baeza et al. 2011: 469)

As mentioned above, Ulex is the main species after two fires. Figure 25 illustrates that, compared to other plants, shrublands consisting of Ulex parviflorus contain an extreme fire risk during summer due to the high amount of dead standing biomass (image 12) (Pausas et al. 2008).

Image 12: Ulex parviflorus accumulating dead standing biomass (Nina Lauterburg 2013)

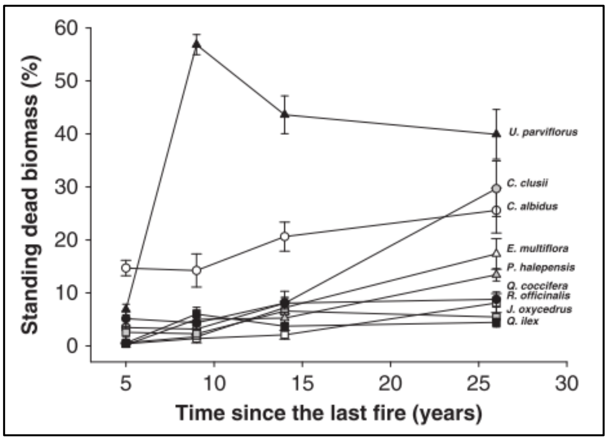


Figure 25: Accumulated dead standing biomass after a fire – Ulex shows the highest fire risk (Baeza et al. 2011: 470)

Also according to Röder et al. (2005: 57) “mature pine forests with only little undergrowth show a higher resilience to fire and a high autosuccession potential, dense shrublands with a high degree of accumulated dry and dead biomass are significantly higher at risk” (Röder et al. 2005).

Since seeder species die after a fire, they first have to develop a root system to recover. Thus, they regenerate slower than resprouters, where the roots are almost not affected by the fire. Areas with a high amount of seeder species are therefore prone to soil erosion and seed loss, because the soil remains uncovered for a certain time after a fire. Due to the fact that the peak of torrential rainfall occurs in autumn just after the fire season, the combination of heavy rainfall and fires may reduce the soil cover and hence the regeneration capacity of the vegetation. This in turn can promote post-fire degradation processes and may result in bare soil (Pausas et al. 2008).

The regime shifts which have been explained above are visible in the fire perimeter in Ayora. Previous to 1979 when the first fire occurred, the forest was dominated by Pinus halepensis, Pinus pinaster and Quercus ilex. Today, the burnt areas are mainly composed of regenerated shrublands with different successional stages and species compositions. According to Baeza et al. (2007: 245) “the main species are the grasses Brachypodium retusum and phoenicoides and the shrubs Rosmarinus officinalis, Ulex parviflorus and Quercus coccifera”. Forests are largely absent, only some small isolated patches which were not affected by the fire contain tree species such as Pinus halepensis and Pinus pinaster (Baeza et al. 2007, Röder et al. 2005).

To conclude it can be stated that the low amount of resprouters combined with the dominance of highly fire-prone seeders has increased the fire risk in Ayora. Furthermore, the recovery rate after disturbances has been reduced. Due to the high fuel amount of the seeder species, the fire risk has further increased, which in turn has established a positive feedback between fire risk and land degradation (Valdecantos et al. 2009). Climatic conditions are also important in terms of fires, e.g. droughts increase the fire risk. Furthermore, it is hypothesized that the effects of disturbances such as fire and land use on the vegetation composition are stronger than the effects of environmental factors (Baeza et al. 2007).

To link the observations in Ayora with the theoretical background of this thesis (regime shift concept and SLM-DPSIR framework), a clear regime shift from pine forest to shrubland can be identified (= state). Figure 26 summarizes the different successional trajectories after fires which have been observed in Ayora. After one fire in a pine forest (e.g. 1979), some trees recovered with on-going secondary succession. However, most of the burnt vegetation is still in a shrubland stage and it is not sure whether the vegetation will recover and again develop to a forest. The areas which have been affected by a second forest fire (e.g. 1991) are also covered by shrubland today. Thus, driven by recurrent wildfires (=drivers), the successional pathways can be interrupted which may trap the vegetation in a specific successional stage. There are still many open questions related to these post-fire successional trajectories. It is questionable if and in which time span the burnt areas are able to recover to forest. Furthermore, the situation after four fires is not clear and the question raises whether there will occur a shift towards grassland.

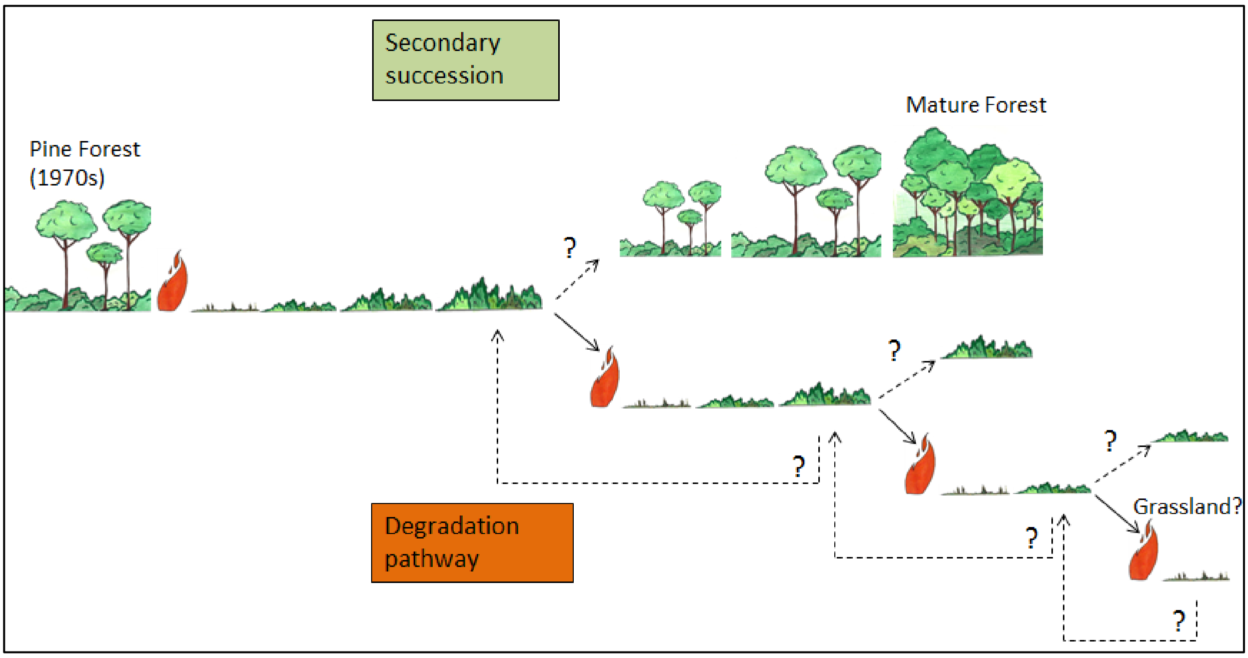


Figure 26: Different successional trajectories after fires as observed in Ayora. After one fire in a pine forest it is possible that the vegetation recovers to a forest. However, a high fire recurrence interrupts the secondary succession and may trap the vegetation in a shrubland state (Nina Lauterburg, Hanspeter Liniger 2014, data sources: Vallejo 1997, experiments of CEAM, field observations)

4.1.3 Discussion of regime shifts related to fires

During the CASCADE plenary meeting in Alicante, some important questions have been pointed out which should be kept in mind when talking about regime shifts. Important discussion points were for example:

- Is the observed shift irreversible?
- How to deal with the time component and when is a shift considered as a shift?
- Which are the drivers of such shifts (socio-economic, climatic)?
- Does the shift have consequences for humans?
- What are the costs for prevention, mitigation or rehabilitation?

The first two questions are very crucial in the situation of Ayora and I thoroughly discussed them with researchers from CEAM. It is quite tricky to apply the regime shift concept on wildfires. A fire causes an abrupt regime shift through the complete elimination of the vegetation. Nevertheless, secondary succession may lead to the recovery of the vegetation. The on-going secondary succession makes it difficult to assess the long-term change in the vegetation, which is considered as the real regime shift. Therefore, defining the temporal scale in which a regime shift is to be considered a catastrophic regime shift is crucial. If taking into account 200 or 300 years, post-fire vegetation regeneration is possible if disturbances such as fire do not persist. However, as defined by researchers from CEAM, one generation is an appropriate time span to evaluate regime shifts and therefore, the observed modifications in the vegetation composition can be seen as a regime shift. Furthermore, due to the abundance of fire-prone seeder species and the projections on global warming, the fire risk will probably further increase and the high fire recurrence is likely to persist in future, hindering vegetation regeneration. Numbers to prove this hypothesis are still missing, but CEAM will try to obtain the data. The other questions mentioned above are discussed in this thesis as well.

4.1.4 Link to theoretical background

The regime shift concept is the base to analyse the regime shifts which already happened in Ayora. The observed changes from holm oak to pine forest and from pine forest to shrubland can be identified as regime shifts. Thus, applying the terminology of the concept to the shift from pine forest to shrubland (which is the focus of the CASCADE project), the change in the vegetation composition due to past land use and the accumulation of fuel can be termed as a change in the underlying variables, maybe combined with a drought. The shock which caused the second negative regime shift is recurrent fire. Compared to the original holm oak woodlands, the state of seeder shrubland is considered as degraded.

4.2 Mapping of land use, land degradation and SLM practices

The following chapter presents the results obtained through the application of the WOCAT mapping questionnaire (see Annex 2). After the characterization of the identified land use systems (LUS), the mapping and analysis of land degradation and conservation measures provides an overview where the various degradation types occur to what extent, and where sustainable land management is implemented.

4.2.1 Land Use Systems

4.2.1.1 Base Map

Based on an existing land use map (SIOSE 2009), the identified land use types (LUT) can be roughly categorized in forest, shrubland, cropland, water and urban areas (figure 27). Since CASCADE focuses on forest fires and related regime shifts, only forest and shrubland have been assessed through the WOCAT mapping, whereas cropland, urban areas and water have not been included in the assessment of degradation and conservation.

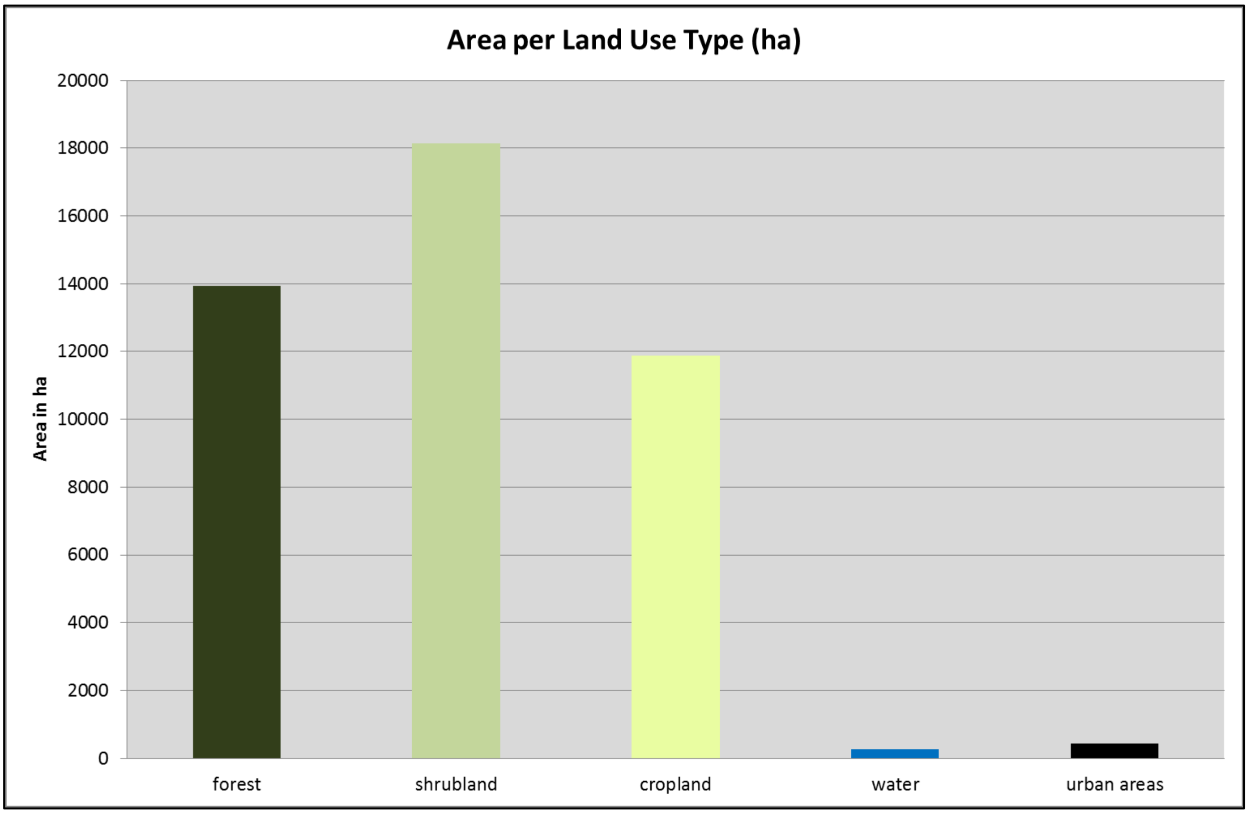


Figure 27: Area per land use type in 2009 (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Since recurrent forest fires constitute the main degradation driver in Ayora, the LUT forest and shrubland have been further differentiated in burnt and unburnt areas. The combination of the land use types with fire recurrence (0, 1, 2, 3 fires) and aspect (north or south exposed) resulted in the land use systems which are displayed on the base map (figure 28). The aspect was included to assess its possible influence on post-fire regeneration and degradation. Through the visualization of the effect of fires on the vegetation, the base map actually illustrates the regime shifts discussed in the previous chapter (e.g. shrubland after two fires).

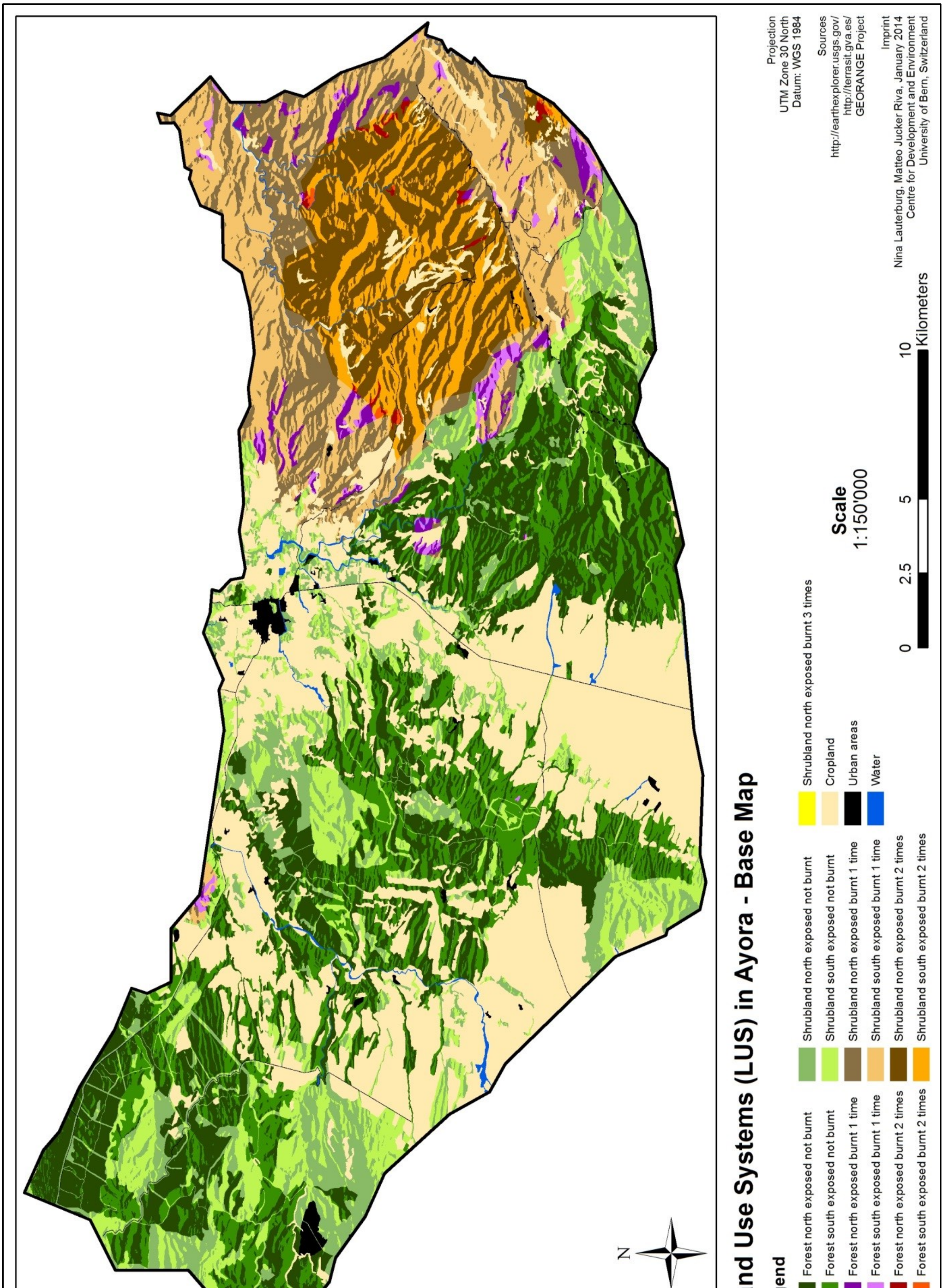


Figure 28: Base Map of Ayora (Nina Lauterburg, Matteo Jucker Riva 2014)

It is evident that the extent of burnt areas in Ayora is quite high (figure 29). However, figure 29 does not include the most recent data. In July 2013 (26 July), right after my field stay, a fire burnt around 600 ha of mature pine forest (previously not burnt), initiated by a machine on dry cropland (figure 30, image 13). Since my field work was already finished, this fire perimeter is not included in the base map and was not assessed in the WOCAT mapping. In order to include this most recent information on forest fires in Ayora, I mapped the fire perimeter applying the normalized burnt ratio (NBR) on a landsat image (figure 30).

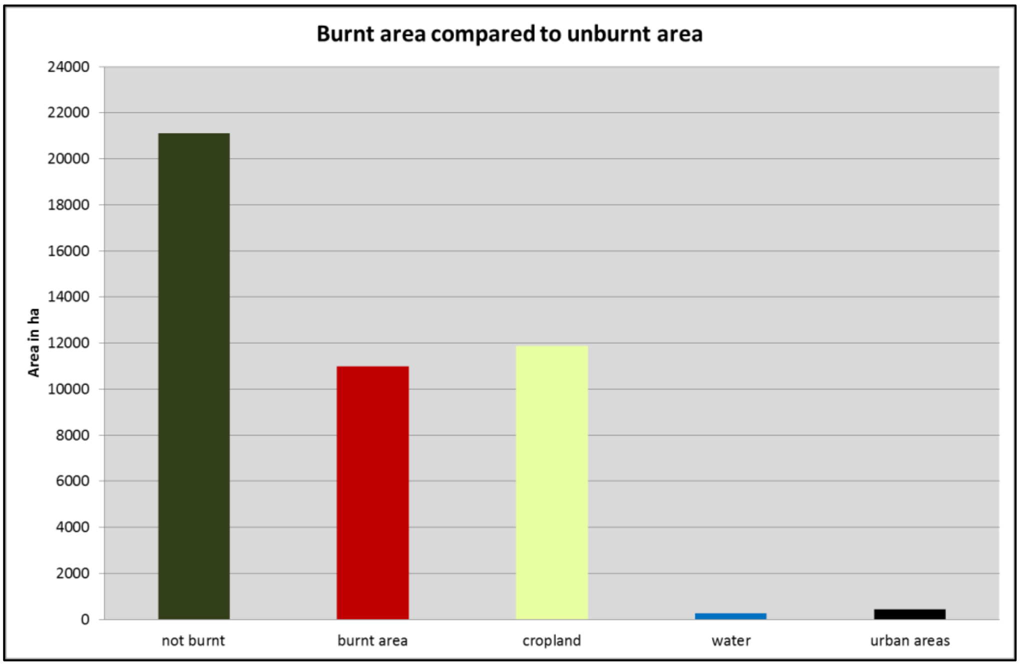


Figure 29: Burnt area compared to unburnt area in 2009 (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

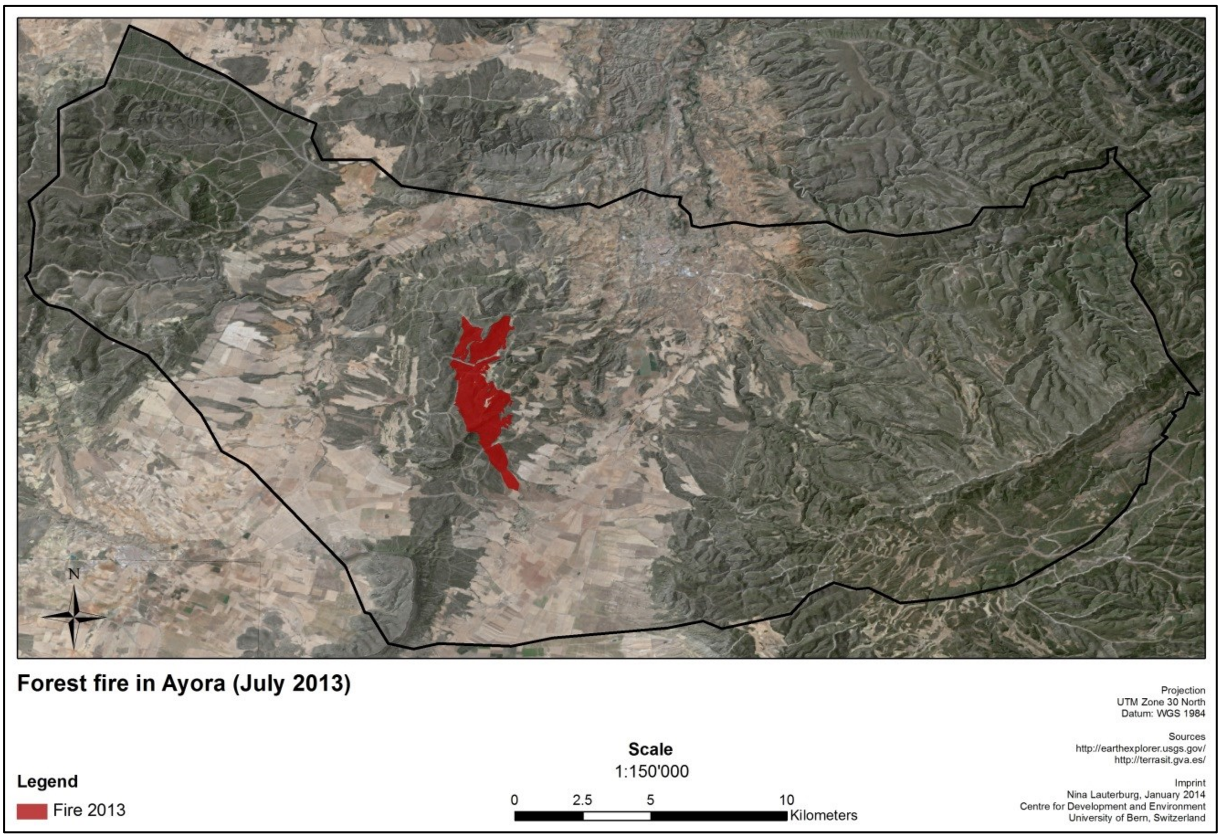


Figure 30: Forest fire in Ayora in July 2013 (Nina Lauterburg 2014, data sources: USGS, Terrasit)

Image 13: The forest fire of 26 July 2013 was initiated by a machine on dry cropland and burnt around 600 ha of mature pine forest in Ayora (SIGIF 2014)

4.2.1.2 Characterization of LUS

This chapter briefly characterizes the identified LUS. The images of the LUS show typical situations which have been considered in the mapping, however there are also exceptional situations where the same LUS is different from the images presented here. Therefore, in chapter 4.2.2 some explanations are given on the influence of the absence or prevalence of past cultivations on degradation and fire risk.

Forest north/south exposed not burnt

In some areas where there was no land use in the past, unburnt isolated patches of the characteristic mixed forests of holm oak (Quercus ilex) and pines (Pinus pinaster, Pinus halepensis) can be found. However, most forests are composed of pines with the dominant tree species Pinus halepensis (or to a minor extent Pinus pinaster). If resprouter species are present, the understorey of unburnt pine forest is often composed of Juniperus oxycedrus, Quercus coccifera, and Rhamnus alaternus. Furthermore, there is a grass layer of Brachypodium retusum. Most of the present forests have developed on abandoned agricultural fields and are now in different successional stages containing a high fuel load. Furthermore, Pinus halepensis has been the main species planted through afforestation programmes conducted by the state. There is no significant difference between north and south exposed forests (image 14 and 15). However, south exposed areas have been less intensively cultivated in the past which might have an influence on the species composition and the prevalent degradation.

Image 14: Forest north exposed not burnt (GEORANGE)

Image 15: Forest south exposed not burnt (CEAM)

Forest north/south exposed burnt once

A part of the burnt forest has naturally recovered and is currently composed of regenerating shrubland and pines (mainly Pinus halepensis), however only a small area is covered by this LUS. In general, the regeneration of Pinus pinaster is lower than recovery of Pinus halepensis. On north exposed areas the forest regenerates faster due to the more favourable conditions. As shown in picture 16, the forest in the back did not burn, therefore the trees in the front regenerated due to the availability of seeds. Picture 17 illustrates a regenerating forest on south-exposed abandoned fields. In the higher elevated area, the forest did not recover.

Post-fire forest regeneration is often characterized by a high density which can be explained by the survival strategy of pines; stimulated by the heat of the fire, the cone opens and disperses a high amount of seeds. In case of lack of management, the dense growth increases the risk of fires.

There are also regenerating forests originating from post-fire forest plantations, however many of these plantations failed.

Image 16: Forest north exposed burnt once (Nina Lauterburg 2013)

Image 17: Forest south exposed burnt once (CEAM)

Forest north/south exposed burnt twice

This LUS does only exist on the base map but not in reality; actually there are no areas burnt twice which are covered by forest today. The most probable explanation seems to be that these trees regenerated after the fire in 1979 but have saved themselves from the second fire in 1991 (image 18). However, they are located within the fire perimeter of 1991 and therefore appear as burnt twice in the GIS layer provided by the GEORANGE project. In general, if a pine forest is affected by two fires within a short time span, this area is now covered by shrubland. Due to these uncertainties and the small area, this LUS was not assessed in the WOCAT mapping.

Image 18: Forest which is mapped as burnt twice; most probably these trees burnt once but have not been affected by the second fire (Nina Lauterburg 2013)

Shrubland north/south exposed not burnt

Vast areas of Ayora are covered by shrubland (matorral) resulting from secondary succession on abandoned fields (image 19). In general, in areas which were cultivated in the past, resprouter shrubs have been removed and therefore today mainly seeder species (e.g. Ulex parviflorus, Rosmarinus officinalis) are present. If there was no cultivation, also Quercus species can be found (e.g. Quercus ilex, Quercus coccifera). Seeder species have a higher fire risk than resprouter species due to their high amount of fuel.

Image 19: Shrubland not burnt (Nina Lauterburg 2013)

Shrubland north/south exposed burnt once

In Ayora, post-fire regenerating shrubland is mainly composed of early-successional seeder species (image 20). Due to their high amount of continuous fuel they contain a high risk of fire. Where there was no cultivation in the past, resprouter species are also prevalent and do recover quite well.

There is no significant difference between north and south exposed shrublands.

Image 20: Shrubland burnt once (Nina Lauterburg 2013)

Shrubland north exposed burnt twice

The area illustrated on image 21 burnt in 1979 and 1991 and is mainly composed of early-successional seeder species, dominated by Ulex parviflorus, Cistus albidus and Rosmarinus officinalis. The shrubland is very continuous and accumulates a high amount of dead standing fuel which contains a high risk of fires. In the back, abandoned terraces provide evidence of past land use in this area and explain the scarce presence of resprouter species. If there has been no cultivation and removal of the vegetation, resprouter species even recover after two fires and contain a lower fire risk.

Image 21: Shrubland north exposed burnt twice (Nina Lauterburg 2013)

Shrubland south exposed burnt twice

The south exposed shrubland which burnt twice differs significantly from the north exposed shrubland and is the most degraded LUS (image 22). It is evident that there is a high percentage of bare soil and only small shrubs and some grasses can be found. This patch has hardly regenerated since 1991.

Image 22: Shrubland south exposed burnt twice (Nina Lauterburg 2013)

Shrubland north exposed burnt three times

In Ayora, there is only one area which burnt three times (image 23). Since this site was not used for agriculture in the past, resprouter species are still present. This patch seems to be in equal or even better conditions than the area burnt twice. Thus, amongst others, the effect of a fire depends on the prevalence or absence of past cropland. However, since there are only few areas which were not cultivated, this site is not really representative.

Image 23: Area north exposed burnt three times (Nina Lauterburg 2013)

Cropland

Despite rural exodus, there is still a considerable area covered by cropland. However, more and more fields are abandoned. Most of the cropland is located in the valley floors (image 25), whereas in the mountains only a small cultivated area can be found (image 24).

Since CASCADE does not focus on cropland, it was not assessed in the WOCAT mapping. However, it is important to note that many fires start on cropland caused by negligent use of machines or traditional burning of residues.

Image 24: Small agricultural plot in the mountains (Nina Lauterburg 2013)

Image 25: Cropland in the valley (Nina Lauterburg 2013)

Urban areas/settlements/roads

This LUS includes the village, which has around 5500 inhabitants, the roads which ensure accessibility of nearly the whole region, and around 150 windmills located on top of the mountain plateau (image 26). The wind mill companies are responsible for improving and maintaining the road network and the firebreaks along these roads. In Jarafuel, a part of the rental fee payed by the wind mill companies is reinvested in forest management.

Image 26: Wind mills and forest roads (Nina Lauterburg 2013)

Unburnt forest and shrubland, shrubland which burnt once or twice, and cropland contain the most extended areas. Only small areas are covered by forest which regenerated after a fire, shrubland which burnt three times, water and urban areas (figure 31).

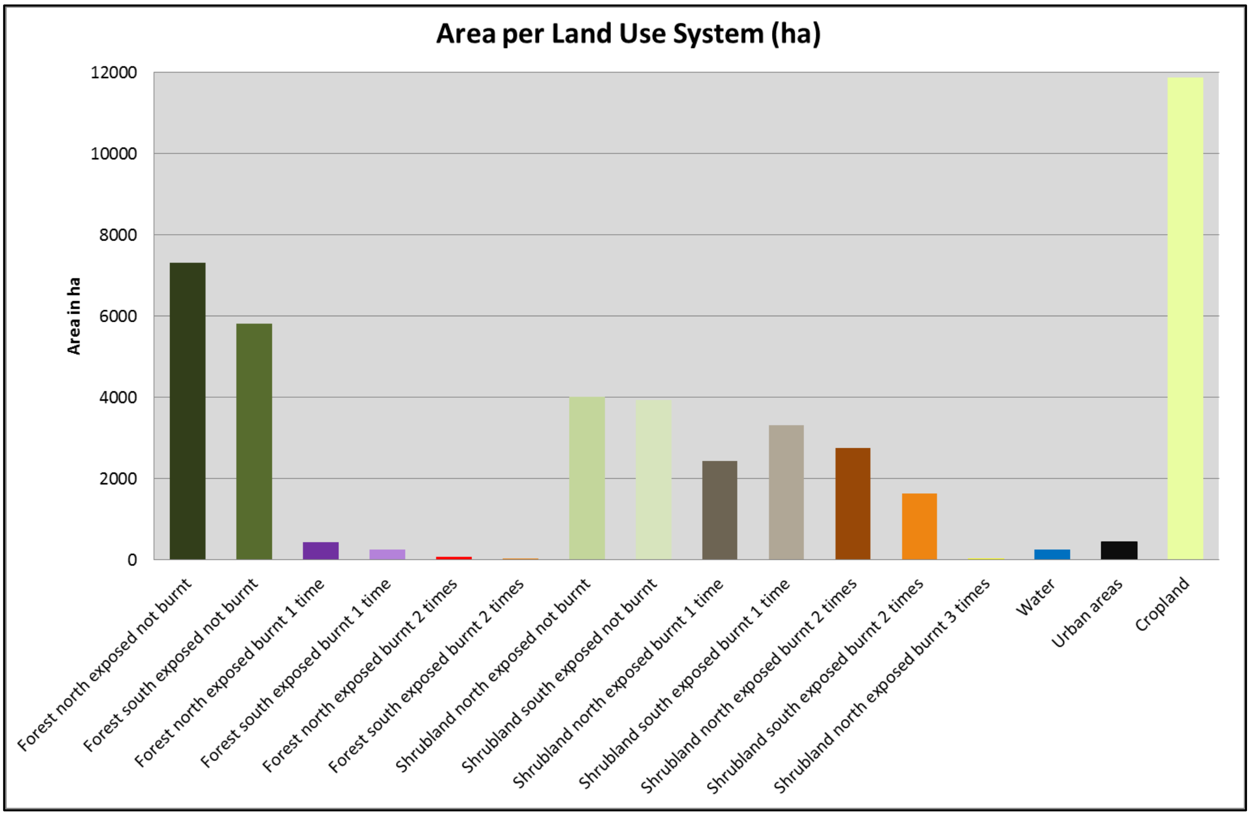


Figure 31: Area per LUS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

It is important to discuss some problems of the base map. The LUS are always related to what is visible today (data of land use map SIOSE 2009). Due to a lack of cartographic data and missing knowledge of stakeholders, it was not possible to state with certainty which vegetation type was prevalent before the fire in 1979. Thus, it is not clear if a shrubland indicated as burnt once was a forest or a shrubland before the fire. However, to draw a conclusion on degradation and on the impact of fires, it is actually crucial to know whether before the fire an area was covered by forest without post-fire recovery, or whether there was already shrubland before the fire. Nevertheless, the base map shows clearly the possibility of different regeneration scenarios after fires. While in some regions the forest recovers, other burnt areas are covered by shrubland, in some cases with a high percentage of bare soil. A major issue of CASCADE is to find out why in some regions a regime shift occurs (e.g. lack of forest regeneration), while other areas show considerable recovery. This issue is further investigated in chapter 4.2.2 on degradation mapping.

4.2.1.3 Area trend per LUS

As mentioned in the explanation of the SLM-DPSIR framework, the area trend and the land use intensity trend are seen as indicators of pressures or direct drivers of degradation. Using the WOCAT mapping questionnaire the dynamics in the region have been analysed considering the last 34 years (1979-2013). In Ayora, there are various issues which make it difficult to draw explicit conclusions on area trends. On the one hand, there is a trend of land abandonment, forest fires and secondary succession after disturbances. On the other hand, abandoned fields and burnt areas have been afforested in some regions. However, the afforestations partly failed or burnt again. Furthermore, there is a lack of knowledge on how the situation was before the fire. Therefore, to obtain knowledge on the dynamics in the region, I combined the indications of the stakeholders with the study of land use maps such as the CORINE land cover (available for the years 1990, 2000, 2006) and SIOSE (2009).

In general, stakeholders assume that before the fire of 1979 the main LUT were forest and cropland. As illustrated in figures 32 and 33, over the last 34 years unburnt forest decreased due to various fires which occurred between 1979 and 2013. Additionally, the area covered by cropland experienced a major decrease caused by land abandonment and transformation into shrubland due to secondary succession. As a result, the area covered by unburnt shrubland has increased. However, it is difficult to draw a conclusion on the dynamics of the unburnt shrubland because on the one hand it has decreased due to fires, on the other hand it has increased its area on abandoned fields. The same problem exists for unburnt forest. Although in Valencia, a small increase in the forested area (1966: 528’772 ha, 1994: 568’553 ha) has been observed (PATFOR 2011), stakeholders argue that despite the forest growth on abandoned fields and through afforestations, the loss of forest caused by fires is exceeding its growth.

Therefore, a general conclusion on the area trend over the last 34 years is that cropland and unburnt forests are decreasing, whereas the area of burnt forests and shrubland (previously unburnt and burnt) is increasing.

In figure 32, the forest which appears as burnt twice has been assessed as forest burnt once which increased its area over the considered time span. As mentioned in the LUS description, these forest patches have probably recovered after the first fire and have not been affected by the second fire, despite their location within the fire perimeter of 1991.

Since stakeholders were not sure about the exact area trends, the land use change will be analysed by another master thesis. These remote sensing based results will contribute to the validation of the WOCAT maps.

To draw a conclusion on area trends in future, it should be noted that it is not sure whether burnt areas will increase or decrease in future. According to the head of fire prevention and extinction (Luis Velasco), the burnt areas have decreased in size in the last few years due to improved infrastructure and organisation of fire prevention/extinction. Therefore, it is possible that future fires will be limited to a certain area due to improved fire fighting. However, stakeholders state that even in the absence of fires, the forested area in Ayora is not likely to increase in the next 20 years.

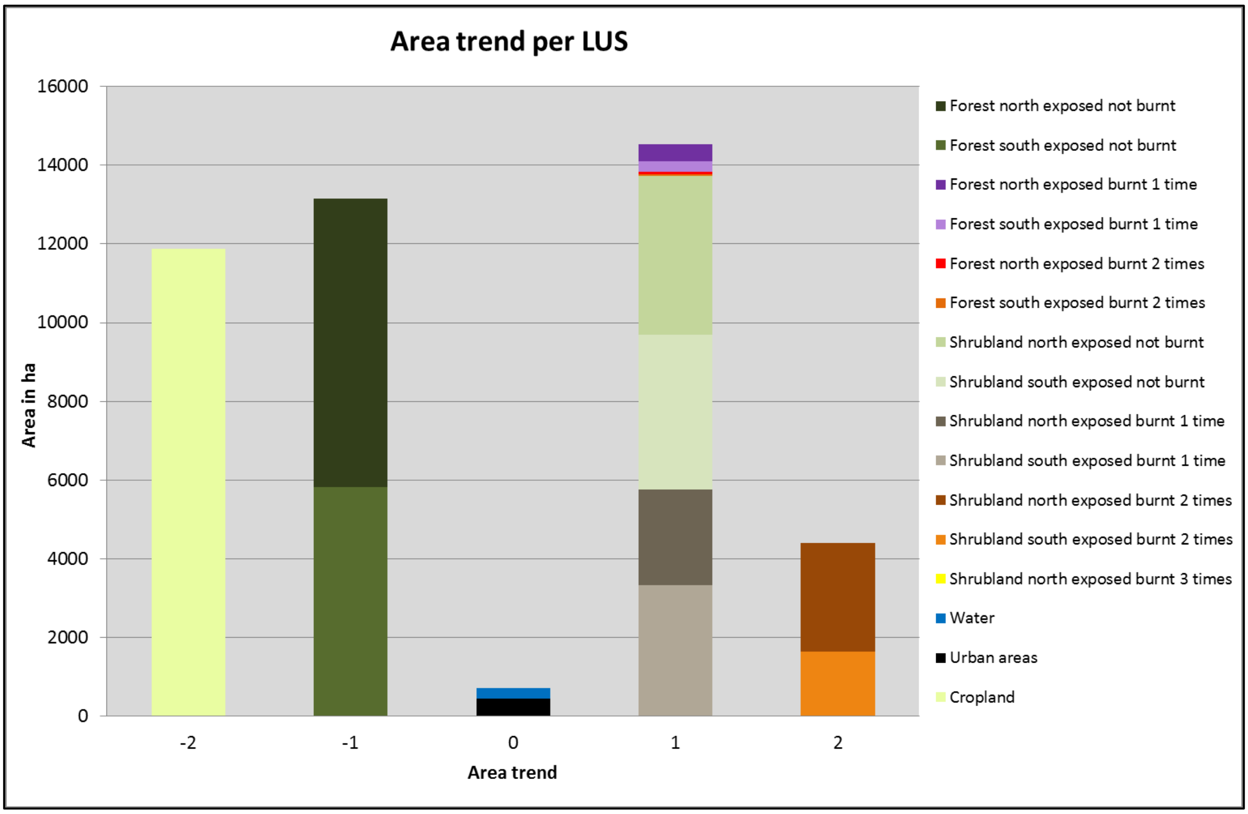


Figure 32: Area trend per LUS (-2=rapidly decreasing, -1=slowly decreasing, 0=remains stable, 1=slowly increasing, 2=rapidly increasing (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

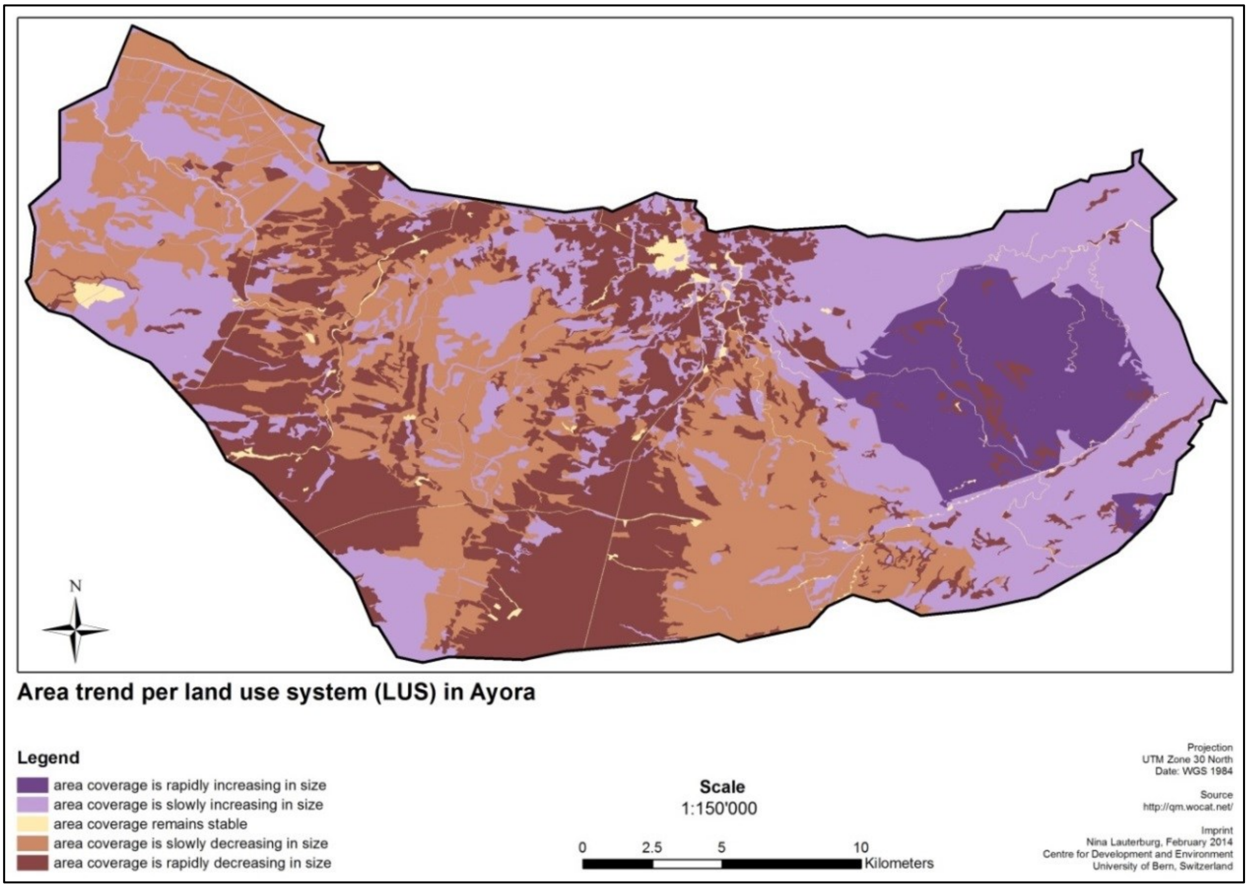


Figure 33: Area trend per LUS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.1.4 Land use intensity trend

As explained previously, the whole region experienced a general decrease in land use intensity. Furthermore, the huge land loss and the degradation caused by the forest fires forced many people to move away. Thus, as shown in figures 34 and 35, a major decrease in land use intensity has been observed on cropland and shrubland (both burnt and unburnt), whereas forests experienced a moderate decrease in land use intensity. However, there are still products of forests and shrubland of considerable importance, e.g. timber and fuel wood in some areas, biomass (energy production), mushrooms, aromatic and medical plants, fruits, seeds, and honey production. The intensity of honey production has maybe even slightly increased compared to the past. But fires are endangering honey production due to the loss of species.

Since in many regions, a decrease in land use intensity results in alleviation of degration it may be confusing that in Ayora it is considered as one of the main degradation drivers. However, land abandonment went along with a lack of management and thus an uncontrolled shrub encroachment and fuel accumulation which resulted in an increase of fires. Therefore, the decreasing land use intensity (land abandonment) and fires are the main direct drivers of degradation. It should be noted that although land abandonment is dominating, there are still agricultural activities and many fires are started on cropland caused by machines or traditional burning of agricultural residues.

4.2.2 Land degradation

Through the WOCAT mapping questionnaire, the post-fire effects and dynamics which are currently still visible have been analysed, considering the time span between 1979 and 2013. Within the SLM-DPSIR framework, land degradation is considered as a state indicator.

4.2.2.1 Degradation types

Since the mapping questionnaire only assesses the major degradation types, this master thesis focuses on the dominant vegetation degradation types (figure 36).

The degradation of the vegetation in Ayora can be grouped into the following types:

- quality and species composition/abundance (Bs)
- quality and species composition/abundance + biomass decline (Bs+Bq)
- quality and species composition/abundance + biomass decline + reduction of vegetation cover (Bs+Bq+Bc)

Furthermore, there is a degradation type “quality and species composition/abundance + increase of pests (Bs+Bp)”, however this type is less important and is therefore not visible on the map. Taking into account that within the CASCADE project the reference ecosystem is a mature pine forest, the most degraded scenario is directly related to the increasing number of fires which is visible on figure 36.

It should be noted that cropland, water and urban areas were not assessed and therefore there is no data available.

The different degradation types per LUS are discussed in the following.

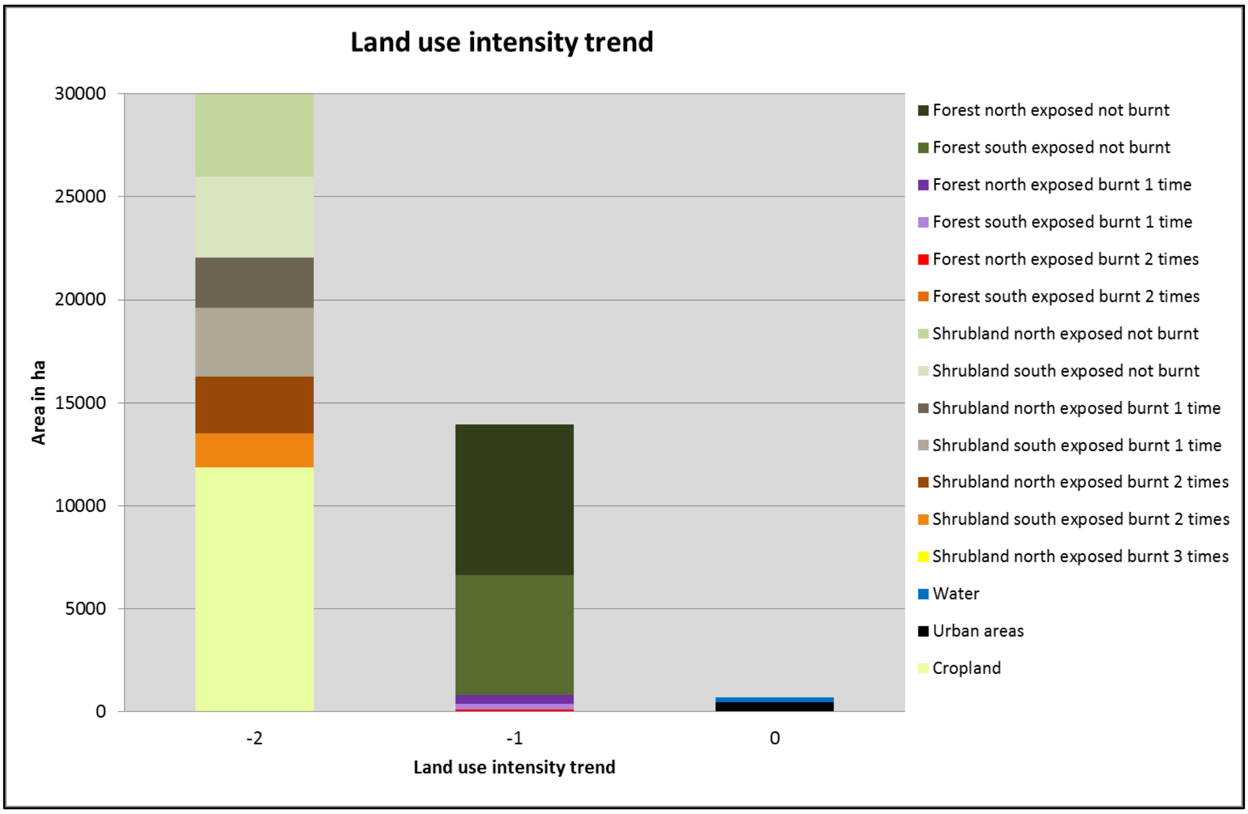


Figure 34: Land use intensity trend (-2=major decrease, -1=moderate decrease, 0=no major changes) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

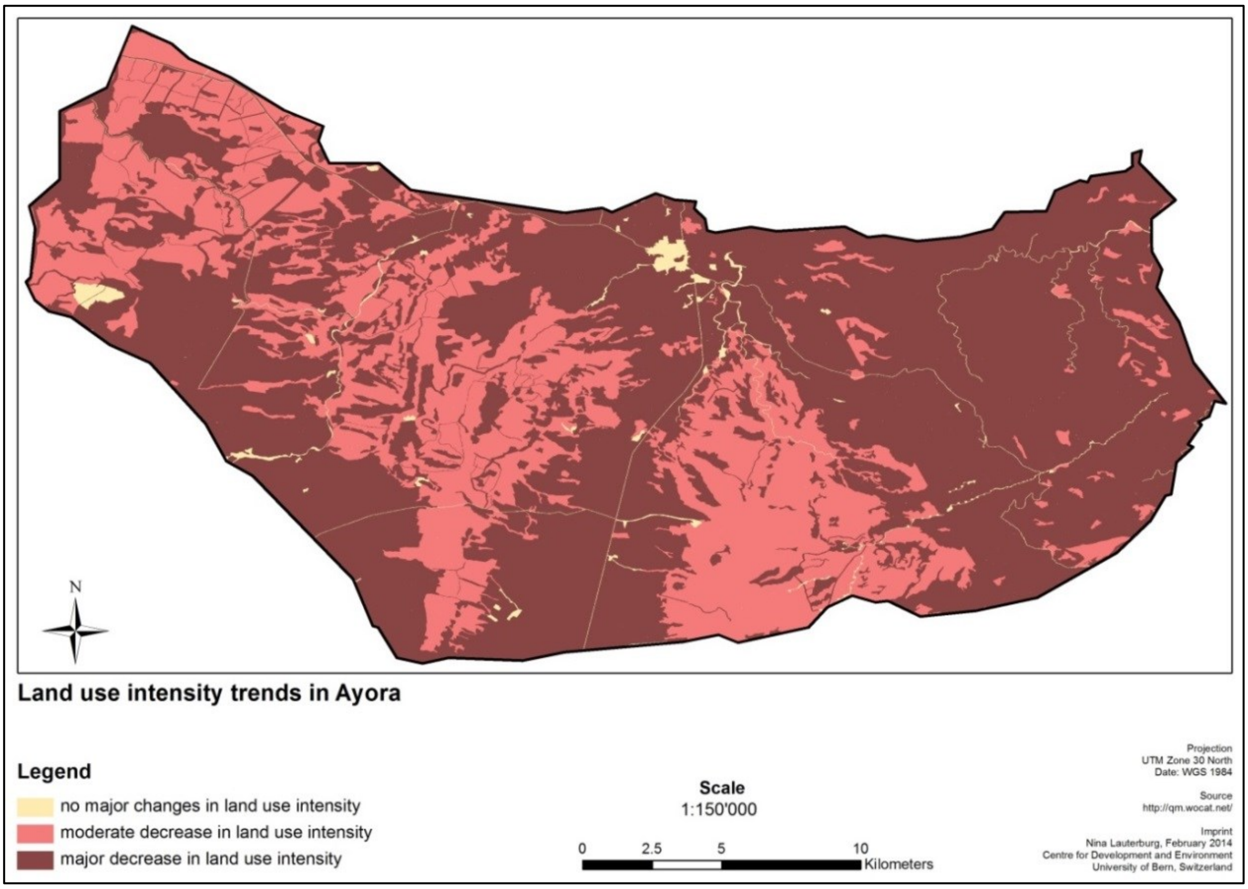


Figure 35: Land use intensity trends (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

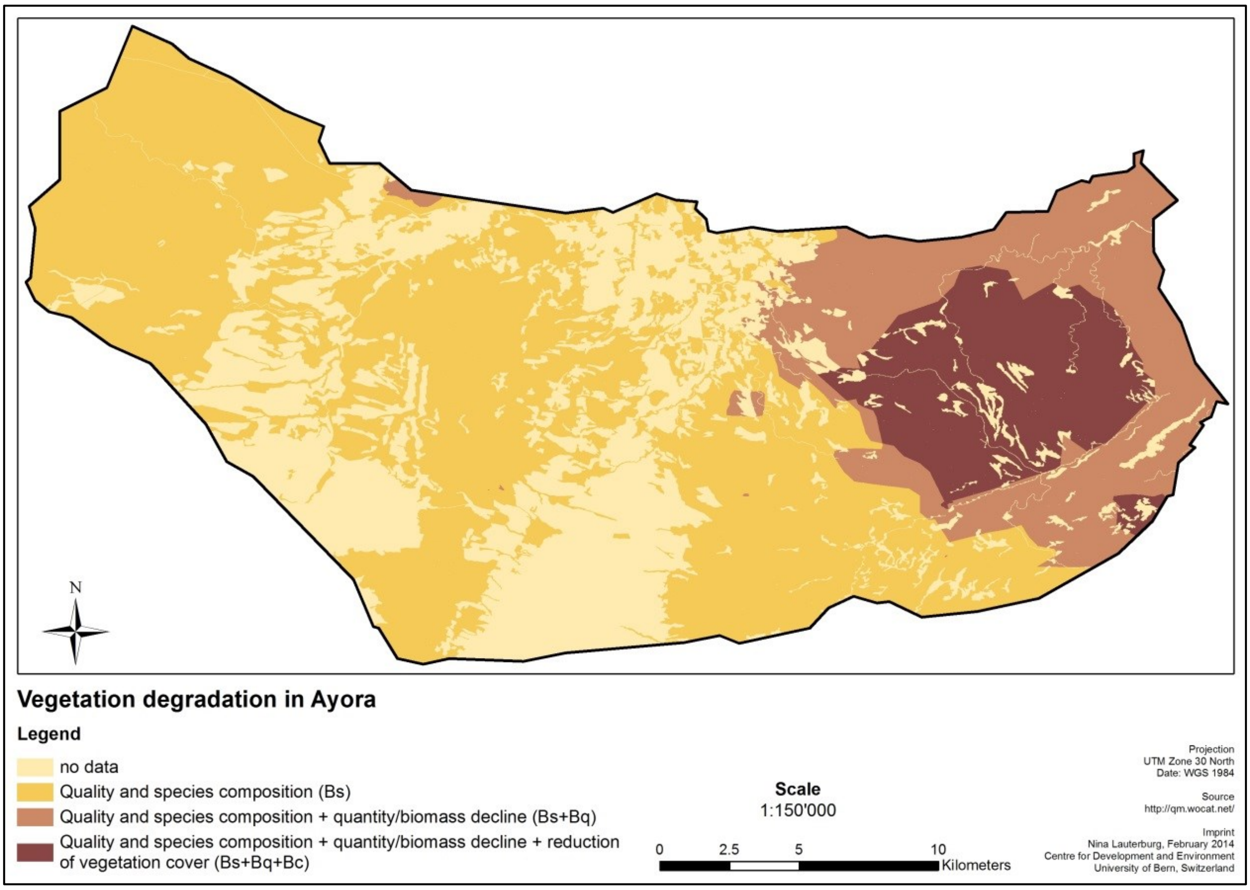


Figure 36: Main vegetation degradation types in Ayora. The abbreviations in brackets are the WOCAT codes used to describe the degradation types (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Unburnt forest and shrubland

In unburnt forest and shrubland the main degradation type is “quality and species composition/ abundance (Bs)”. Due to the anthropogenic removal of resprouter species in the past, vast areas of forests and shrublands experienced a change in the species composition from more fire resistant resprouter species to fire-prone seeder species. Abandoned fields are currently colonized by early-successional seeder shrubs which contain a high fire risk due to their high amount and continuity of fuel (image 28). Unburnt pine forests either regenerated naturally on abandoned fields or originate from afforestations (monoplantations of Pinus halepensis). However, also these forests contain a considerable fire risk (image 27). Thus, the change in the species composition increased the fire risk in both forest and shrubland and can therefore be considered as a major degradation type.

Forest and shrubland burnt once

The change in the species composition described above increased the vulnerability of the vegetation to fires. Therefore, this degradation type plays a major role in burnt areas. Furthermore, if there is an extremely high fire intensity, the species composition may be further changed from forest to shrubland. However, after one fire there is still the possibility of forest recovery if the area is not affected by a second fire within a short period of time.

Both in burnt forest and in burnt shrubland there is a high fire risk. Due to the regeneration strategy of seeder species, the burnt forests often recover very densely (image 29). The density may be around 50’000 pines per ha, whereas an appropriate density would be around 800 pines per ha. This in turn decreases the species quality, resulting from the high competition for nutrients, water and light. Post-fire shrubland is mainly composed of early-successional fire-prone seeder species (image 30).

Through the increased vulnerability of the vegetation, a fire can cause a biomass decline compared to the situation before the fire. Therefore these LUS contain a combination of the degradation types "quality and species composition/abundance (Bs)" + "biomass decline (Bs+Bq)".

Additionally, the combination of the degradation types "quality and species composition/abundance + increase of pests (Bs+Bp)" has to be mentioned for burnt pine forests, although it is less important. If pines are affected by pests, they die and accumulate dead standing biomass, thus increasing the risk of fires. There are more pests in burnt than in unburnt forests, because the vegetation is already weak and therefore less resistant against pests.

Shrubland burnt twice or three times

High fire recurrence results in an increasing degradation. In areas which burnt twice or even three times within a short time period, the forest does not recover anymore and a regime shift to shrubland is observed (image 31). The high fire recurrence interrupts the natural succession and seeds disappear, thus hindering vegetation regeneration. The result is mainly a fire-prone seeder shrubland which is almost permanent and it is still not known whether this pattern will remain in future. Shrublands composed of seeder species again increase the fire risk which triggers short-term fire cycles and promotes a positive degradation feedback. Furthermore, it is assumed that the combination of disturbances such as recurrent fires and climate change may result in extreme degradation. Since seeder species recover more slowly than resprouter species, the soil remains unprotected for a longer time which may increase soil erosion.

Thus, there is often a combination of the degradation types "quality and species composition/abundance + biomass decline + reduction of vegetation cover (Bs+Bq+Bc)". Especially in south exposed areas (image 32), where regeneration is slow and where the most extreme degradation was identified, stakeholders assumed that further degradation may follow such as the combination of "loss of topsoil/surface erosion (Wt)" + "crusting (Pk)" + "reduced organic matter content (Cn)" + "aridification (Ha)". The combination of all these degradation types could reduce the regeneration capacity of the vegetation. In the worst case, a pattern of bare soil with few vegetation cover could arise.

It should be noted that the north exposed shrubland burnt twice contains an extreme fire risk, whereas the same situation on south exposed areas has a lower fire risk due to the low vegetation cover. The area burnt three times has a lower fire risk than the area burnt twice (north exposed) due to the abundance of resprouter shrubs. If the area burnt three times would consist of seeder species, the fire risk would be much higher.

Image 27: Unburnt forest with a high vertical and horizontal continuity (Nina Lauterburg 2013)

Image 28: Unburnt shrubland: Secondary succession on abandoned field (Nina Lauterburg 2013)

Image 29: Forest burnt once in 1979 with a high density and low quality of the vegetation (Nina Lauterburg 2013)

Image 30: Shrubland burnt once in 1979 (Nina Lauterburg 2013)

Image 31: Shrubland north exposed burnt twice (Nina Lauterburg 2013)

Image 32: Shrubland south exposed burnt twice (Nina Lauterburg 2013)

Degradation in a recently burnt area

No recently burnt area was assessed by the WOCAT mapping. However, possible degradation types will be listed here. Depending on the severity and extent of the fire, degradation types may include loss of topsoil (Wt), mass movements (Wm), reduced organic matter content (Cn), crusting (Pk), aridification (Ha), decline of surface and groundwater quality (Hp, Hq), reduction of vegetation cover (Bc), loss of habitats (Bh), biomass decline (Bq), detrimental effects of fires (Bf), quality and species composition (Bs), loss of soil life (Bl). Furthermore, offsite degradation effects (Wo) such as "deposition of sediments, downstream flooding, siltation of reservoirs, and pollution of water bodies with eroded sediments" (Liniger et al. 2008a: E7) may become important. Image 33 illustrates an area in Torre de Manzanas which was affected by a fire in 2012.

Image 33: Area burnt in 2012 in Torre de Manzanas: Pictures illustrate regeneration of present resprouters (center) and massive growth of seeder species such as Cistus (right) (Nina Lauterburg 2013)

Importance of the number of perturbations (anthropogenic disturbances in the past + fires)

While mapping the degradation, it has become evident that it is crucial to differentiate between areas which experienced anthropogenic disturbances in the past and areas which have not been modified. Where key species (resprouters) have not been removed the vegetation recovers quite well even after two fires, whereas the past agricultural activities combined with the removing of resprouter species show its effects in terms of a change to fire-prone seeder species (image 34).

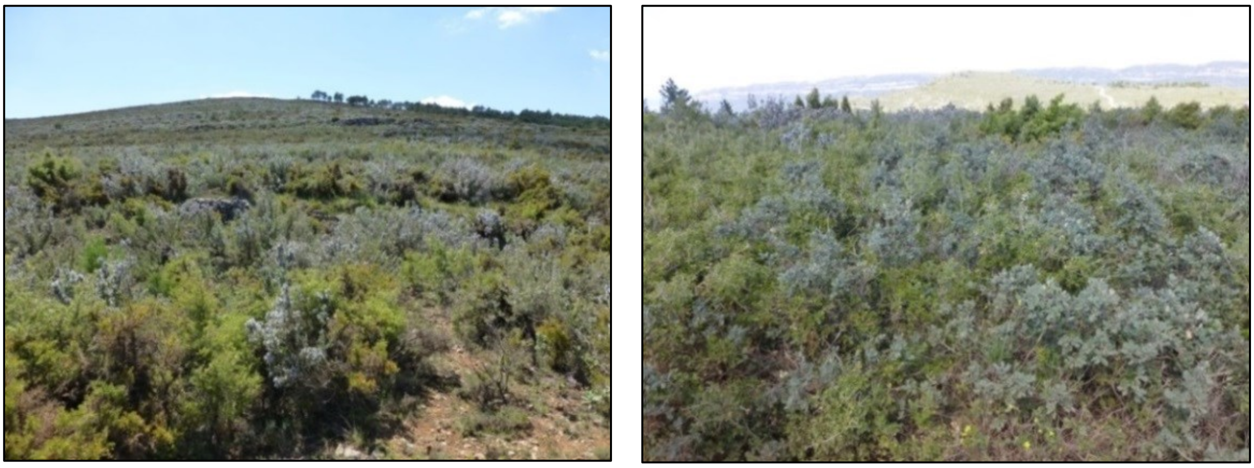


Image 34: Shrubland burnt twice composed of seeders which was formerly cultivated (left) and composed of resprouters which was not cultivated in the past (right) (Nina Lauterburg 2013)

CEAM tested the effect of three fires on an experimental plot which was cultivated in the past. Three recurrent fires caused a shift to a highly fire-prone vegetation composition dominated by Cistus albidus. The area which burnt three times assessed through the WOCAT mapping was not cultivated in the past and therefore differs from the experimental conditions. Although there is a biomass decline and a reduction of the vegetation cover, due to the presence of resprouter species this area is not that degraded as expected (image 35).

Image 35: Shrubland burnt three times composed of seeders which was formerly cultivated (left) and composed of resprouters without cultivations in the past (right) (CEAM, Nina Lauterburg 2013)

Both situations demonstrate that it is not only the number of fires which is driving degradation but actually the combination of perturbations (past cultivations + recurrent fires) which is crucial for the degradation degree, the impact of fires, the regeneration capacity and the probability of a regime shift.

An additional asset for mapping degradation would be the differentiation between seeder and resprouter shrubland (which is not the case in my base map) due to the fact that these shrubland types are very different in terms of fire vulnerability and post-fire regeneration. To map areas with a high degradation and a significant fire risk, and to draw a conclusion on regime shifts, this difference is crucial. However, there is no remote sensing data available so far.

4.2.2.2 Extent of vegetation degradation

The previously presented degradation types do not have the same extent in all LUS. There are two main conclusions which can be drawn from the WOCAT mapping:

- Unburnt vegetation: The extent of degradation is higher in shrubland than in forest.
- Burnt vegetation: In general it can be stated that the extent of land degradation is increasing with the number of fires.

Figure 37 and 38 illustrate the extent of vegetation degradation per LUS in %. The highest degradation extent can be found in south exposed shrubland which burnt twice; 80% of this LUS are considered as heavily degraded. The area burnt three times has a lower extent of degradation than shrubland burnt twice. However, as already mentioned, it can actually not be compared to the other situations due to the fact that it was not cultivated in the past. The extent of degradation in a north exposed area burnt three times which was formerly cultivated would be around 70%.

If the absolute degraded area is calculated, it becomes evident that not only the shrubland burnt twice is severly degraded, but also the unburnt forests and shrublands (figure 39). The change in species composition affects a vast area and constitutes a high fire risk.

Furthermore, a small area of forest burnt once is threatened by pests.

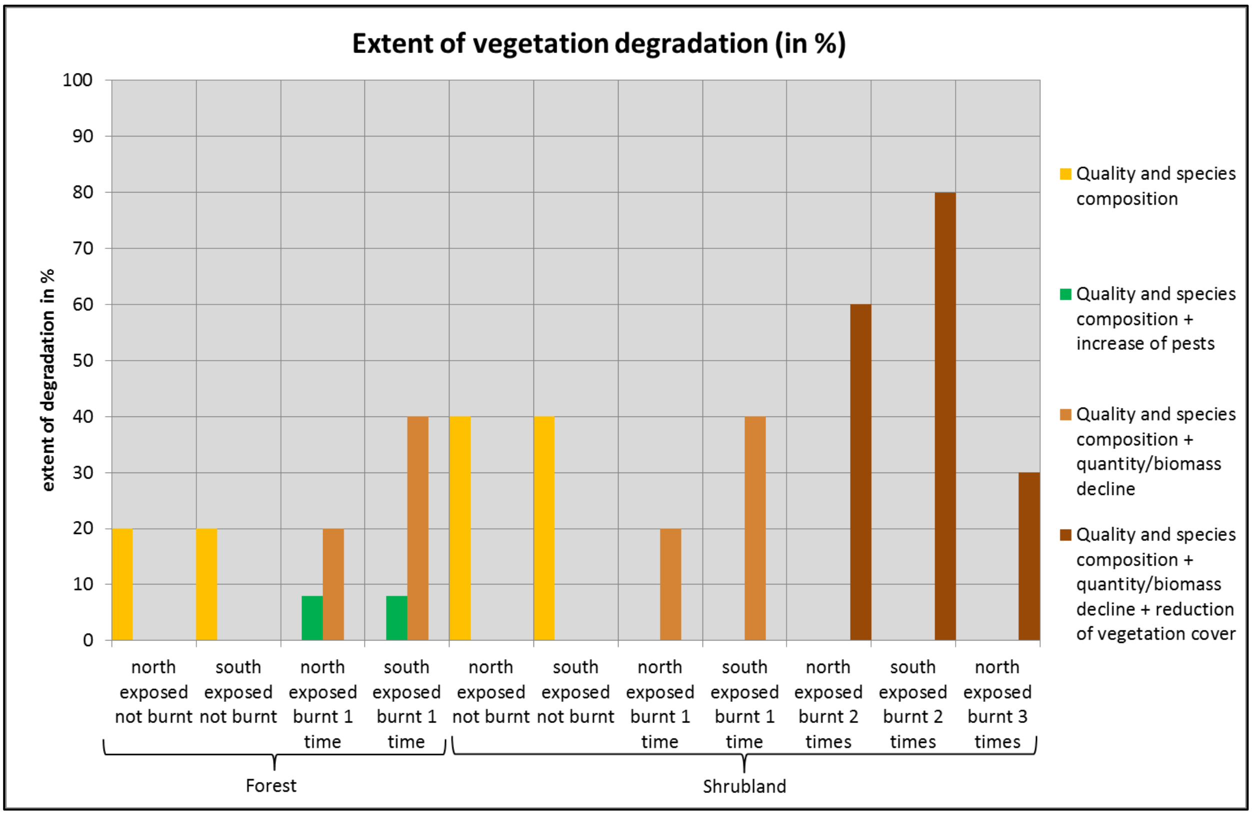


Figure 37: Extent of vegetation degradation per LUS in % (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

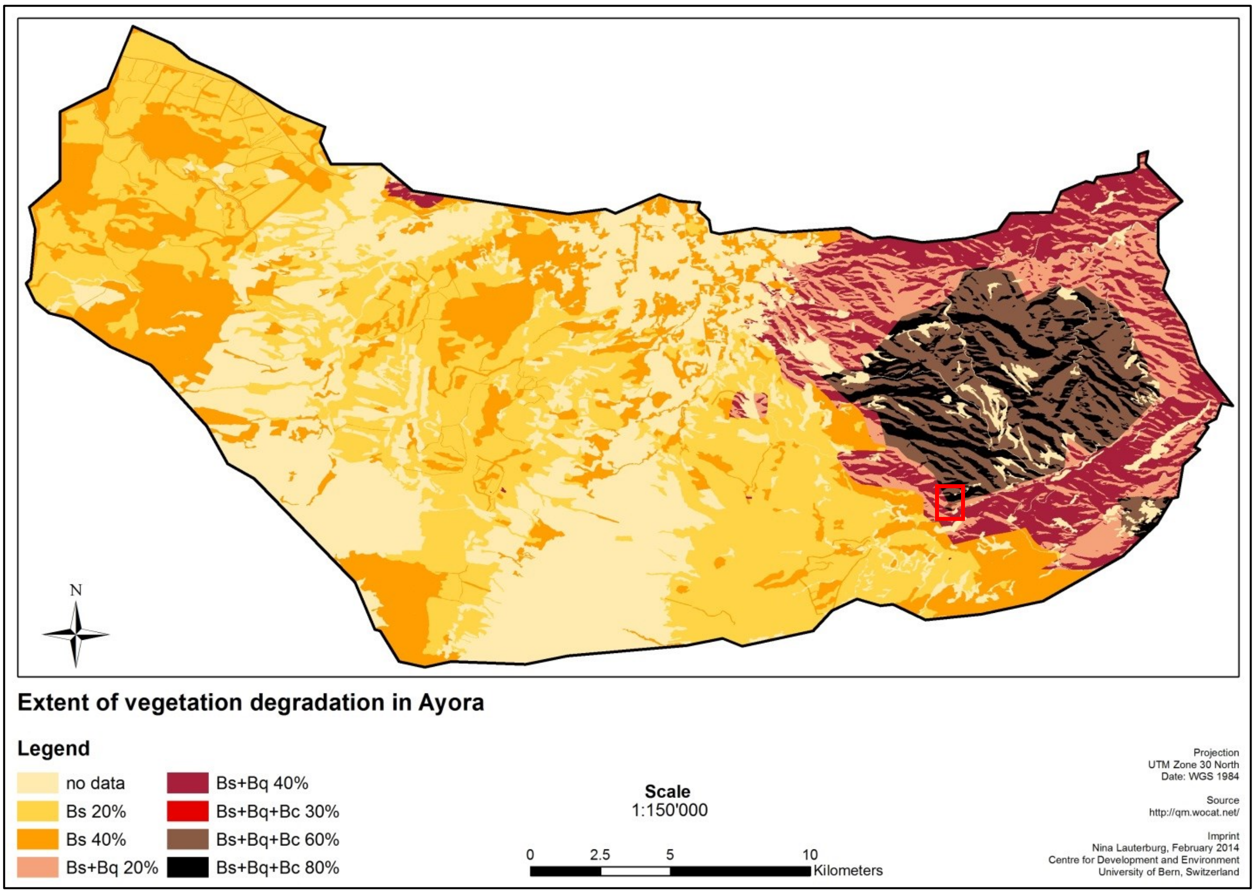


Figure 38: Extent of vegetation degradation per LUS in %. The extent marked in red is located in the shrubland which burnt three times (red box) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

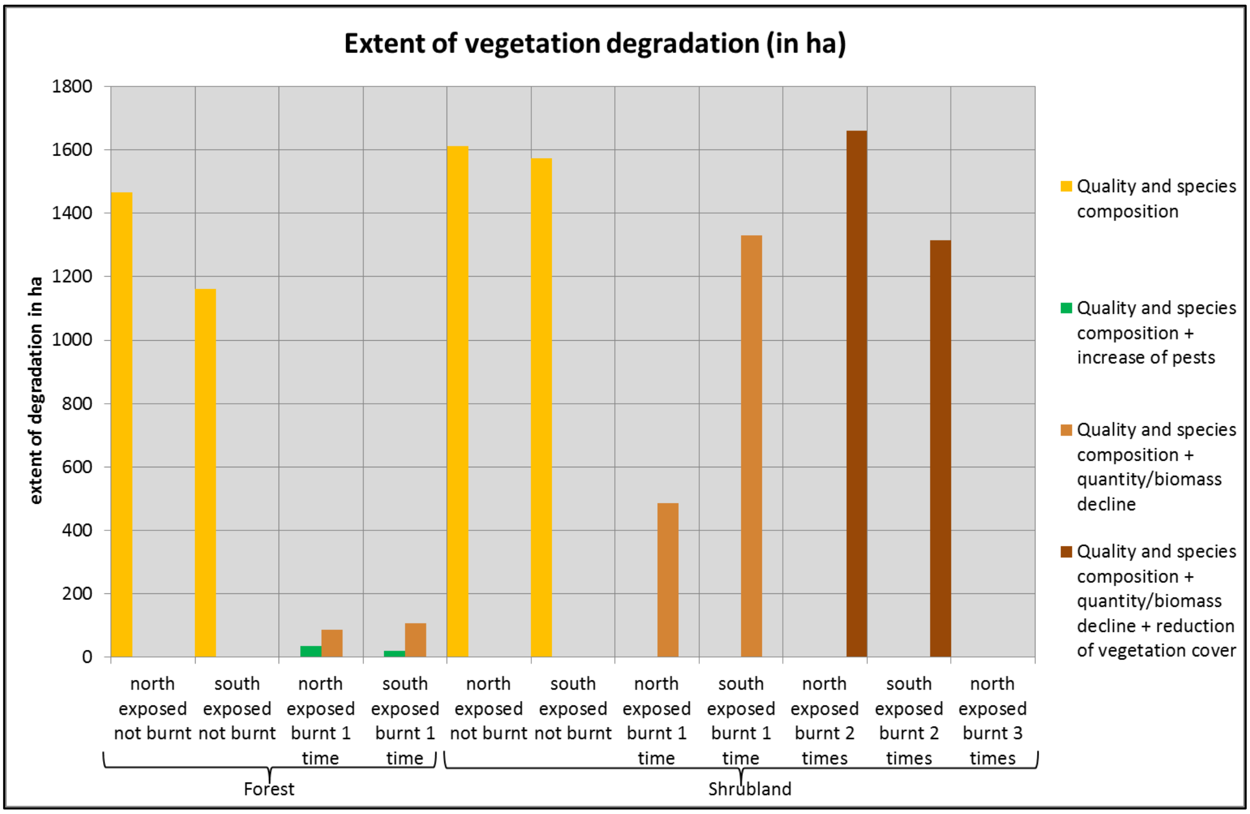


Figure 39: Extent of vegetation degradation in ha (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.2.3 Degree and rate of vegetation degradation

The degree of degradation is defined as "the intensity of the land degradation process" (Liniger et al. 2008a: E9) and is considered as a state indicator in the SLM-DPSIR framework. The degree can either be light, moderate or strong. In Ayora, the degradation degree is light in forest (both unburnt and burnt) as well as in shrubland burnt once (north exposed). A moderate degradation occurs in unburnt shrubland, shrubland burnt once (south exposed), shrubland burnt twice (north exposed) and shrubland burnt three times. Only in the case of shrubland burnt twice (south exposed) the degree of degradation is strong (figure 40 and 41).

"Whereas the degree of degradation indicates the current static situation, the rate indicates the trend of degradation" (Liniger et al. 2008a: E9) over the considered time period (34 years). In the SLM-DPSIR framework the rate is considered as a state indicator and can either indicate decreasing or increasing degradation. Notably, there is no decrease in degradation observed in Ayora. Degradation is slowly increasing in unburnt and burnt forests, moderately increasing in unburnt shrubland and shrubland burnt once or three times, and rapidly increasing in shrubland burnt twice (figure 42 and 43).

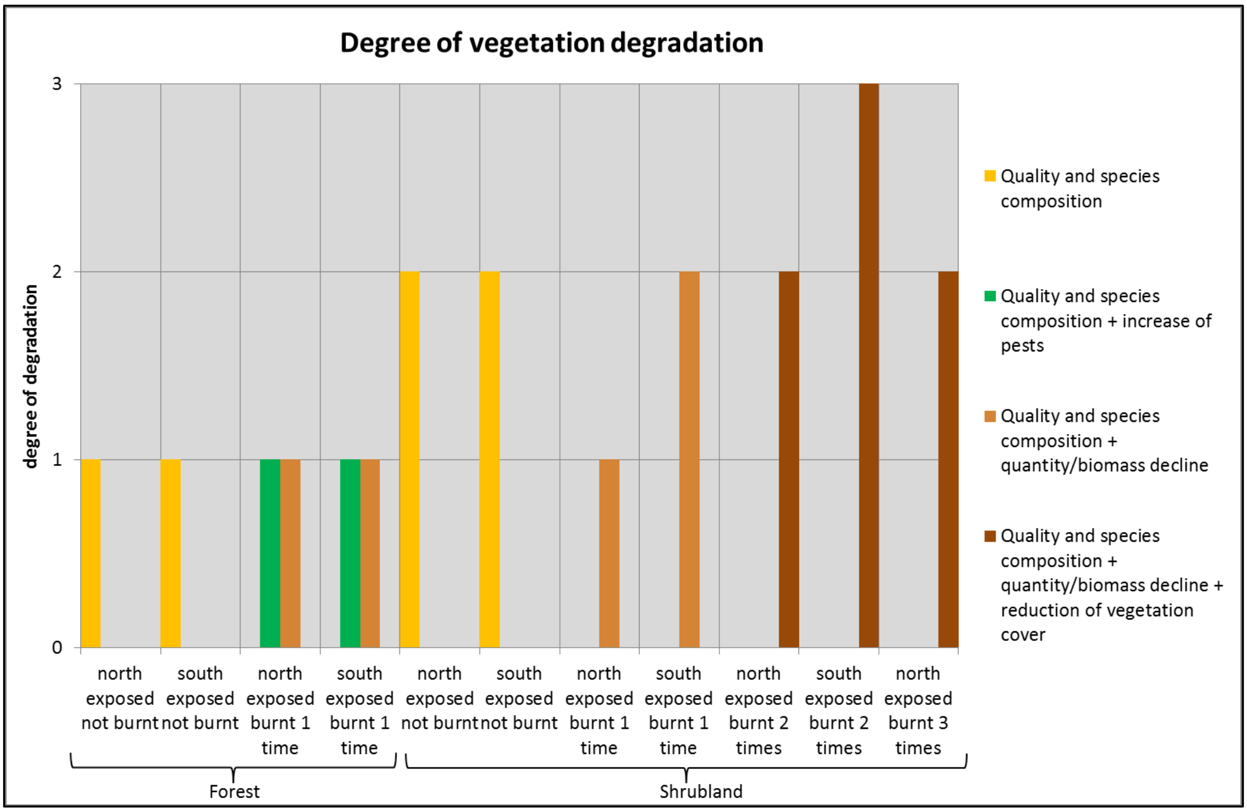


Figure 40: Degree of vegetation degradation (1=light, 2=moderate, 3=strong) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

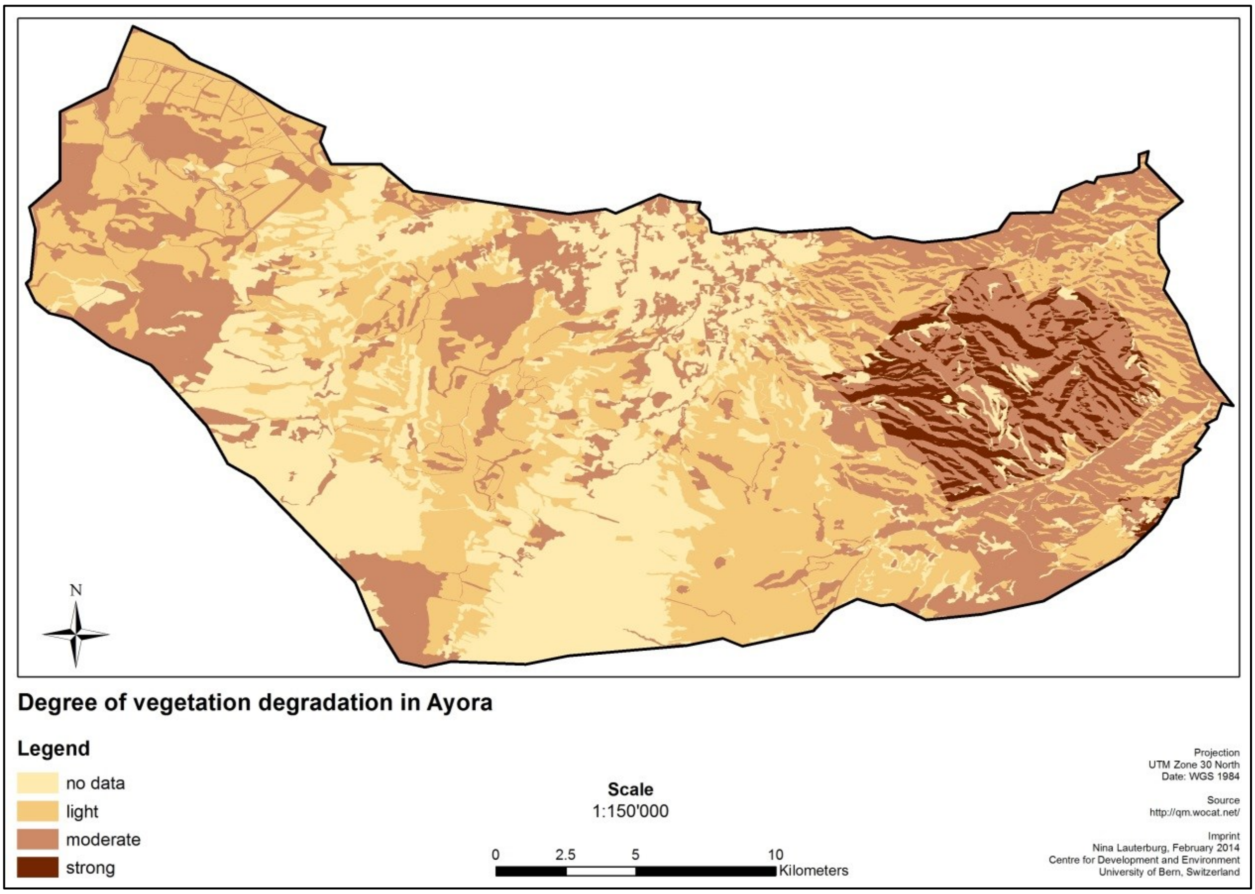


Figure 41: Degree of vegetation degradation (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

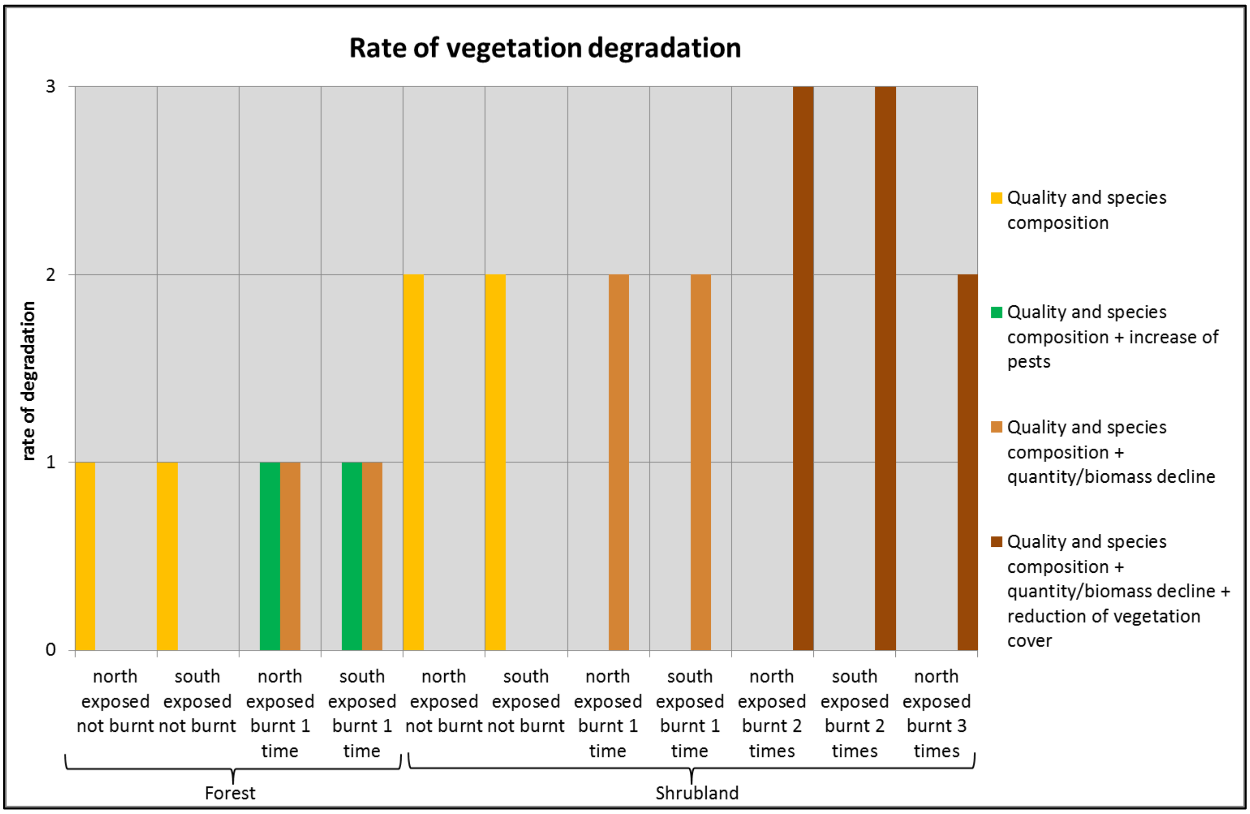


Figure 42: Rate of vegetation degradation (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

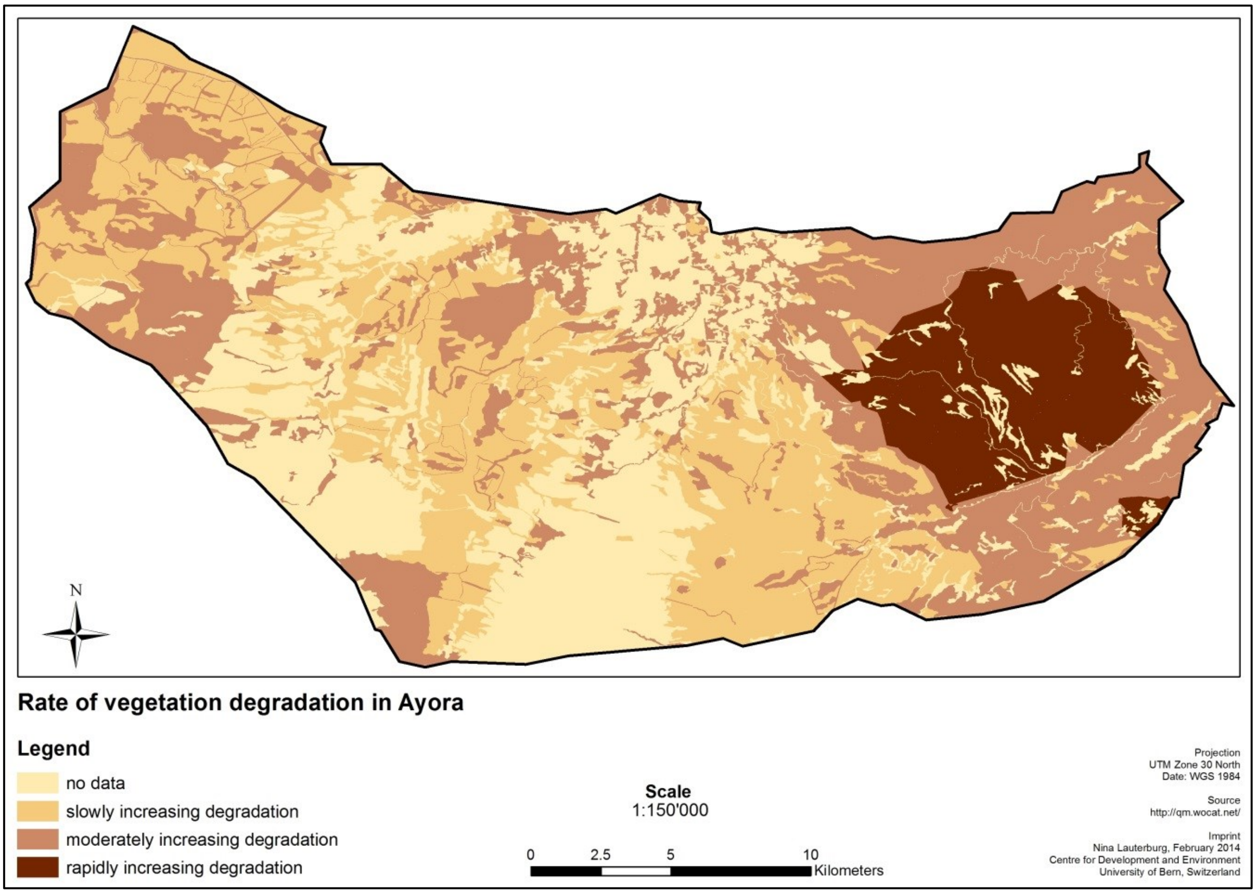


Figure 43: Rate of vegetation degradation (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Thus, by comparing the degree and the rate of vegetation degradation, it becomes evident that all degradation types have increased in both their degree and rate over the last 34 years (figure 44).

The conclusion which can be drawn for management is that especially the areas burnt twice have to gain more attention. However, also the other areas contain a considerable fire risk and should be addressed through conservation practices.

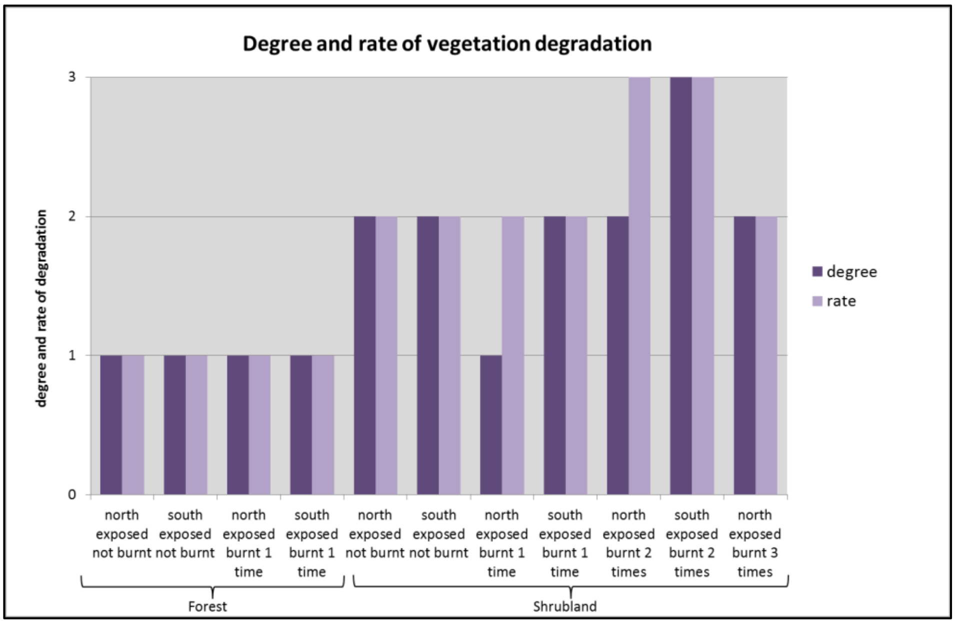


Figure 44: Degree and rate of vegetation degradation (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.2.4 Indirect drivers of vegetation degradation

Along with (anthropogenic and natural) direct drivers of vegetation degradation and fire risk, also indirect drivers have been assessed during the mapping process. Stakeholders explained that both the exploitation of resources in the past and the low demand for forest products at present due to a change in the consumption pattern resulted in an uncontrolled growth of forests and shrublands. Furthermore, the low population density in Ayora leads to a lack of labour in forest management. Also land tenure influences vegetation degradation; the local and regional administrations only execute management practices on public land. The intensity of management depends on the availability of budget invested by the state. One of the most important indirect drivers of degradation mentioned by the stakeholders was the lack of investment in forest management which is further increased by the current economic crisis in Spain. Additionnally, governance and forest politics are crucial; before the devastating fire in 1979 fire prevention and extinction infrastructure was lacking which partly explains the dimension of this event. At present, the government increasingly focuses on the problems related to fires. Furthermore, the loss of knowledge of urban people who use villages and their surrounding natural areas for recreation endangers forests and shrublands. Contrary to rural people who know about the fire risk, urban people are not anymore aware of it. Especially during summer this lack of knowledge constitutes a high risk.

4.2.2.5 Impacts of degradation on selected productive, ecological and socio-economic ecosystem services

The degradation has both negative but also some positive impacts on productive, ecological and socio-economic ESS. The general conclusion which can be drawn from this assessment is that there is an increasing negative impact with an increasing number of fires (figure 45). Figure 46 presents the detailed impacts of degradation per LUS, both negative and positive. In Annex 3, there are further figures on the impacts of degradation on ESS. In the following, some selected impacts are discussed in relation to the vegetation degradation and fires.

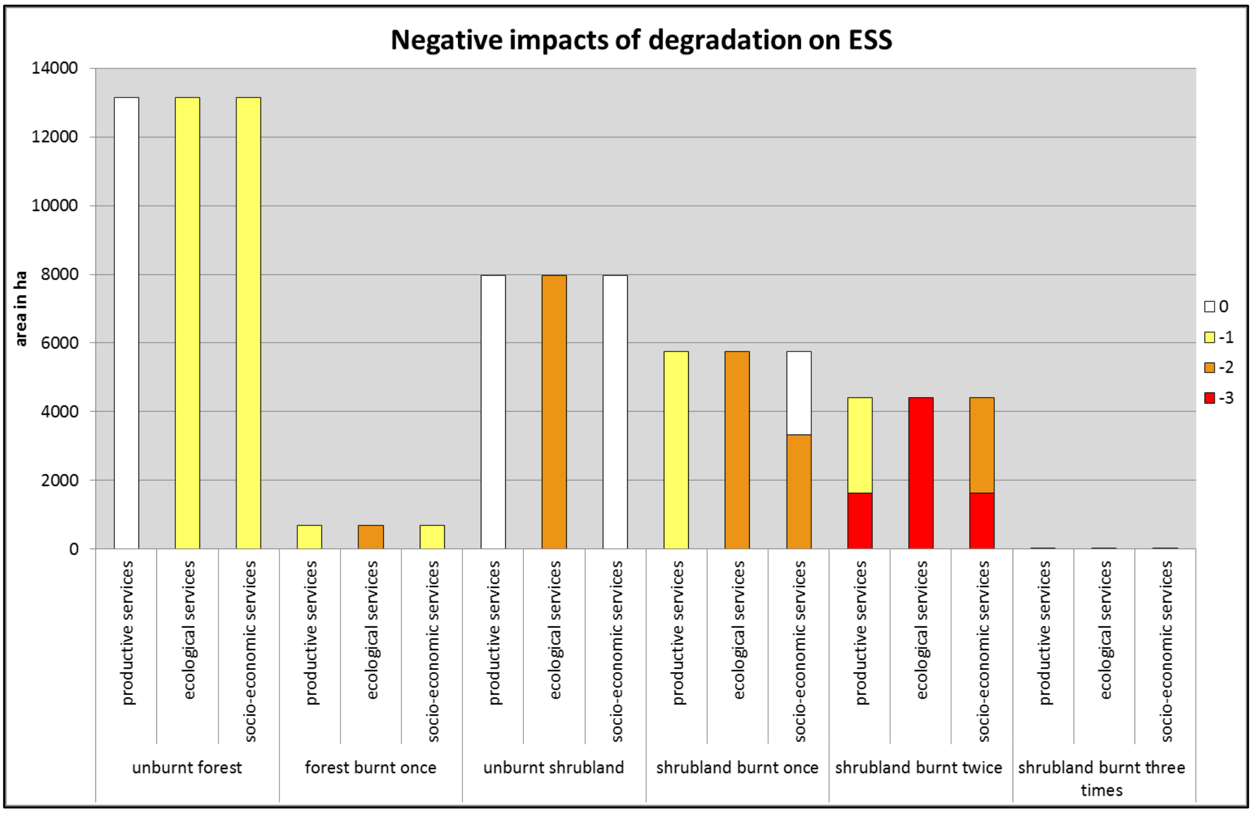


Figure 45: Negative impacts of vegetation degradation on ESS. The impacts in the small area covered by shrubland burnt three times are -1 for productive services, -2 for ecological services and -1 for socio-economic services (-1=low negative impact, -2=negative impact, -3=high negative impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

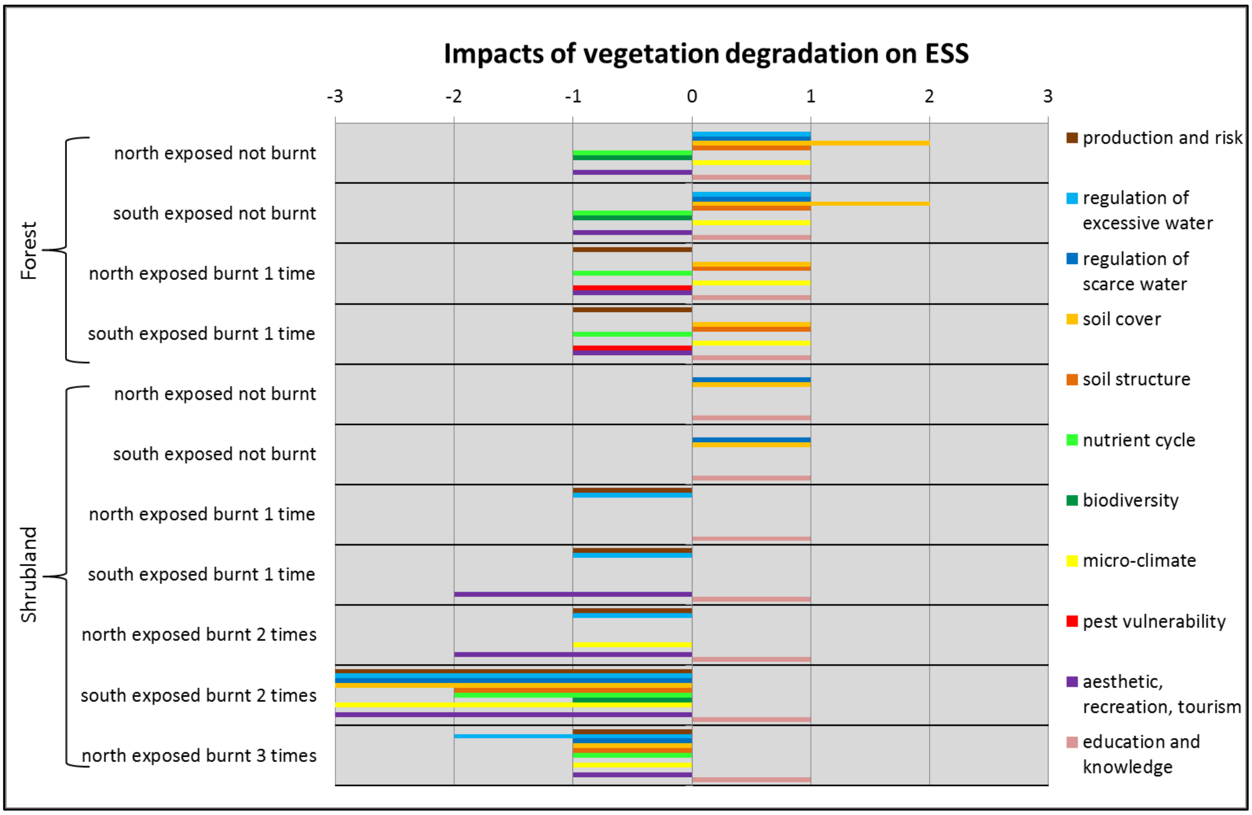


Figure 46: Impacts of vegetation degradation on ESS (-3=high negative impact, -2=negative impact, -1=low negative impact, 1=low positive impact, 2=positive impact, 3=high positive impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Impacts of degradation on selected productive services

Important productive services of forests and shrublands in Ayora are timber, biomass, animal production and honey production. All of these activities experience a negative impact with the increasing number of fires.

The dense growth of pines in forest and afforestations results in a bad quality of the timber and in a decrease of biomass.

Honey production is a very important activity in Ayora. Honey made of rosemary is the one which is most sold, therefore beekeepers are interested in shrublands composed of rosemary. If a forest or a shrubland burns several times, honey production can no longer be carried out due to a loss of plants. This situation becomes very clear in the south exposed shrubland which burnt twice.

Image 36: Honey production is an important activity in Ayora (Hanspeter Liniger 2013)

It should be noted that on recently burnt areas grazing is forbidden for up to 5 years, therefore animal production also experiences a negative impact.

Impacts of degradation on selected ecological services

Most of the ecological services experience a negative impact with the increasing number of fires. Recurrent fires have negative impacts on soil cover and the water cycle. After a fire, the loss of vegetation cover results in an increase of runoff and a decrease of infiltration. Therefore, the regulation of both excessive and scarce water is disturbed. These effects are particularly strong in the south exposed shrubland burnt twice where bare soil and crusting lead to aridity and erosion. In unburnt forests, the density of trees shows a positive effect because runoff is slowed down and infiltration is enhanced.

The soil cover is high in unburnt areas and is decreasing with high fire recurrence. However, north exposed shrubland burnt twice still shows a quite good soil cover. In contrast, south exposed shrubland burnt twice has a high percentage of bare soil. The south slopes are much more exposed to the Mediterranean summer climate, thus burnt vegetation recovers slower and seems to be more exposed to consequent degradation of the vegetation cover and exposure of bare soil to erosion. Less vegetation cover on southern slopes is also likely to have a negative impact on the micro-climate leading to less shade, higher temperatures, decreasing soil moisture, and an increase in wind speed.

The nutrient cycle is probably disturbed in all LUS due to modifications of the vegetation composition, resulting from past land use or monoplantations. However, in the south exposed shrubland burnt twice a disturbance of the nutrient cycle is most probable due to the reduced vegetation growth and depletion of soil caused by erosion and aridity. Furthermore, fires highly disturb the carbon cycle.

When drawing conclusions on the impact of degradation on biodiversity, it should be noted that biodiversity is a risky concept when understood only as species richness. In this sense, Ulex parviflorus shrubland has the highest species richness while Quercus coccifera shrubland presents a low number of species, due to the fact that the number of species decreases when natural succession progresses. Therefore, depending on their recurrence, fire may maintain species richness. However, if there is a high fire recurrence, biodiversity may also decrease.

In dense forests where individuals are weak due to high competition, trees are highly vulnerable to pests. This in turn increases the amount of dead individuals and thus the fire risk.

Impacts of degradation on selected socio-cultural services

The forest has a high aesthetic and recreational value. Urban habitants like to spend their weekends in the rural areas. Both very dense forests as well as burnt areas cause a decrease in these values. People complain that they cannot walk through dense forests or shrubland. In summer, shrubland does not provide shade which is therefore not attractive for recreation.

Nevertheless, the dense growth of forests and the recurrent wildfires strengthened the awareness of (at least rural) people for the importance of management and the impacts of fires. This can be considered as a positive impact of degradation.

Impacts of degradation on fire risk

Figure 47 and 48 illustrate the impacts of degradation on fire risk.

An important question is why shrubland should be considered worse than forest. Along with the decrease of the above discussed ESS, the major problem is that shrubland composed of seeder species increases the fire recurrence which might lead to a downward degradation spiral. Fire hazard is lowest in shrubland dominated by Quercus coccifera, increases in shrubland dominated by Rosmarinus and is highest in shrubland dominated by Ulex parviflorus.

However, as visible in figure 47, in the south exposed shrubland burnt twice the fire risk has actually decreased due to the high extent of bare soil and thus the interruption of the continuity. The same is valid for the shrubland burnt three times, furthermore there are resprouters which are less fire prone.

In unburnt forest, the high density, the bad quality of trees and the high fuel amount also increase the fire risk. Dead or sick trees are more flammable.

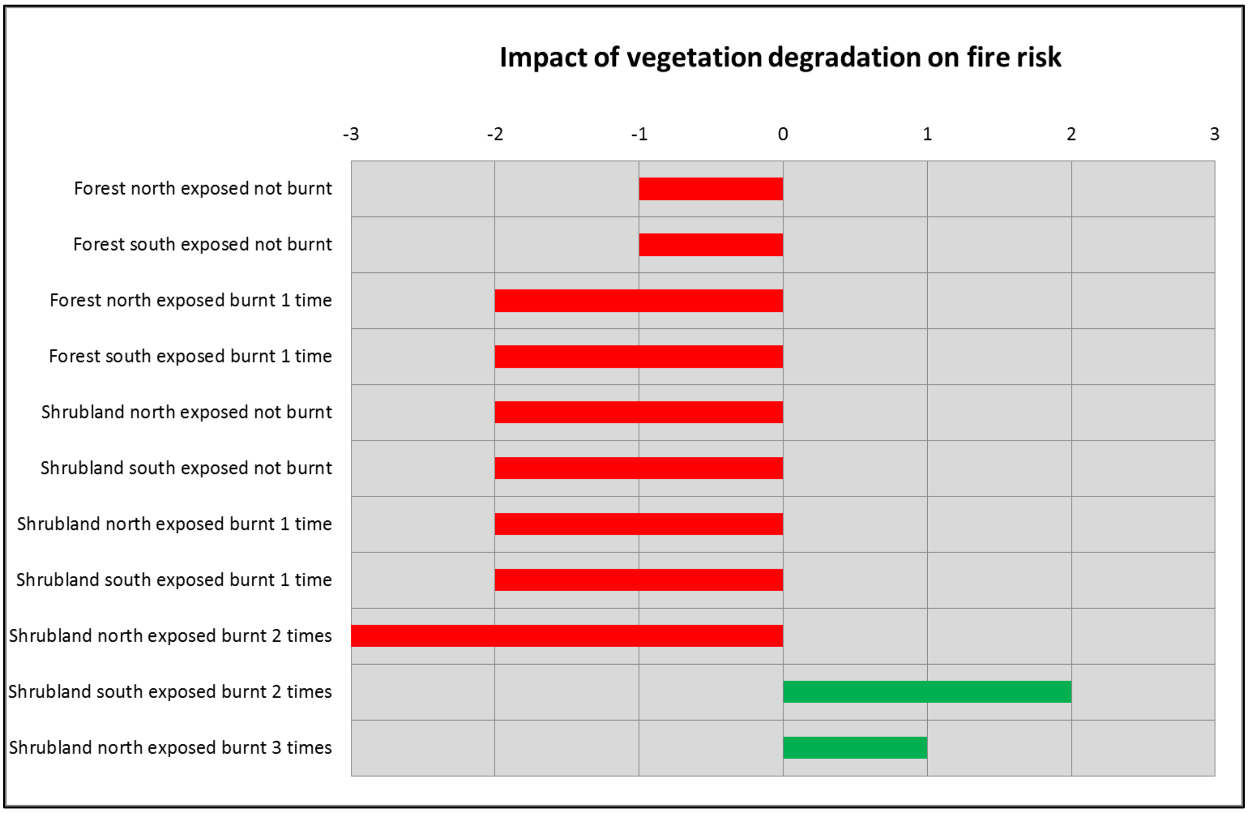


Figure 47: Impact of vegetation degradation on fire risk (-3=high negative impact, -2=negative impact, -1=low negative impact, 1=low positive impact, 2=positive impact, 3=high positive impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

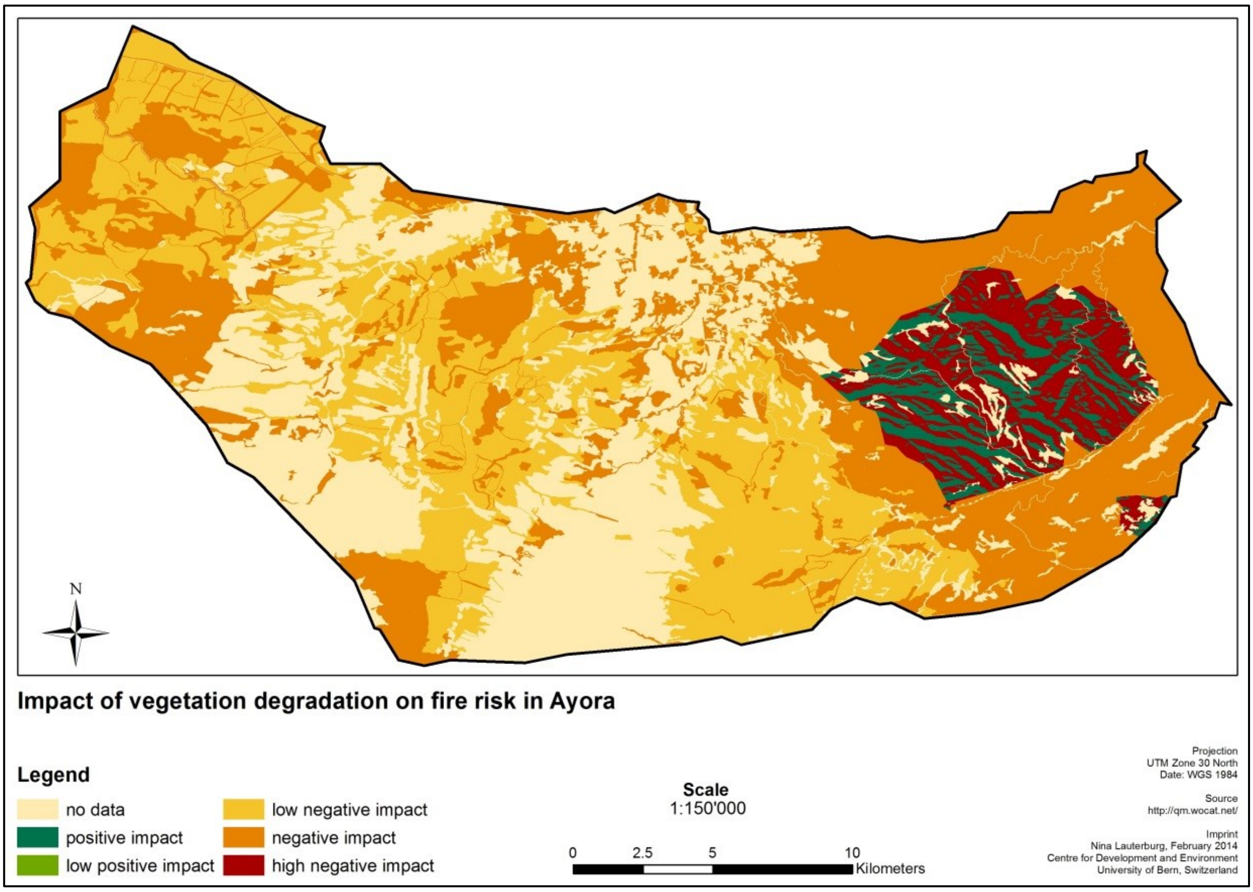


Figure 48: Impact of vegetation degradation on fire risk (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.3 Land conservation

In the following chapter, the conservation measures which have been identified in the field are presented. In the SLM-DPSIR framework conservation measures are considered as response indicators, thus the reactions to deal with land degradation. The results of the WOCAT mapping contribute to the evaluation of those forest management practices.

4.2.3.1 Conservation measures

As a consequence of several devastating fires and their negative impacts on productive, ecological and socio-economic ecosystem services, the government of Valencia introduced management interventions in order to improve fire prevention and extinction as well as to promote mature forests. Important SLM practices which can be found in Ayora and which have been assessed through the mapping questionnaire include the establishment of a firebreak network, selective forest clearings (to reduce the fuel load and the competition between different plants) and numerous Pinus halepensis afforestations aiming in post-fire rehabilitation or restoration of abandoned fields. All of them belong to the conservation group “AP: Afforestation and forest protection” and are categorized as vegetative measures (Table 18).

Name of the technology	Conservation measure	Purpose
Firebreaks	Clearing of vegetation (V3)	Prevention of fires
Afforestation	Tree and shrub cover (V1)	Rehabilitation of burnt or abandoned areas Prevention of soil erosion
Selective forest clearing	Clearing of vegetation (V3)	Prevention of fires

Table 18: Overview of management practices in Ayora (Nina Lauterburg 2014)

Each of the above presented practices is presented briefly in the following. However, they have been assessed with the WOCAT questionnaire on technologies and are therefore discussed in detail in the results on SLM technologies (chapter 4.3).

Firebreaks

The purpose of firebreaks is the prevention of fires. The basic principle of a firebreak network is to split continuous forest areas (where a lot of fuel is built up) into smaller forest patches separated by vegetation-free strips (image 37). The spread of the fire is hindered or limited through the interruption of hazardous fuels. Furthermore, fires are slowed down and the strips facilitate the access for fire fighters.

Image 37: Firebreaks (Nina Lauterburg 2013)

Afforestation

In Ayora, afforestations have been done on abandoned cropland and on burnt areas where pines were not expected to recover by themselves (image 38). The afforestations between 1979 and 2013 were mainly done on burnt areas. The major tree species which has been used is Pinus halepensis because it is easy to handle and it has the highest survival and growth rates after planting. Furthermore, the timber had a high value in the past. In the 1990s, they started to introduce quercus seedlings. However, quercus is much more demanding than pines both in resources and conditions. Furthermore, the plant quality in forest nurseries was rather low. Therefore, there are almost no holm oak formations originating from afforestations.

The purpose of post-fire afforestations is the prevention of soil erosion and the rehabilitation of burnt areas.

Image 38: Post-fire afforestation with Pinus halepensis (Nina Lauterburg 2013)

Selective forest clearing

Selective forest clearing includes activities such as thinning and pruning. It aims in reducing the accumulation of fuel and its continuity (both vertical and horizontal), as well as the competition for resources between regenerating trees (image 39). Thus, the purposes of this management practice are the prevention of fires and the promotion of ecosystem resilience to fires.

Image 39: Selective forest clearing (Nina Lauterburg 2013)

4.2.3.2 Extent of SLM technologies

This chapter illustrates the extent of the above described conservation measures as a percentage of each land use system.

As shown in figure 49, all LUS are covered by firebreaks to an extent of 70% and 90%. The extent is that high because the chart indicates the area which is protected by the firebreaks (and not only the cleared area). Selective forest clearing is only done on less than 10% of the forested area. However, this indication should be taken with caution due to the fact that stakeholders were not sure about the extent of this management measure. Notably, this practice is not applied in shrubland. Afforestations which were executed within the considered time span are mainly implemented on burnt shrubland, covering 30% of shrubland burnt once and around 20% of shrubland burnt twice. Figure 50 illustrates the extent of conservation measures in hectares.

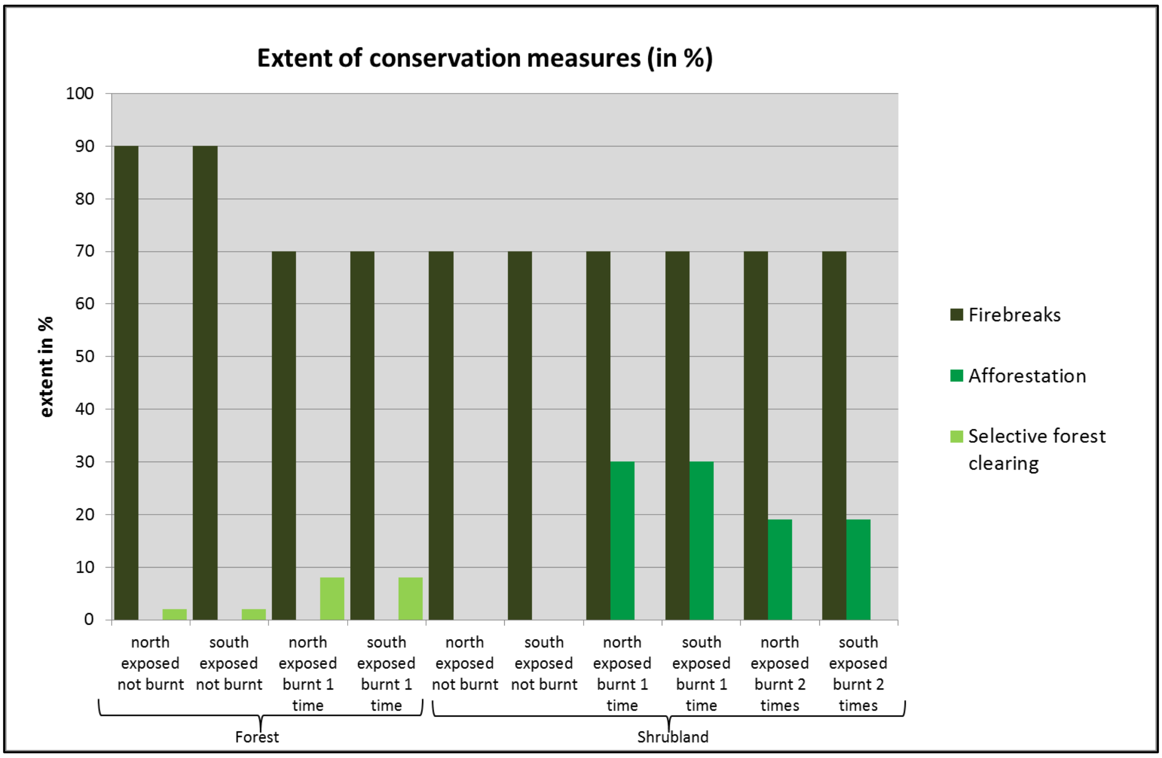


Figure 49: Extent of conservation measures in % (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

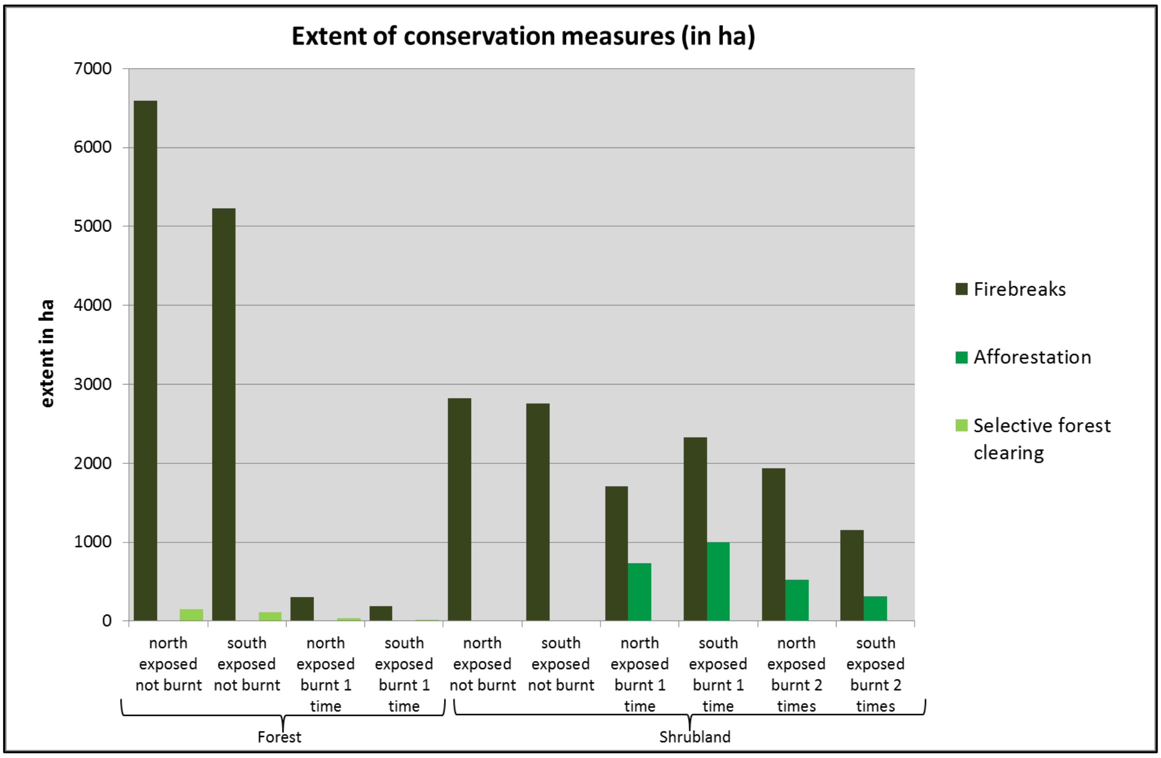


Figure 50: Extent of conservation measures in ha (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Firebreaks

Almost the whole area is covered with and thus protected by firebreaks, however not all of them are well maintained (Figure 51). Most of the firebreaks were established between 1998 and 2002 within a pilot project which is described in the chapters on SLM technologies and approaches. However, some firebreaks already existed before the execution of the pilot project and some were established afterwards. The dimensions of these firebreaks are explained in chapter 4.3.1.2.

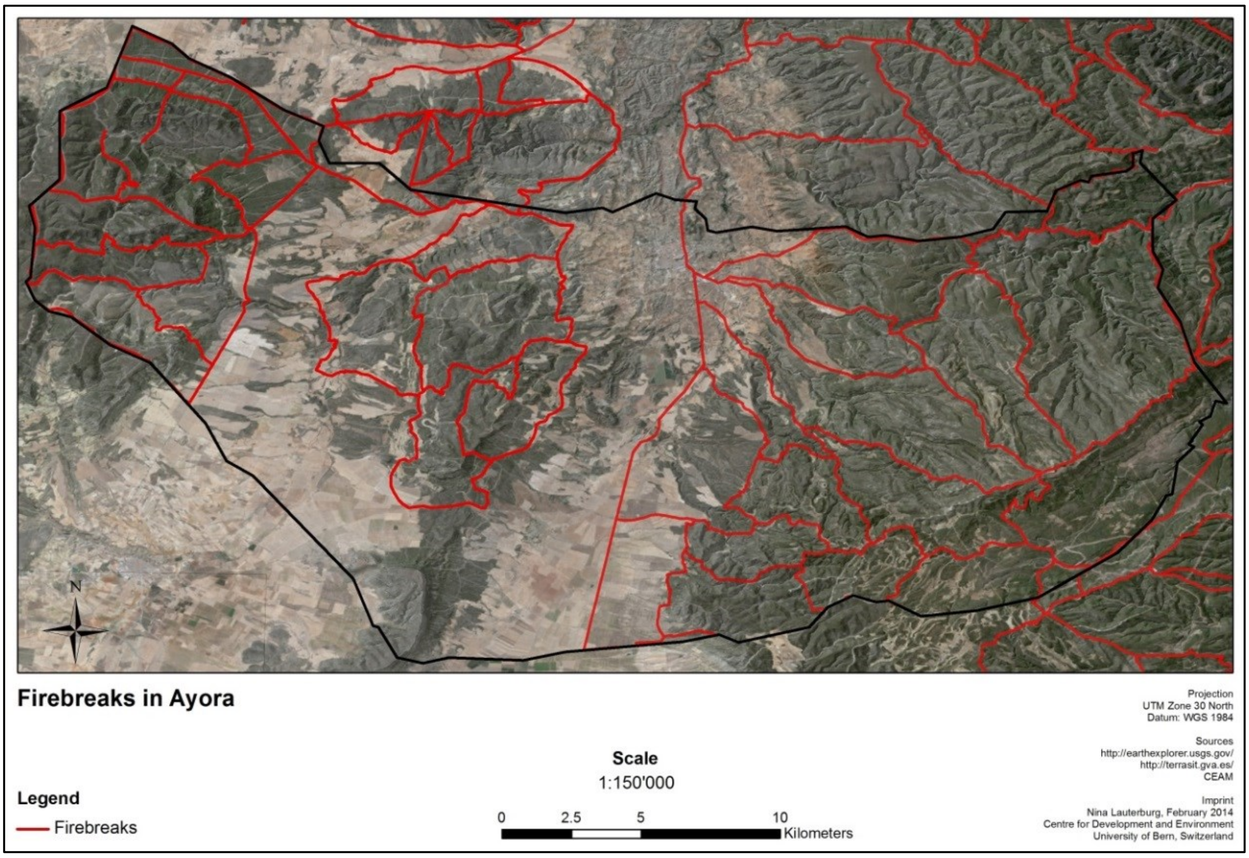


Figure 51: Firebreaks in Ayora (Nina Lauterburg 2014, data sources: USGS, Terrasit, CEAM)

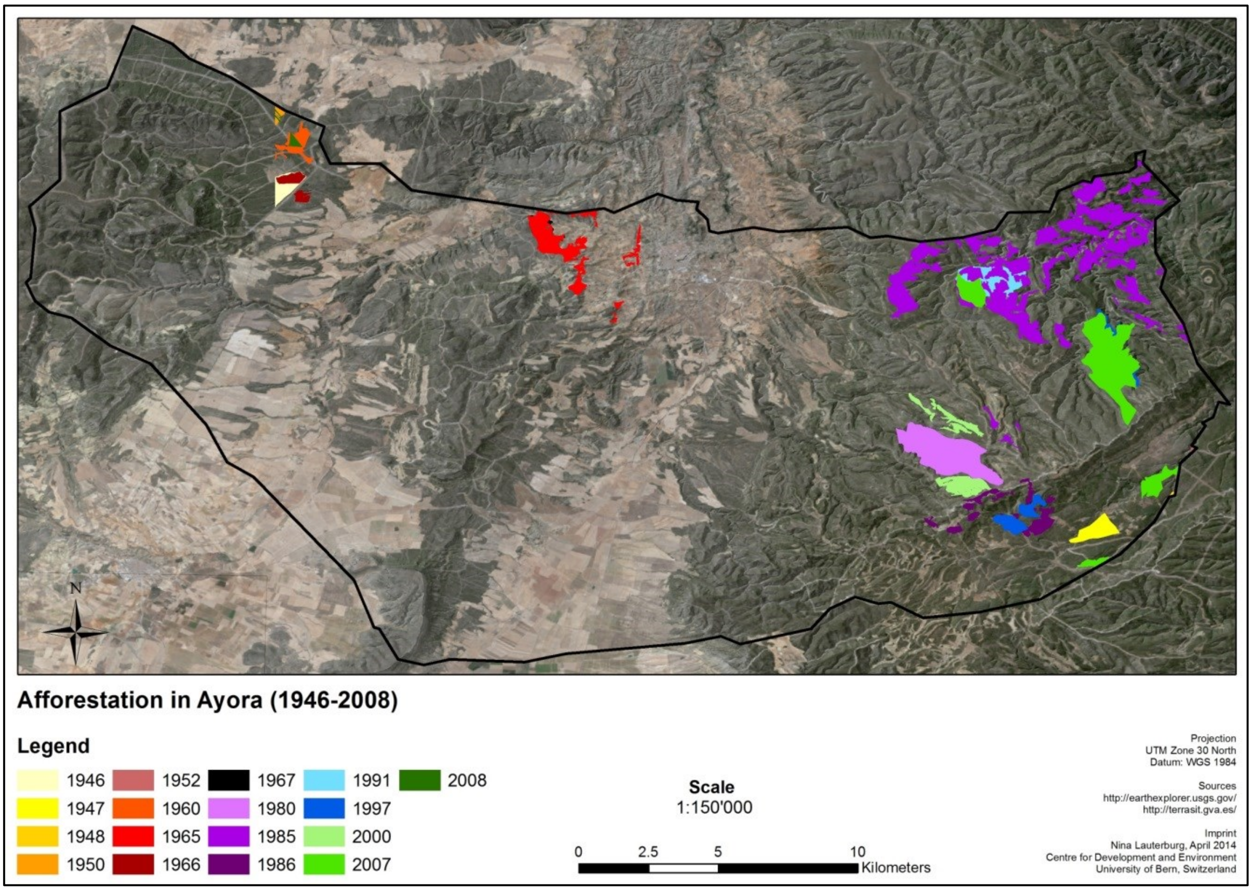


Figure 52: Afforestations in Ayora 1946-2008 (Nina Lauterburg 2014, data sources: USGS, Terrasit, GEORANGE)

Afforestation

Figure 52 provides an overview where afforestations have been realized between 1946 and 2008. According to area calculations based on the GIS layer provided by the GEORANGE project, afforestations amount to 3101 ha which is 6.9% of the total area of Ayora. Within the shrubland burnt once, 1748 ha have been afforested which is around 30% of the area of this LUS. Within the shrubland burnt twice, the afforested area amounts to 839 ha which is around 20% of this LUS. Figures 49 and 50 only include the afforested area since 1980. However, stakeholders argued that most of the afforestations failed and therefore it is possible that the GIS layer (figure 52) illustrates afforestation projects without considering their success.

Selective forest clearing

There are no clear indications on the extent of selective forest clearing. However, some general information is provided here. Selective forest clearing (thinning and pruning) is applied in unburnt forest (natural and afforested) and forest burnt once (which recovered with a high density), mainly next to roads or within recreation areas, on less than 10% of the forested area. This indication should be taken with caution due to the fact that stakeholders were not sure about the extent of this management measure.

On shrubland no selective clearing is applied, although stakeholders mentioned that it would be required to apply this management practice as well on shrublands in order to prevent fires effectively.

Finally, the total conserved area has been calculated. Figure 53 leaves the impression that almost the whole area is conserved. However, the high conserved area results from the indications of the protected area by firebreaks. Considering that not all firebreaks are well maintained and that the afforestations failed to a big part, this result does not imply that there is no need for further management practices.

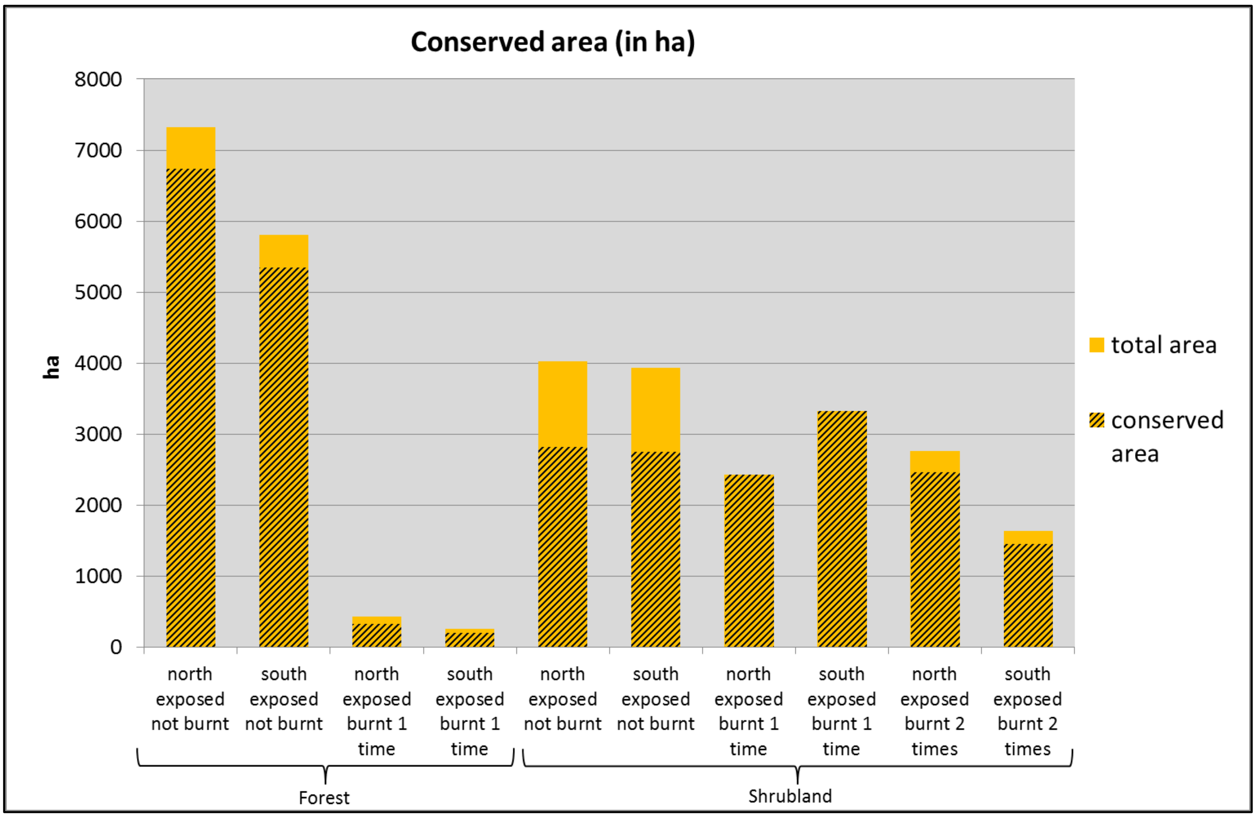


Figure 53: Conserved area compared to the total area per LUS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.3.3 Effectiveness and effectiveness trend of implemented SLM technologies

The effectiveness and the effectiveness trend of the above presented conservation measures have been assessed using the WOCAT mapping questionnaire. The effectiveness of a SLM technology indicates “how much it reduces the degree of degradation, or how well it is preventing degradation” (Liniger et al. 2008a: E21). The effectiveness can either be low, moderate, high or very high. According to Liniger et al. (2008a: E21) “SLM technologies may become increasingly or decreasingly effective over time for various reasons”. Therefore, the effectiveness trend, which can either be decreasing, stable or increasing, indicates whether a conservation measure is appropriate under certain conditions.

Figure 54 illustrates the effectiveness and the effectiveness trend of the documented conservation measures. Stakeholders argued that firebreaks, afforestations and selective forest clearings are effective if there is recurrent maintenance. The effectiveness of firebreaks and selective clearings is considered to be moderate, whereas the effectiveness of Pinus halepensis afforestations is judged as low.

Once firebreaks are established and maintained, there is no change in the effectiveness trend. Afforestations show a decrease in the effectiveness trend due to a lack of management which again increases the fire risk. The effectiveness trend of selective forest clearing is increasing if it is repeated several times. The possibility increases that resprouter species again establish which in turn would increase the resilience of the forest to fire and promote a healthier forest. If selective clearing is done only once, the effectiveness trend would not be positive due to the fact that the forest again grows densely.

A major concern hindering the effectiveness of applied conservation measures is the lack of investment into maintenance.

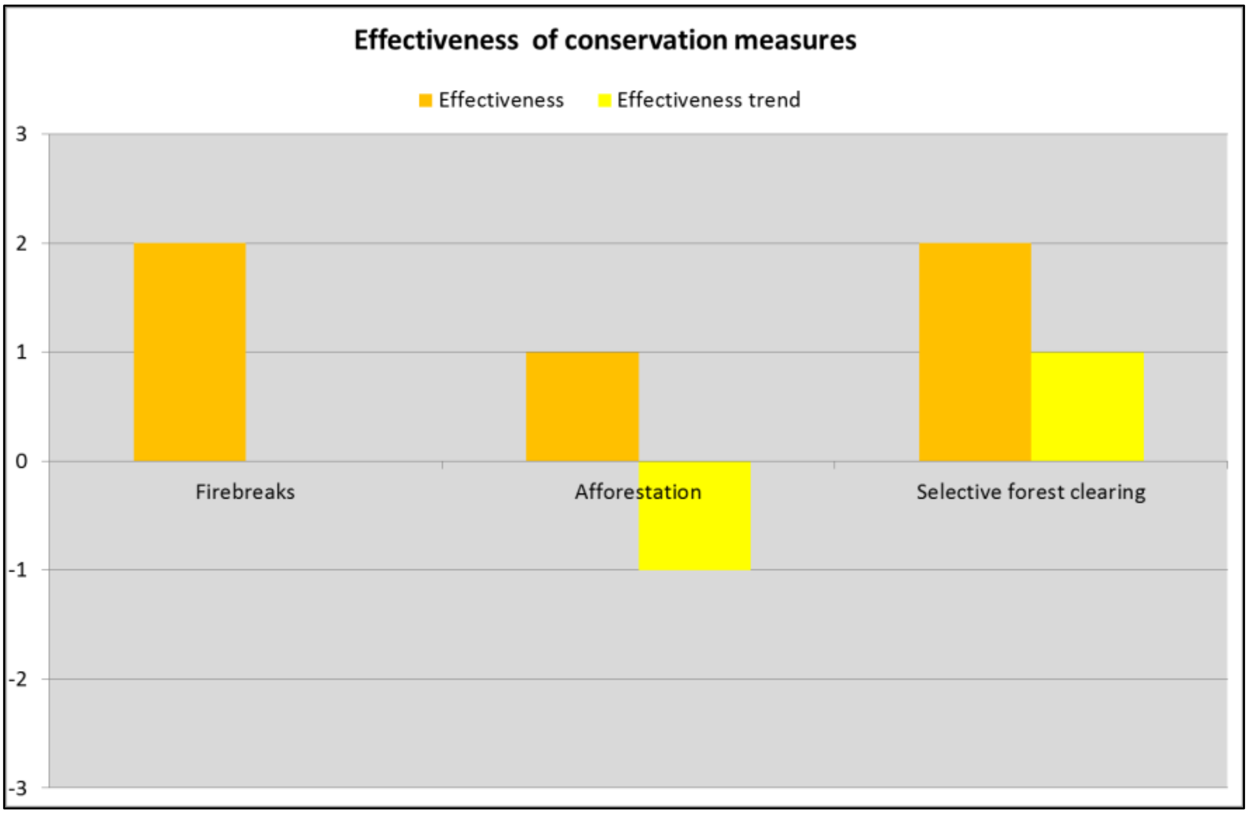


Figure 54: Effectiveness of conservation measures (effectiveness 1=low, 2=moderate, effectiveness trend -1=decrease in effectiveness, 1=increase in effectiveness) (Nina Lauterburg 2014, data sources: WOCAT mapping questionnaire)

Firebreaks

Although the fire which occurred in 2013 passed several firebreaks (figure 55), Spanish newspapers reported that fire extinction was well organized and it is probable that without firebreaks the burnt area would have been much bigger.

Firebreaks are an effective measure by providing access for fire fighters. However, it should be noted that in most cases firebreaks do not stop a fire without human intervention. They may only slow down the velocity of the fire. If the firebreak is too small or poorly maintained, the fire easily passes the firebreak.

Figure 55: Forest fire in July 2013 and firebreaks (Nina Lauterburg 2014, data sources: USGS, Terrasit, CEAM)

Afforestations

Successful afforestations are effective in preventing soil erosion and enhancing forest growth. In case of a successful afforestation, the colonisation of other tree and bush species may be promoted. However, without management, the risk of fires again increases due to the dense growth and fuel accumulation. Since most afforestations failed, it is difficult to judge whether they are effective. Furthermore, monoplantations cannot really be considered as effective in terms of sustainable management.

Selective forest clearing

Selective forest clearings (thinning, pruning) are considered as very effective; not only to prevent fires, but also to decrease the competition between different species which again promotes the growth of a healthy forest. This in turn improves the conditions of the trees and increases their resilience towards disturbances such as fires or pests.

Selective clearings are also applied in afforestated forests. Image 40 illustrates afforestations which were done 60-70 years ago and selectively cleared 5-6 years ago. The picture on the left shows a forest which was less intensively managed compared to the situation on the right, where the pines are in better conditions. In both situations it is evident that through management, trees and shrubs have been removed from the forest.

Image 40: Examples of managed afforestations (Nina Lauterburg 2013)

4.2.3.4 Impacts of conservation measures on selected productive, ecological and socio-economic ecosystem services

In the following, both positive as well as negative impacts of the conservation measures on selected ESS are presented and discussed. Figure 56 summarizes the impacts of all three conservation measures and figure 57 illustrates the impacts of each measure. Although positive impacts are dominating for all measures, firebreaks and afforestations also have some negative impacts. Since there is no significant difference between the impacts on the analyzed LUS (forest and shrubland, both unburnt and burnt), they are assessed in general. It should be noted that these figures only summarize what has been assessed for the prevailing conditions in the field, however in other areas impacts may differ. In chapter 4.3 further benefits and disadvantages are added to this list.

Firebreaks

Impacts of firebreaks on selected productive services

Due to the clearings on the firebreak strips (complete clearing) and their surrounding areas (selective clearing), growth of young grasses is promoted. Shepherds benefit from this additional fodder supply to graze their animals. However, grazing within firebreaks is not a common practice in Ayora. A part of the wood, which is removed from the forest when firebreaks are established, can be sold or used for bioenergy production (biomass).

Honey producers do not directly benefit from firebreaks, they are not allowed to put their bee hives within firebreaks due to the fact that they are made of wood and would therefore increase the risk of fire propagation. However, through the establishment of firebreaks, the road network was improved which facilitates access for honey producers.

Impacts of firebreaks on selected ecological services

Vegetation clearing may locally reduce soil cover and influence nutrient cycling and micro-climate. However, in most areas, the removed vegetation is chipped and applied in-situ as mulch, therefore negative impacts are usually low. In Portugal, firebreaks are highly vulnerable to soil erosion. In Ayora this is not the case because the soil is protected through the mulch layer and the high stone content of the soil. Therefore, firebreaks do not increase significantly the risk of soil erosion, only on steep slopes and very locally. Nevertheless, the use of heavy machinery may have a negative impact on soil structure.

Biodiversity in terms of species richness may be enhanced through the creation of open spaces. However, the quality of these species is another issue. The growth of early-successional seeder species within the firebreaks, combined with a lack of maintenance, may again increase the fire risk.

Impacts of firebreaks on selected socio-economic services

Firebreaks have a positive impact on the awareness of local population on the importance of fire prevention. Furthermore, livelihood security is increased due to improved fire protection and the creation of jobs in forest management for rural people. If firebreaks effectively reduce the burnt areas, infrastructure such as roads, water ponds and houses experience fewer damages (e.g. fewer fires will result in a reduction of transported sediments in water ponds and on roads, less burnt houses).

Firebreaks have a huge negative impact on the aesthetic value but people are aware of the need of firebreaks and also argue that it is still better to establish firebreaks than to risk a vast burnt area.

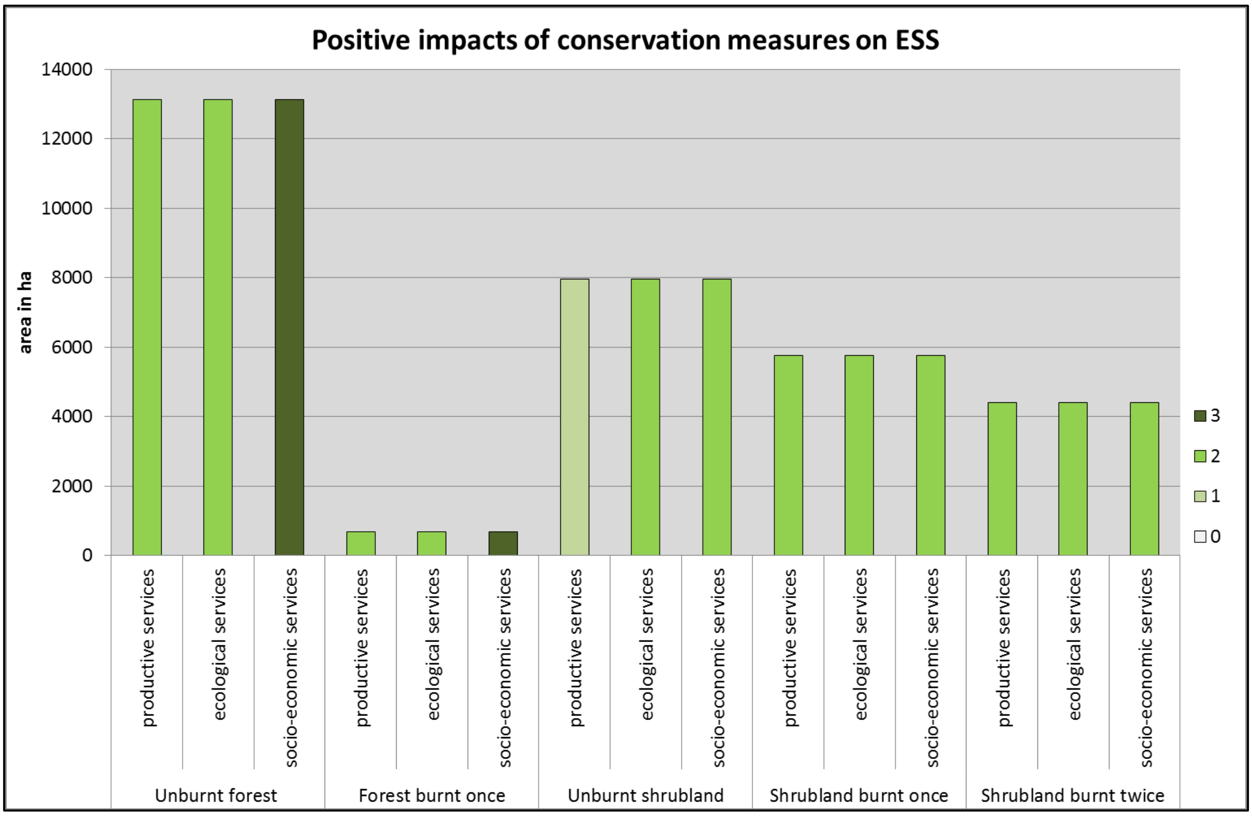


Figure 56: Positive impacts of conservation measures on ESS (1=low positive impact, 2=positive impact, 3=high positive impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

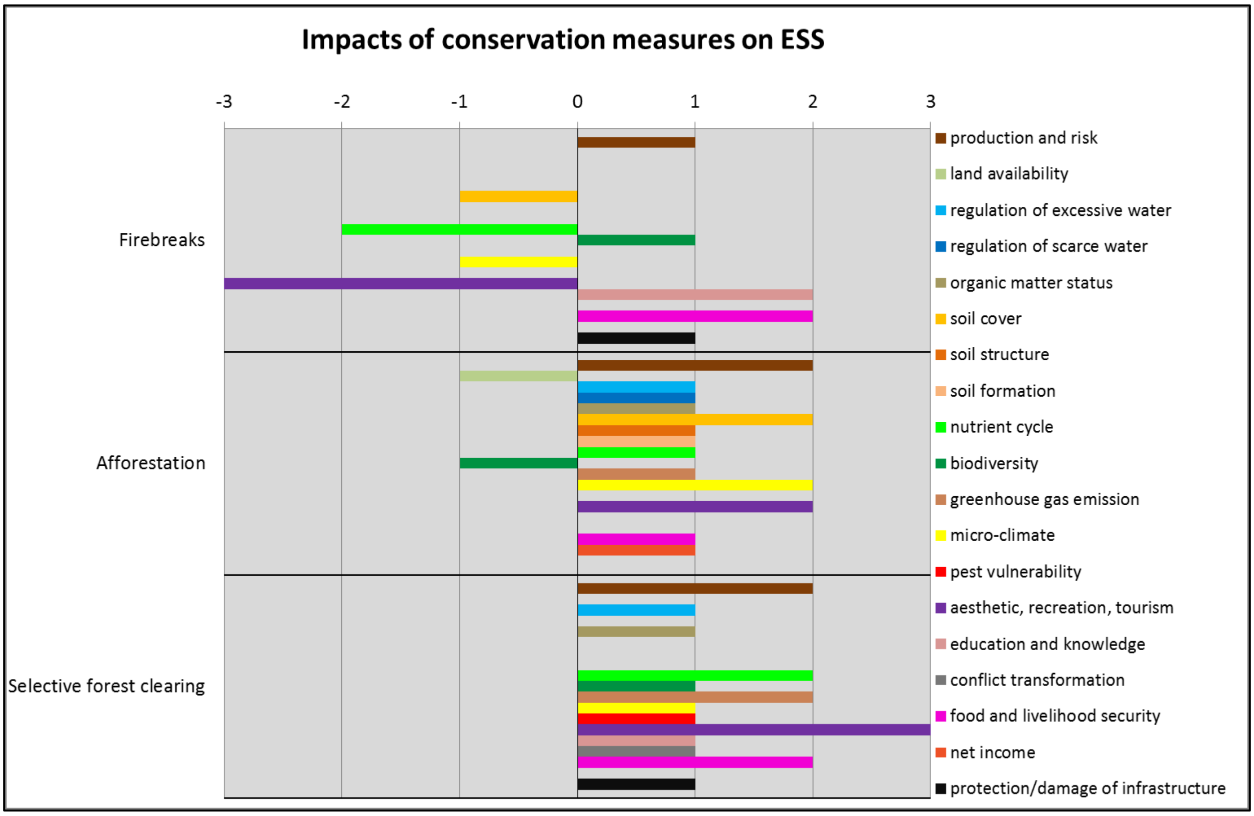


Figure 57: Impacts of conservation measures on ESS (-3=high negative impact, -2=negative impact, -1=low negative impact, 1=low positive impact, 2=positive impact, 3=high positive impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Afforestations

The impacts of afforestations on ESS have been assessed in comparison to a burnt or bare area. It should be noted that impacts may differ if compared to natural shrubland.

Impacts of afforestations on selected productive services

Afforestations result in an increase of wood and biomass production. However, stakeholders mentioned that there is less land available for agriculture although it is questionable whether anybody would use this remote area for cultivations.

Impacts of afforestations on selected ecological services

Compared to the burnt area, the tree cover reduces runoff and enhances infiltration, thus regulating both scarce and excessive water. There is less soil loss and less crusting than on bare areas. Furthermore, organic matter and soil cover increase, nutrient cycling and photosynthesis are enhanced, and the micro-climate is positively influenced through the creation of shade (lower soil temperatures) and the reduction of the wind velocity.

There are also some negative impacts of afforestations. The pest and fire risk increase in dense forests where trees are of bad quality. Furthermore, late-successional resprouter species hardly establish within pine plantations. Additionnally, as a result of the use of heavy machines and changes in the topography during the planting process, surface runoff and sediment yield may increase.

If the afforestations are compared to natural shrubland, there are other effects. According to Maestre et al. (2004), the plantation with Pinus halepensis may result in enhanced runoff and soil loss. Soil hydrology and fertility may only be improved locally. Furthermore, as a consequence of the increase in trees there may be an increase in water use.

Impacts of afforestations on selected socio-economic services

Afforestations have a high positive impact on recreation and the aesthetic value. Many stakeholders prefer forest from bare land or shrubland and it reminds people of the situation before the fire. However, stakeholders complained about the high density which hinders from walking through the forest and which results in difficulties for hunters; animals can hide in the forest and are less accessible. Livelihood security is increased through the creation of jobs at the moment of plantation. Furthermore, net income may increase through wood production. However the sale of timber lost its importance due to the high costs of wood extraction and the low wood price on the market.

Many stakeholders argued that it was an error to do so many afforestations because in many regions nature would have regenerated by itself and it would have been possible to save a lot of money.

Selective forest clearing

Impacts of selective forest clearing on selected productive services

Through selective clearings, growth of young grasses is promoted. Shephers benefit from this additional fodder supply and farmers experience fewer losses on their fields due to the fact that wild animals stay in the forest rather than destroying the cultivated areas (image 41 right). Furthermore, a part of the wood removed from the forest can be sold, used for bioenergy production (biomass) or as fuel wood.

Impacts of selective forest clearing on selected ecological services

The creation of open spaces through selective forest clearing results in a reduction of competing species, in an increase of vegetation quality and in the promotion of biodiversity. Through the application of mulch, soil cover is improved, soil moisture is increased and nutrient cycling is enhanced. The artifical speed up in litterfall, branches and twigs, which is caused by this management practice, increases organic matter. Furthermore, photosynthesis and micro-climate are improved.

Impacts of selective forest clearing on selected socio-economic services

In general, selective forest clearing is the most appreciated measure by many local stakeholders. Selective clearing is considered to be very important for the aesthetic and recreational value of the region. People prefer thinned forests due to improved access to the forest. The knowledge on conservation and fire prevention is also enhanced through this measure.

Additionnally, livelihood security is increased through the better protection against fires and the creation of employment in forest management for rural people (image 41 left).

Image 41: Forest management creates jobs (left) and enhances fodder production, thus wild animals stay in the forest rather than destroying cultivated fields next to the forest (right) (Nina Lauterburg 2013)

Impacts of conservation measures on fire risk

Since prevention of fires is a major goal of management practices in Ayora, the impact of the conservation measures on fire risk has been assessed (figure 58). To conclude it can be stated that firebreaks are effective in preventing fires, however they only work with human intervention. Selective forest clearings are effective as well through the reduction of the fuel load and the removal of weak or dead plants. Afforestations actually increase the fire risk due to the dense growth and the lack of management. Afforestations do not aim in fire prevention but more in rehabilitation of disturbed areas or prevention of soil erosion, but there is a need to manage the forests in order to decrease the fire risk in the region.

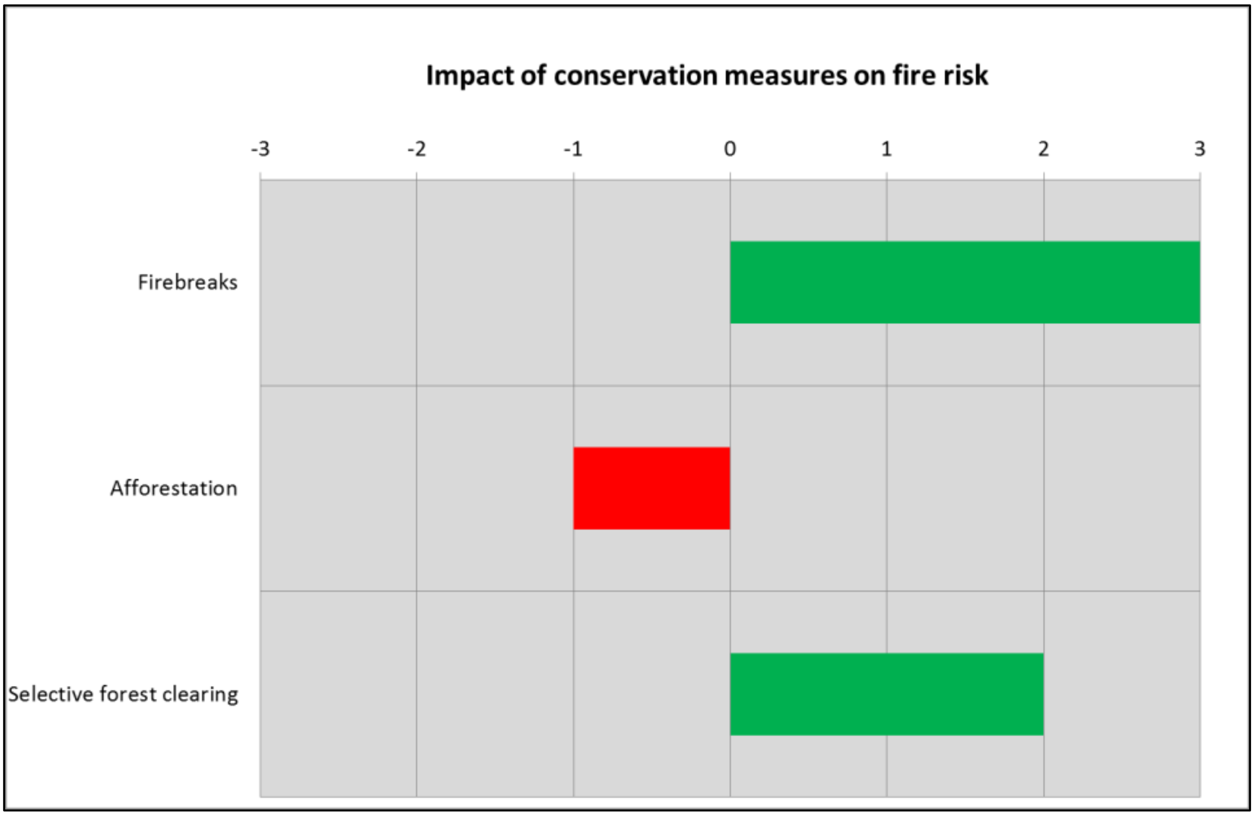


Figure 58: Impacts of conservation measures on fire risk (-3=high negative impact, -2=negative impact, -1=low negative impact, 1=low positive impact, 2=positive impact, 3=high positive impact) (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

4.2.4 Expert recommendation

Through the interviews conducted with stakeholders, some expert recommendations on management were collected and are presented in the following.

Both on unburnt and burnt forest as well as on unburnt and burnt shrubland (both north and south exposed), firebreaks should be maintained or where appropriate, be established in order to prevent fires. Furthermore, selective forest clearings should be executed. It is required to remove biomass from the understory especially to reduce the amount of fuel, and branch pruning of large trees is required to reduce the vertical continuity between forest layers. However, also unburnt and burnt shrublands should be cleared selectively to reduce the continuity and the amount of fuel resulting from shrub encroachment. This is currently not done. The combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could contribute to an increase of the ecosystem resilience to fires. This technology is discussed in detail in chapter 4.3.4.

4.3 Documentation and impact assessment of local SLM technologies

In this chapter, the SLM technologies presented in the previous chapter are explained more in detail through the documentation of case studies. The WOCAT documentations can be found in Annex 4.

4.3.1 Firebreaks

The basic principle of a firebreak network is to split continuous forest areas into smaller patches separated by vegetation-free strips with the aim of controlling the spread of large forest fires. Firebreaks are also termed as fire preventive silvicultural measures. Image 42 provides some impressions of firebreaks in Ayora.

Image 42: Firebreaks in Ayora (Nina Lauterburg 2013)

4.3.1.1 Background

The firebreaks have been established between 1998 and 2002 within a pilot project of the "Plan de Selvicultura Preventiva de Incendios en los Sistemas Forestales de la Comunidad Valenciana (PSP)" ("Plan of Fire Preventive Silviculture in the Forests of Valencia") carried out by the company VAERSA (public company of the Generalitat Valenciana). The PSP is presented in detail in the results on approaches (chapter 4.4). The total surface protected by the firebreaks accounts to 33'851 ha (including the municipalities Requena, Cofrentes, Jalance, Jarafuel, Zarra and Ayora) whereas the management measures are executed on 1944.81 ha. The total length of the elements is 498.5 km.

It should be noted that most of the information provided in this chapter is derived from this particular project (GVA 1996) and may not be valid for all firebreaks in the region; only a part of the firebreaks have been established within this project.

4.3.1.2 Technical Description

A firebreak is a strategically located strip on which the vegetation cover has been partially or totally removed down to mineral soil. The main purposes are 1) to interrupt the continuity of hazardous fuels across a landscape to decrease the area affected by fires, 2) to provide areas where fire fighters are protected and can work more efficiently (access), 3) to slow down a fire, to reduce the fire intensity and damages, and 4) to provide strips where fuel management is facilitated. Firebreaks are often located on mountain ridges and/or along existing roads to guarantee the access for fire-fighting vehicles and to keep the visual and ecological impact limited. Furthermore, they are created with 45° to the dominant wind direction to facilitate fire extinction.

Firebreaks can range between a protected area of 2000-6000 ha (first order), 500-1500 ha (second order), and 100-300 ha (third order), together forming a system isolating separate areas by wide strips (figure 59).

The territory was split up by criteria such as quality of the vegetation and potential risk, trying to divide the area in parcels of approximately 6000 ha if the risk is low/moderate and parcels of 500 ha if the risk is high/extreme. This parcelling aims in limiting the burnt area to a maximum of 6000 ha.

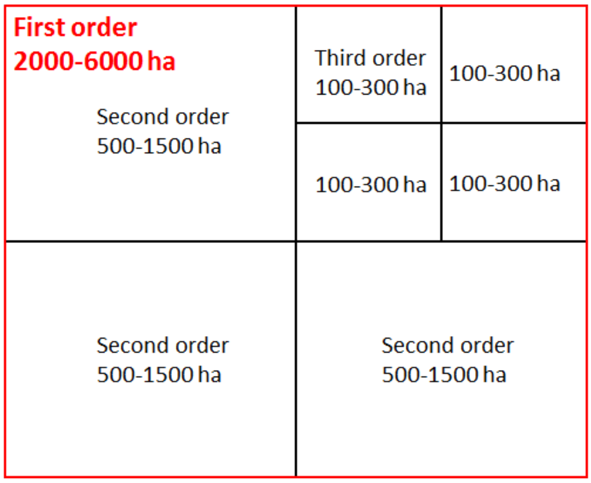


Figure 59: Firebreaks are classified in first, second and third order (Nina Lauterburg 2013)

Each firebreak consists of a bare strip (banda decapado), a cleared strip (banda de desbroce total), and a selectively cleared strip (faja/banda auxiliar). The width of the strips depends on the order of the firebreak (figure 60).

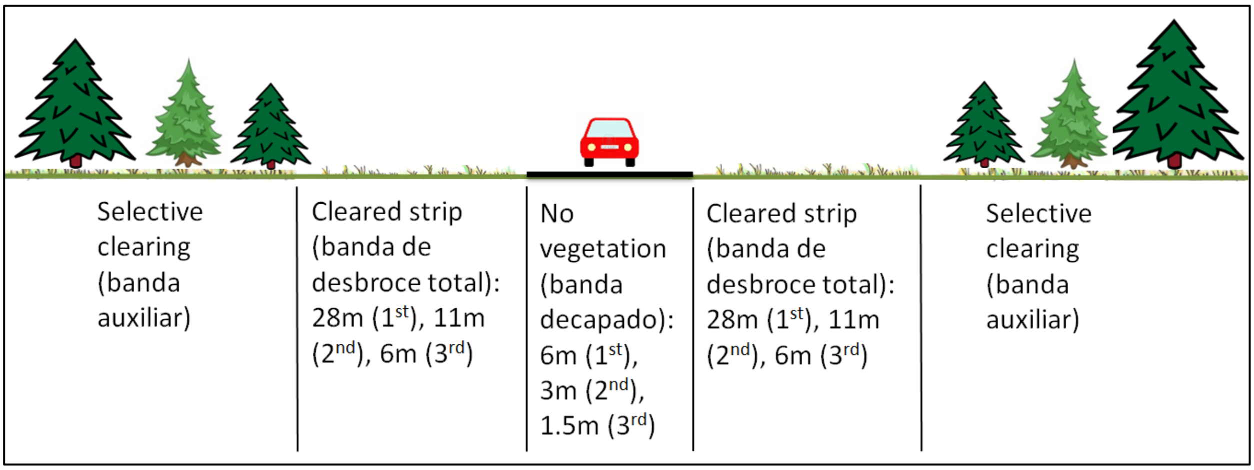


Figure 60: Technical drawing of firebreaks in Ayora. Each firebreak consists of a bare strip, a cleared strip and a selectively cleared strip. The numbers in brackets indicate the width for first, second and third order (Nina Lauterburg 2013, data source: GVA 1996)

The width of the bare area (banda decapado), where the vegetation is removed totally down to mineral soil, ranges between 6m (first order), 3m (second order) and 1.5m (third order). Existing vegetation-free areas (e.g. roads, mountain ridges, agricultural fields, water bodies, etc.) are used to establish firebreaks. Along roads the risk of fire ignition may be higher due to vehicles or people throwing away cigarettes. If there is no vegetation-free area available, trees and shrubs have to be cleared and chipped entirely using chainsaws and special tractors (image 43). Forest tractors are not used frequently in the Mediterranean region and therefore agricultural tractors have to be adapted due to the fact that they are too weak for firebreak establishment. However, modifying an agricultural tractor for forest management (e.g. bigger wheels) is extremely expensive.

Image 43: Tractor used for firebreak establishment and maintenance (Nina Lauterburg 2013, CEAM)

As shown in figure 60, on each side of the bare area there is a totally cleared strip (banda de desbroce total). The width depends on the climatic zone, the firebreak order and the hazard of fuel, therefore ranging between 28m (first order), 11m (second order) and 6m (third order). Almost all the existing vegetation is cleared, only some isolated mature trees are not cut if they do not contribute to the propagation of a fire. A part of the extracted wood is used as fuel wood, the rest is chipped and distributed on the soil as mulch.

On both sides of these strips there are auxiliary strips (banda auxiliar) where selective clearing is applied until reaching a desired density of the forest. Sick trees are cleared with priority. Species of high ecologic value and low flammability are not cleared, such as Juniperus phoenicea, Juniperus oxycedrus and Quercus ilex. The width of these elements can vary according to the prevalent conditions. The remaining trees which are not removed should have a distance of at least 1.5m between tree branches and the understorey.

4.3.1.3 Maintenance

The maintenance of firebreaks is extremely important. Without clearing, fire-prone species will encroach which decreases the effectiveness of the firebreak.

Image 44 illustrates a well-maintained firebreak which was cleared on the same day the picture was taken, compared to a firebreak with a lack of management and shrub encroachment.

Image 44: Well-maintained firebreak (left) and lack of management (right) (Nina Lauterburg 2013)

The maintenance depends on the particular conditions such as vegetation type and growth, stone content, slope, altitude, etc. The required activities are planned in collaboration with different stakeholders, such as forest agents, forest engineers and governments (local and regional).

In the here described project the maintenance was carried out in three phases (2001-2004, 2004-2008 and 2008-2012). Firebreaks of the first order are cleared every 2 years ("decapado" and "desbroce total") or every 4 years ("banda auxiliar"), whereas firebreaks of second and third order are cleared every 4 years.

4.3.1.4 Costs

It was a challenge to provide exact costs of the technologies presented in this master thesis due to different information sources and lack of knowledge of the stakeholders. Therefore, the indicated costs should be taken with caution.

The establishment and the maintenance of firebreaks are labour-intensive and expensive. Based on official project documents of the regional government and information from different stakeholders, the costs of the execution of the whole pilot project were around 3 Mio Euro (3'250'755 Euro, paid by the Generalitat Valenciana), whereas the costs of the third maintenance phase, taking place from 2008 to 2012, amount to 1.5 Mio Euro. The total costs were divided by the treated area which accounts to 1770 Dollar per ha for establishment and 557 Dollar per ha for maintenance. The establishment costs of the firebreaks in Portugal (documented in the WOCAT database) are similar; the indicated costs were around 1744 Dollar per ha.

The establishment costs can be affected by numerous factors. If the measure is carried out on a steep slope or if the vegetation density is very high, the work is much more difficult and takes more time. Furthermore, a high stone content of the soil hinders effective work with machines and endangers forest workers. As already mentioned, the transformation of a normal tractor to forest management puposes can be extremely expensive. Bigger wheels or additional protection measures (e.g. against stones) are required. Four wheels cost at least 6000 Euros. The hiring costs of a normal agricultural tractor are around 674 Dollar per ha. The establishment costs are reduced if there is already a road available.

As indicated above, maintenance is much cheaper than establishment due to the fact that most of the vegetation has already been removed. Important to note is that firebreaks are sensitive to climate extremes such as an increase in seasonal rainfall. Due to faster vegetation growth, maintenance costs may increase.

4.3.1.5 Benefits and disadvantages

Firebreaks have both benefits/strengths as well as disadvantages/weaknesses. In this chapter the information provided by stakeholders is summarized and added to the list on impacts on ESS (chapter 4.2.3.4). Probably there are more issues which are not covered here.

Benefits/Strengths

Firebreaks slow down the spreading of a fire and facilitate the access for fire fighters. Furthermore, through the establishment of firebreaks, forest roads have been constructed or are better maintained. To fight efficiently against fires a well organized and prepared infrastructure including roads, firebreaks, water ponds, fire fighting media (trucks, helicopters, labour) is needed. Without this infrastructure fire extinction is almost impossible. If firebreaks are well maintained, they indeed contribute in limiting the burnt area and to reduce the devastating effects of a forest fire. Image 45 illustrates a firebreak where a fire was stopped.

The ecological, economic and socio-cultural damages caused by fires are huge. If the burnt area is limited, less money has to be invested in forest restoration. Positive ecological impacts are for example the protection of biological resources and the reduction of carbon dioxide emissions (less or smaller fires).

For local people firebreaks have both social and economic benefits. Along with fewer land losses of farmers, hunters and honey producers due to better fire prevention, the establishment and the maintenance of firebreaks provide jobs for rural people allowing them to increase their livelihood conditions. People do not depend on unemployment payments and are therefore more accepted in society. A part of the extracted wood is used for biomass, fertilizers, pellets, or firewood.

Image 45: This firebreak contributed to stop a forest fire. Mature unburnt forest to the left of the firebreak, and natural regeneration of burnt forest with selective clearing after some years to the right of the firebreak (Nina Lauterburg 2013)

Disadvantages/weaknesses

Although firebreaks are considered as an appropriate technology for fire prevention and extinction, there are also some disadvantages.

People often criticise the negative aesthetic impact which in turn decreases the recreational value. Furthermore, firebreaks are not that efficient because after clearing the growth of fire-prone species is promoted which again increases the fire risk. Notably, if there are strong and dry winds, smaller firebreaks are useless because the fire just passes over.

Economically, the extreme high establishment and maintenance costs are a major concern. Furthermore, through the lack of financial resources, working in forest management goes along with a considerable job uncertainty. Additionnally, the work is dangerous and physically exhausting.

How to sustain benefits and how to overcome weaknesses

The above mentioned benefits can be sustained through recurrent management of firebreaks. Due to the fact that prevention measures are often less expensive than post-fire rehabilitation activities, increased investment into forest management and fire prevention would be required. In other regions, some good practices can be found to cover the maintenance costs and to overcome the lack of financial resources. For example in Andalucia the maintenance of firebreaks is supported by grazing, subsidized by the state. However, grazing in the mountains is not cost-effective and thus not attractive for shepherds in Ayora, therefore subsidies from the state would be required to cover the additional costs. Due to a lack of subsidies and the small number of shepherds, today there is no maintenance through grazing. Usually, grazing activities are centered in the valley, near to cultivated fields or where there is water available whereas in the mountains, the access to water is not ensured. Therefore, CEAM investigated on the effect of installing water ponds in the mountains to achieve firebreak maintenance through guiding shepherds to desired areas.

To increase the effectiveness, big firebreaks should be established and maintenance should be ensured. As an alternative to complete vegetation clearing, CEAM suggests to plant more fire-resistant species within some spots in the firebreaks to increase the resilience of the ecosystem. Green living plants have a higher humidity content which slows down a fire. The idea of green firebreaks is already discussed in other countries. However, to maintain green firebreaks irrigation is required which is difficult in this remote and semi-arid area. Fog collectors could increase the water availability.

4.3.2 Afforestation with Pinus Halepensis

Another traditional management measure is the afforestation of regenerating shrublands with pines, mainly Pinus halepensis (image 46).

Image 46: Successful afforestation with Pinus halepensis in Ayora (Nina Lauterburg 2013)

4.3.2.1 Background

In the 1950s and 1960s, vast areas of Spain have been afforestated. According to Chirino et al. (2006: 19) "Pinus halepensis plantation was the most widespread forest administration management policy in most areas of Spain". Furthermore, during the 1980s and the 1990s many Pinus halepensis afforestations have been carried out on burnt areas (PRACTICE Deliverable D3.1b n.d.). Between 1945 and 1986, around 3.8 Mio ha have been afforested in Spain, whereas 90% of the planted species were pines. However, many afforestation trials also failed (Pausas et al. 2004).

As a consequence of the devastating fire of the year 1979, strong erosion processes occurred on the bare soil and hindered the vegetation to regrow. Therefore, the government mandated to afforest the burnt areas in 1985 (image 46). The main purpose of the afforestation was the prevention of soil erosion and the rehabilitation of the burnt area. The documented afforestation is one of a few examples of afforestation trials which succeeded. Unfortunately, nobody could provide direct and complete information on the afforestation process.

4.3.2.2 Technical description

The afforestation, covering around 100 ha, was executed in 1985 (November-February/March) through the collaboration of regional forest services (planner, forest engineers, forest agents) and local villagers.

First, the planting holes (60cm x 60cm x 60cm) were created with a machine (Caterpillar) using a "spoon". This process loosens the soil. Since the soil had a low stone content, it was suitable for the establishment of a forest. It should be noted that they did not use a ripper because they already knew about the destructive impacts of this machine to the soil.

To facilitate the operation of machines to create planting holes, the Pinus Halepensis seedlings were planted manually on a line (figure 61). The linear arrangement is still visible when observing the plantation from the distance, but when finding oneself within the forest this alignment is not visible anymore since the forest grew very densely. Today there is a forest where young pines are growing naturally ("children" of the planted ones), but also resprouter species (e.g. Quercus) can be found, which regenerated without having been planted and apparently were dispersed by birds. This shows the success of this plantation effort.

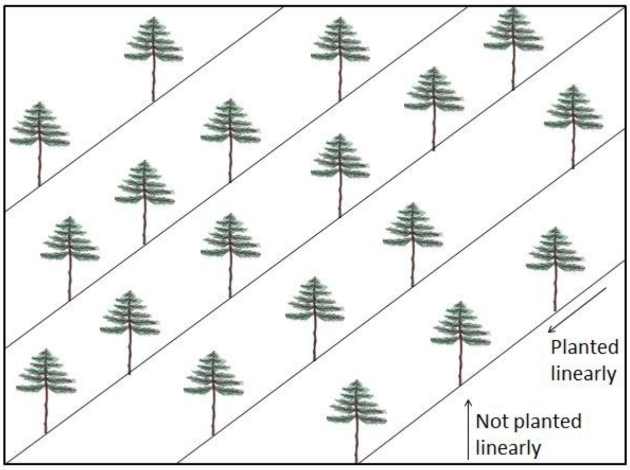


Figure 61: Technical drawing of afforestation with Pinus halepensis in 1985 (Nina Lauterburg 2013)

The success of an afforestation depends on numerous factors such as fire recurrence, aspect and humidity, soil amount and fertility, variability of the weather conditions (e.g. droughts, freezing). Thus, the conditions are more favourable on north facing slopes and on former cropland. Especially the first summer after the plantation is determining; if it is too dry the plant will not grow (roots are too short to reach the humidity deeper in the ground). However, there is always uncertainty on the wheather conditions which will follow the afforestation process. Additionnally, the origin of the seedlings is important because it determines whether the plant is already adapted to the local climatic conditions. Another threat is browsing, thus the removal of seeds or damage of seedlings caused by wild animals. Furthermore, the selection of appropriate machines and the availability of trained people are crucial; if the seedlings are not planted properly, the afforestation may fail.

4.3.2.3 Maintenance

The aim of most afforestations was to first plant pines, to manage the afforested areas by selective clearing some years later and to introduce other species afterwards. However, in most cases only the first step has been done due to a lack of financial resources.

Although the documented afforestation was successful, the trees were planted too densely. Knowing about this problem, around the year 2003 the forest was cleared selectively to reduce both the continuity of the fuel and the competition between the species (“ayuda regeneración”, image 47). This in turn reduced the fire risk. However, the forest again has become extremely dense and would require management; unfortunately no management project is planned for the near future.

Image 47: Management project "ayuda regeneración" (“regeneration help”) of the documented afforestation (Nina Lauterburg 2013)

4.3.2.4 Costs

The here indicated costs are derived from the PRACTICE project and different stakeholders due to the fact that the costs at the time the afforestation was implemented are not known. Today, the total costs of an afforestation amount to 4857 Dollar per ha (around 3600 Euro per ha), whereas the maintenance costs are around 2428 Dollar per ha, referring to a selective forest clearing.

The costs of a plantation can be affected by numerous factors. Depending on the slope steepness and the stone content of the soil, the work may take more time and the use of machines may be impeded. Furthermore, adverse climatic conditions may increase the costs.

4.3.2.5 Benefits and disadvantages

The benefits and disadvantages of the documented afforestation have been assessed in relation to a bare area. However, it should be noted that compared to a well established shrubland, the benefits and disadvantages may differ.

Benefits/strengths

The afforestation resulted in the rehabilitation of an area affected by the devastating wildfire of 1979. It is an example out of many afforestation trials which succeeded. The success becomes evident through the presence of healthy old pines, but also through the growth of young pines and resprouter species such as Quercus which have not been planted. Hence, pines may contribute to the establishment of broadleaved resprouter species, e.g. the trees may be used by birds as perches and fruits are easily found around those pines.

Pinus Halepensis seedlings grow faster and show a higher survival rate than other species, therefore the natural process of forest growth is enhanced. Compared to a bare area, the plantation of pines improved the soil cover and stability which in turn decreased soil erosion. The increase of the vegetation cover and the reduction of soil erosion also resulted in off-site benefits, such as a reduction of downstream flooding and transported sediments. Therefore, infrastructure such as roads or water ponds experienced fewer damages.

Furthermore, the afforestation provided jobs for rural people which resulted in economic benefits.

Disadvantages/weaknesses

Although the afforestation was successful, there are also some disadvantages.

According to Maestre et al. (2004) monoplantations with Pinus halepensis are not sustainable due to several facts. They result in the simplification of the landscape and alterations of habitats. This in turn may influence the diversity of birds. Furthermore, there is a high accumulation of highly flammable and continuous fuel and since the pines are all of the same age this facilitates the spread of fires. Various studies argue that compared to other land use types, Pinus halepensis forests have been more affected by fires (Velez 1986, Herranz 2000). This afforestation thus constitutes a high fire risk and is therefore not considered as an appropriate management practice in a fire-prone area.

Some stakeholders criticized the linear planting due to its unnatural visual impact.

How to sustain benefits and how to overcome weaknesses

To sustain the benefits and to overcome the weaknesses of this afforestation recurrent management (i.e. selective clearing) is required. Managing the forest would not only decrease the fire risk and the competition between the species but also allow favourizing desired resprouter species. Additionnally, jobs would be generated which is especially important during the current economy crisis in Spain.

It is not fully clear whether Pinus Halepensis plantations are a useful tool for restoration and it is also questioned whether it is sustainable to plant only Pinus Halepensis. However, it depends on the specific objective of management efforts whether this strategy is considered as sustainable. If the objective of the plantation is to have forest instead of bare land in a short period of time, this species seemed to be the most suitable (CASCADE 2011, Maestre et al. 2004). However, if the aim is to increase biodiversity and resilience to fire, it is not sustainable to plant only one species.

Therefore, it was mentioned that afforestations should be executed considering principles of fire prevention. The experts suggest replacing monoplantations by multi-species plantations. Key species which have been lost due to past land use (late-successional resprouting species) should be reintroduced in order to stimulate successional processes, to increase the diversity and thus to promote the ecosystem resilience to disturbances. For example the combination of planting pines and oaks may result in benefits due to the fast growth of pines and the high fire resilience of oaks. However, high costs or the limited success of shrub establishment within Pinus halepensis forest are challenging this task (Rojo et al. n.d., Maestre et al. 2004, Pausas et al. 2004).

Various methods have been proposed which may enhance seedling survival, such as water harvesting, preconditioning of the seedlings, tree-shelters, fertilizer and mulch. Furthermore, effects of other plants ("nurse plants") can be used to benefit from shade, soil properties, and retention of soil and nutrients. There is also the perch effect which consists of providing perches such as dead trees to birds in order to promote colonisation of resprouter species (Pausas et al. 2004).

4.3.3 Selective forest clearing

The main purposes of thinning dense forests are the prevention of fires by reducing the connectivity and the amount of fuel, and to improve regeneration by eliminating the competition between different species.

Image 48 illustrates two situations where forests regenerated naturally with a high density (left), and forests which were managed by selective clearing (right). After management, the trees are in better conditions.

Image 48: Dense forests (left) compared to managed forests with selective clearing (right) (Nina Lauterburg 2013 (above), PRACTICE n.d. (below))

4.3.3.1 Background

After disturbances such as past land use or fires, many forests regenerated with a high and continuous fuel accumulation which made it extremely difficult to control forest fires once they have started. Therefore appropriate vegetation management to increase the resilience of the vegetation to fires and to reduce the competition is required.

4.3.3.2 Technical description

On average the forest is thinned until reaching a density of 800-1200 trees/ha. In order to be selective and to preserve desired species, the clearing is done with small machines such as brushcutters and chainsaws (image 50). Dead or sick plants and also a part of the fire-prone shrubs such as Ulex parviflorus and Cistus albidus are removed. If there are both Pinus pinaster and Pinus halepensis, Pinus halepensis is cleared because they compete with each other. More fire resistant resprouter species such as Juniperus, Rhamnus alaternus, Quercus species or Fraxinus ornus are not removed which promotes a more fire-resistant vegetation composition in future.

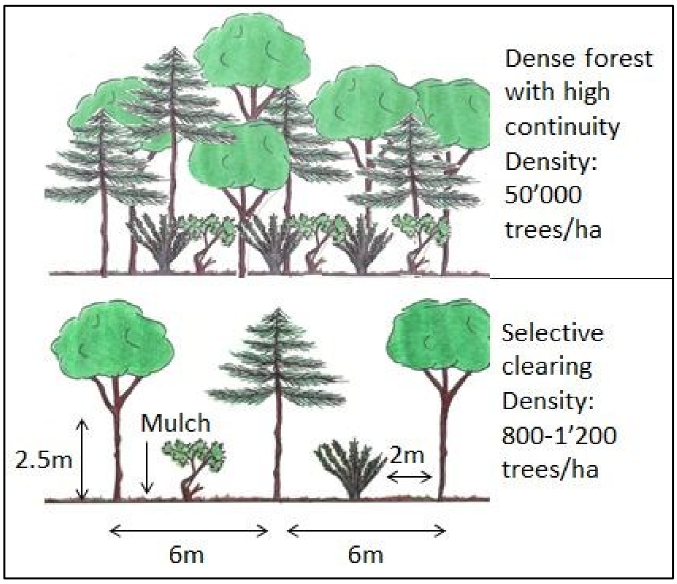


Figure 62: Technical drawing on selective forest clearing (Nina Lauterburg 2013)

The remaining trees are pruned ("poda") until a maximum height of 2.5m to improve the conditions of the species. Furthermore, around each shrub an area of 2m should be cleared and between trees there should be a distance of 6m. However, these are ideal distances which are not always respected in reality. After felling trees and shrubs a part of the residues is chipped in-situ and covers the soil as mulch (figure 62).

4.3.3.3 Maintenance

The cleared areas have to be maintained depending on the speed of the vegetation growth (which amongst others depends on soil, slope and humidity). It should be noted that recurrent maintenance is crucial to ensure the effectiveness of the technology.

4.3.3.4 Costs

The total costs of a selective clearing, which are derived from the PRACTICE project and different stakeholders, amount to 2428 Dollar per ha, whereas the costs of the maintenance activities (e.g. second clearing) are much lower because the area was cleared already some years before.

In this case, 9 people have been working as a team. Under the best conditions (e.g. good access and terrain) they can clear 0.8 ha per day. It should be noted that clearing with small machines such as brushcutters and chainsaws is much more expensive than clearing with tractors, but in most cases the use of small machines is required in order to be selective. In this case the costs are paid by the municipal council, which receives a part of the money from the rental fee paid by the wind mill company.

The costs can be affected by numerous factors, e.g. slope steepness and vegetation density. If the clearings are done regularly, it takes less time and it is therefore cheaper than the first clearing. Thus, the maintenance costs increase the longer the period between the first clearing and the maintenance activities. Furthermore, maintenance costs may increase with an increase in seasonal rainfall due to enhanced vegetation growth.


Image 49: Before clearing (left) and situation immediately after forest clearing (right) (Nina Lauterburg 2013)


Image 50: Selective clearing using small machines such as brushcutters and chainsaws (left). The residues are chipped in-situ protecting the soil as a mulch layer. Selective clearing allows preserving desired species (right) (Nina Lauterburg 2013)

4.3.3.5 Benefits and disadvantages

Selective forest clearing has been evaluated as an effective and highly sustainable management practice. Benefits and disadvantages mentioned by the interview partners are presented in the following.

Benefits/strengths

Through selective forest clearing the fuel amount and connectivity is reduced which is crucial for preventing large forest fires and therefore degradation (image 49). Furthermore, there is a reduction of competition between plants which is essential to ensure a healthy forest (more nutrients, light, space). Since weak or dead plants are eliminated and the conditions of remaining species improved, the vegetation is more resistant against disturbances (pests, fires).

With respect to other management practices, fuel management through vegetation clearing has some advantages, e.g. the possibility of being selective in order to preserve desired species (image 50). Furthermore, since the roots are not removed from the ground, stability and productivity of the soil are ensured. The mulch results in ecological benefits such as an increase in soil moisture, prevention from erosion, enhancement of nutrient cycling and a reduction of the soil surface temperature (image 49).

There are both social and economic benefits for local people.

Image 51: Cleared forest with chipped material applied as mulch and fresh grasses providing fodder to animals (Nina Lauterburg 2013)

Vegetation removal produces fresh vegetation growth, therefore more diverse and nutritious fodder is provided to animals (game and livestock) in the cleared areas which is a benefit for shepherds and hunters (image 51). Also wild animals use this fodder supply which in turn keeps them in the forest rather than destroying cultivated fields of the farmers. This leads to conflict mitigation. Furthermore, honey producers make use of the enhanced growth of shrubs and the additional space created by selective clearing to place their beehives and to increase honey production.

Forest management contributes to rural development; most of the workers were unemployed before working in forest management. Furthermore, a part of the extracted wood is used for biomass, fertilizers, pellets, or firewood. In Jarafuel, a village just next to Ayora where most of the land is public, removed wood is usually distributed to retired villagers for free. This fuel wood is used for heating and cooking, thus reducing rural poverty (less money has to be spent on oil or gas) (image 52).

Image 52: Fuel wood gained from forest clearings (left) and oven of retired person where fuel wood is used for cooking and heating (right) (Nina Lauterburg 2013)

Additionally, managed forests are highly appreciated due to their high aesthetic and recreational value.

Disadvantages/weaknesses

The high costs of management activities are a major concern and without recurrent management the fire risk increases. The open space created through selective clearing may promote the growth of fire-prone seeder shrubs. Due to a lack of investment in forest management, selective clearing is only applied in some areas, however vast areas would actually require management.

How to sustain benefits and how to overcome weaknesses

Recurrent management and increased investment into forest management are required. A good mechanism to cover the high management costs is applied in Jarafuel, where 10% of the rental fee paid by the wind mill company is reinvested in forest management. Furthermore, many local stakeholders mentioned the importance of reactivating traditional activities (such as grazing, agriculture, wood gathering) and that the villagers should get economic compensation to maintain the forest in a good state. If local people benefit from forest management, the motivation to manage forests sustainably may increase. Thus, the collaboration of local villagers and state is needed to ensure a long-term and sustainable forest management.

Furthermore, the combination of fuel management with the plantation of later successional resprouter species may decrease the management costs in the long-term. This management practice is explained in the next chapter.

4.3.4 Selective clearing and planting experiment to promote shrubland fire resilience

This chapter presents the results of an experiment carried out by CEAM. Although this technology is currently not applied but only an experiment providing interesting insights of an appropriate management practice, it has been assessed with the WOCAT questionnaire on technologies. The information provided here is based on Valdecantos et al. (2009) and on discussions with researchers from CEAM. Within this experiment, different fuel management techniques were examined in three study sites with a similar history of land use, vegetation composition, soil characteristics, and a typical post-fire scenario with scarce occurrence of resprouter species. The study sites Morera, Roñoso and Gachas are shown in figre 63.

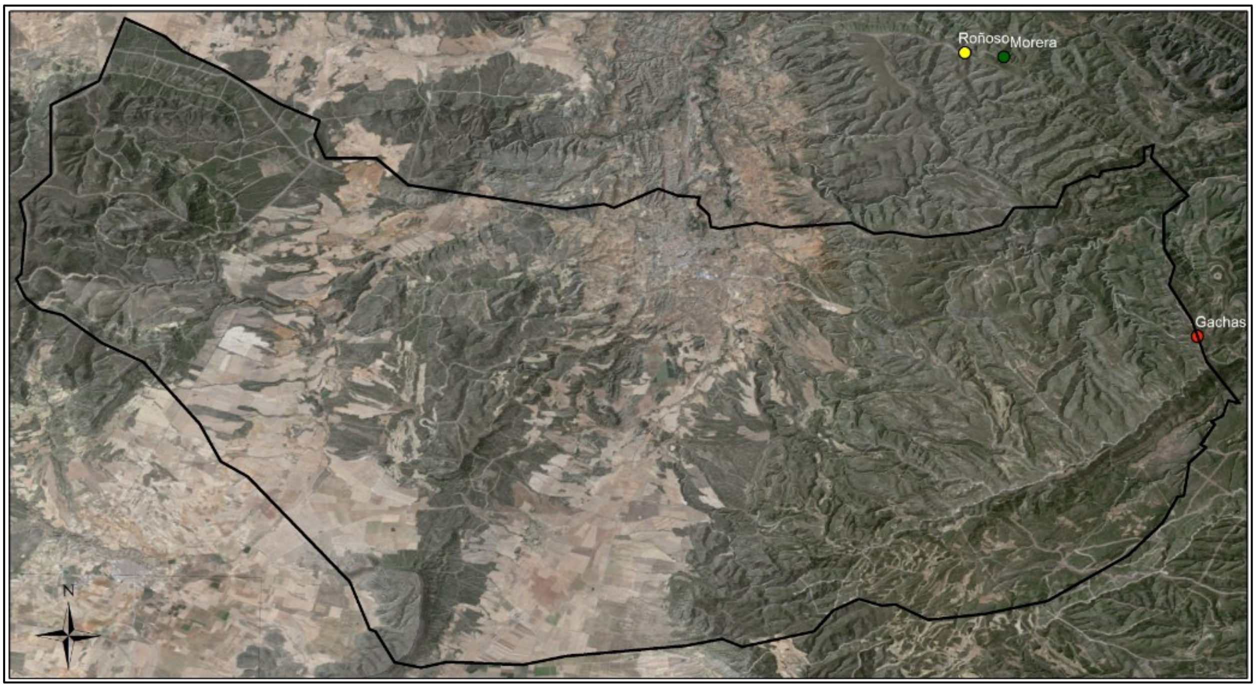


Figure 63: Study sites of selective clearing and planting experiment (Nina Lauterburg 2014, data sources: USGS, Terrasit, CEAM)

4.3.4.1 Background

The fire risk in a shrubland dominated by seeder species increases with the ongoing temporal succession (figure 64). In order to manage fire-prone vegetation effectively, it is important to understand the successional trajectories towards later successional stages dominated by resprouter species where the resilience to fires is higher (Baeza et al. 2007, Valdecantos et al. 2009). Therefore, succession management is a common practice (Luken 1990). In this case, succession management consists of fuel reduction and the plantation of more fire resistant resprouter species (Baeza et al. 2006, Valdecantos 2009).

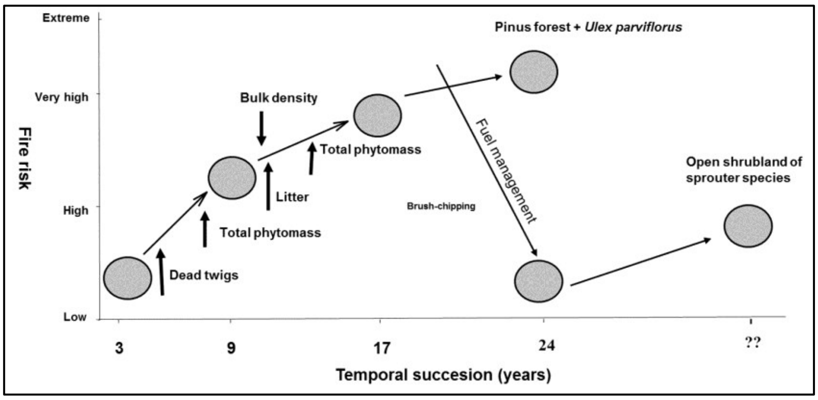


Figure 64: Succession management in a fire-prone seeder shrubland consists of fuel reduction and the plantation of more fire resistant resprouter species which decreases the fire risk (Baeza et al. 2006)

4.3.4.2 Technical description

The main purpose of this experiment was to find out which management technique is the most appropriate to prevent fires. In each study site, the experimental area covered around 5000 m^2 (3 plots of 1000 m^2 each, one plot of 2000 m^2). In each site, four plots were established to test the effect of the following management techniques: 1) control (no action, reference), 2) clearing, 3) planting (within the shrubland) and 4) the combination of clearing and planting (figure 65).

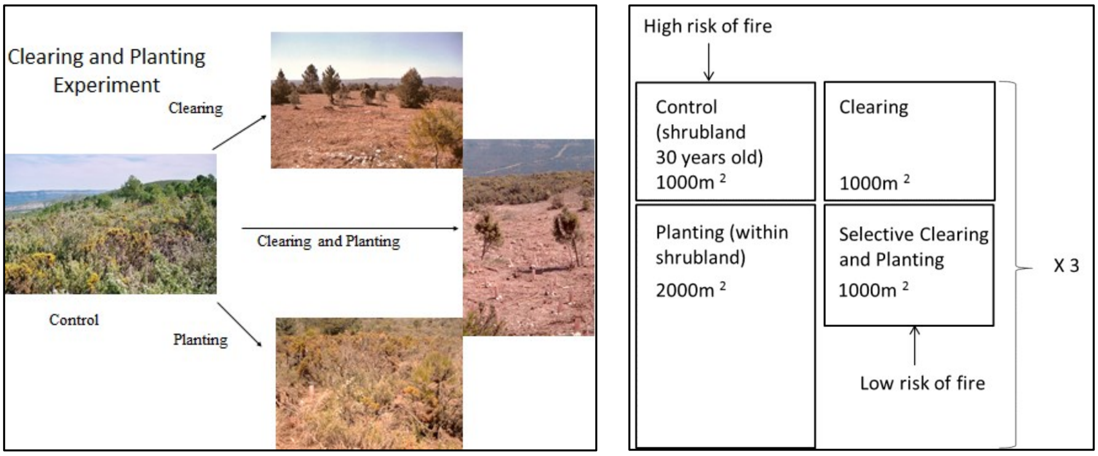


Figure 65: Experimental design of vegetation management experiment (Nina Lauterburg 2013, data sources: CEAM, Valdecantos et al. 2009)

One plot was cleared without any additional management, whereas in another plot resprouter seedlings have been introduced (planting within shrubland). To facilitate the plantation process within the shrubland, several 2m wide strips were cleared leaving in between untreated 5m wide strips where seedlings were introduced (image 53).

Image 53: Clearing of 2m wide strips to facilitate planting within 5m wide untreated shrubland strips. Seedlings were protected by a tree shelter (CEAM, Valdecantos et al. 2009)

However, the experiment showed that the combination of selective clearing of fire-prone shrubs and planting of more resistant resprouter species is more effective than only clearing or only planting with respect to fire prevention. The combination of these actions is therefore considered as the most suitable management practice. Thus, only this specific practice was documented with the WOCAT questionnaire and is now presented more in detail.

Combination of clearing and planting

To test the effect of the combination of clearing and planting, a clearing machine was used to clear a plot of 1000 m^2 in all three sites. Species such as Ulex parviflorus, Rosmarinus officinalis and Cistus albidus were removed, whereas the few resprouters such as Juniperus oxycedrus and Quercus ilex and also some seeder trees such as Pinus halepensis and Pinus pinaster were left standing. The planting holes (0.35 m^2) were created with a tractor using a backhoe. The slash and brush chips generated by the clearing were reused in the planting holes as mulch which resulted in ecological benefits. In February 2003, three different native resprouter species of late successional stages (Quercus ilex, Rhamnus alaternus and Pistacia lentiscus) were planted and protected by a plastic tree shelter to prevent browsing (figure 66, image 54). The seedlings were grown for 8 months in a nursery in Santa Faz (Alicante) and were then transferred to a nursery in La Hunde (Ayora) one month before planting.

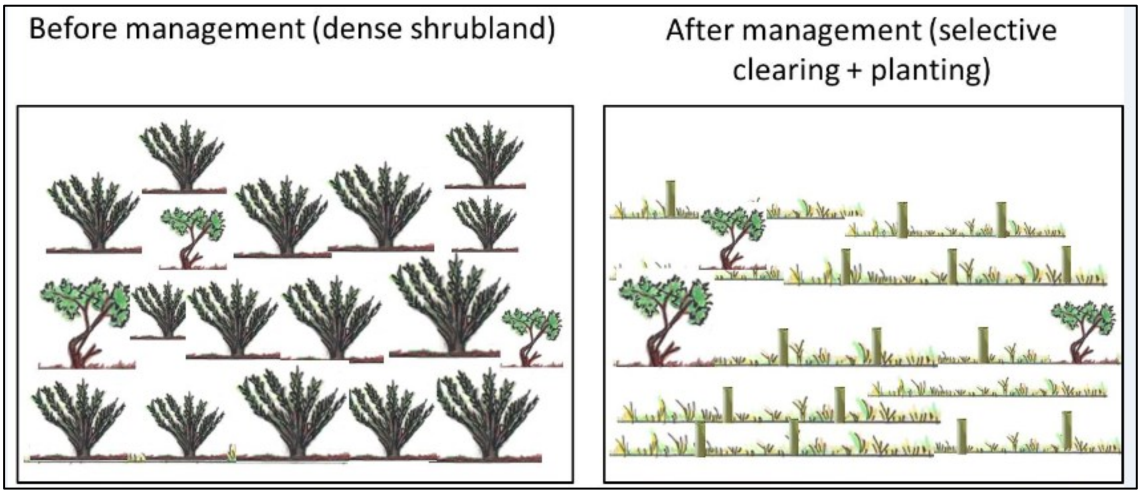


Figure 66: Technical drawing of selective clearing and planting. Tree shelters represent planted seedlings (Nina Lauterburg 2013)

Image 54: Dense shrubland before management (left), cleared shrubland and planted seedlings (center), tree-shelter protecting seedlings after plantation (right) (Nina Lauterburg 2013, CEAM)

It should be noted that the application of this practice on a vast continuous area is not the aim, but rather to apply the treatments on some selected spots to reduce the continuity of fire-prone shrubland and to increase the probability of dispersal of resprouters (e.g. by birds), thus to enhance the capacity of the ecosystem to regenerate by itself.

4.3.4.3 Maintenance

There was no maintenance included in the experiment. If this management practice would be applied on a larger scale, selective clearing would be an appropriate action. However, according to researchers from CEAM, the idea is not to apply any maintenance in the first 10 years after the establishment.

4.3.4.4 Costs

The here indicated costs are derived from indications of CEAM, however they should be taken with caution because they can vary depending on various factors. Furthermore, since the management practice would not be applied on a continuous area the costs would be lower than indicated here. The costs of a selective clearing are around 1470 Dollar per ha whereas the costs of the plantation (both labour and machines) amount to approximately 7150 Dollar per ha. Thus, the total costs amount to 8621 Dollar per ha. The maintenance activities (e.g. second clearing) would be much less expensive, accounting to around 446 Dollar per ha.

The costs are affected by numerous factors, e.g. slope steepness and vegetation density. If the clearings are done regularly, it takes less time and it is therefore cheaper than the first clearing. Thus, the maintenance costs increase the longer the period between the first clearing and the maintenance activities. Furthermore, maintenance costs may increase with an increase in seasonal rainfall due to enhanced vegetation growth.

4.3.4.5 Benefits and disadvantages

Benefits/strengths

Shrubland management is not done so far in Ayora, however especially these areas contain a high fire risk and management is required to decrease the fire hazard. The combination of selective clearing and planting showed a suitable way to manage fire-prone areas and was successful in the reintroduction of native more fire resistant resprouter species. Notably, after two drought seasons, Quercus ilex and Rhamnus alaternus showed survival rates above 80% which is extremely high compared to other reforestation trials. This technology contributes effectively to prevent fires and has potential to reverse the regime shift of shrublands dominated by seeder species.

Compared to the other management techniques, there are some advantages of the combination of clearing and planting. Clearing the vegetation reduces the fire risk and enhances seedling establishment and growth. The mulch protects the soil from erosion, reduces both the soil surface temperature and the germination of competing seeds, increases soil moisture, and enhances carbon conservation. Through the application of mulch, the growth of Ulex parviflorus after clearing is reduced by around 50% compared to clearing without mulching.

Additionnally, selective clearing allows to preserve desired species and by planting resprouter species the natural processes are accelerated. Once established, resprouter species persist for a long time which promotes an increase of the vegetation resilience.

If the aim of management is to decrease the fire hazard and to increase the resilience of the vegetation to disturbances, selective clearing combined with the introduction of resprouter species can be considered as a sustainable and effective management practice.

In case of upscaling this practice, local people could benefit from the creation of jobs. CEAM is currently trying to find fundings.

Disadvantages/weaknesses

The high costs of management activities are a major concern. Furthermore, depending on the site, some soil may be exposed to erosion due to mechanical clearing. After clearing, an increase in wind velocity might occur as well.

In case of upscaling this experiment, the technology could result in a reduction of the animal production in the short-term because grazing would have to be restricted after planting to ensure the growth of the planted seedlings. However, since the technology would not be applied over vast areas but only locally on some spots, the fodder supply would probably still cover the needs of the animals.

How to sustain benefits and how to overcome disadvantages

To sustain the benefits and to overcome the weaknesses of this technology recurrent management and increased investment into forest management are required.

This technology implies a combination of techniques (clearing and planting). Costs may be reduced by implementing individual techniques but benefits may also be reduced. Options instead of planting species could be just favouring the natural growth and recovery of desired resprouter species.

4.3.5 Other measures for fire prevention and extinction in Ayora

Along with the above presented forest management strategies, other measures have been observed in the field which contribute to fire prevention and extinction. Several interview partners stressed that the state invests more money in fire extinction than in fire prevention and that fire prevention should gain more attention. However, these measures are also important for effective fire fighting, therefore they are mentioned briefly in the following.

The region of Ayora is controlled by forest observatories which are usually located on top of a mountain and contribute to alarm fire fighting brigades in case of fire detection (image 55 and 56, figure 67).

Image 55: Forest observatory (SIGIF 2014)

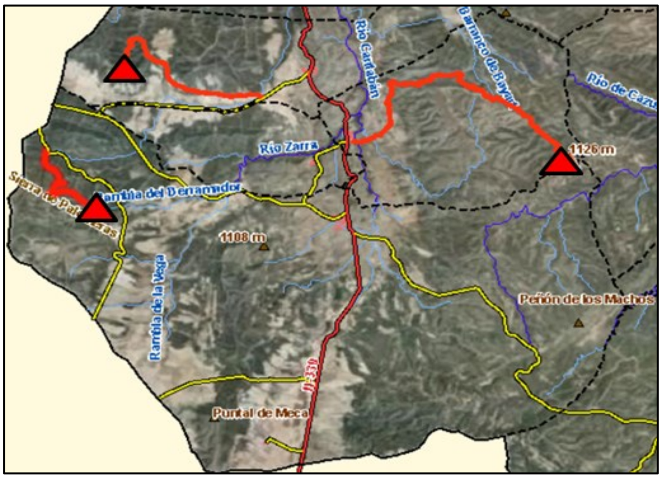


Figure 67: Location of forest observatories with access roads (SIGIF 2014)

According to the information provided by the GVA the functions of a person working in an observatory are to detect fires the most early possible and to transmit this information. Furthermore, the probability of fires is calculated through the analysis of meteorological data using SIGIF (integrated information system). This information system is presented as well in this chapter.

Image 56: Forest observatory on top of a mountain (Nina Lauterburg 2013)

Apart from forest observatories, the whole region of Ayora is covered by water ponds for fire extinction (image 57, figure 68). Most of these ponds are accessible for both trucks and helicopters and provide water in case of a forest fire. According to Luis Velasco García (Head of the Prevention and Extinction Service, Regional Ministry of Governance Valencia), the aim is to create a network of water ponds of 200 to 300 m^3 storage capacity where one pond serves for 2000 ha. This would allow helicopters to recharge water tanks in less than 5 minutes of flying time.

Image 57: Water pond for fire extinction (Nina Lauterburg 2013)

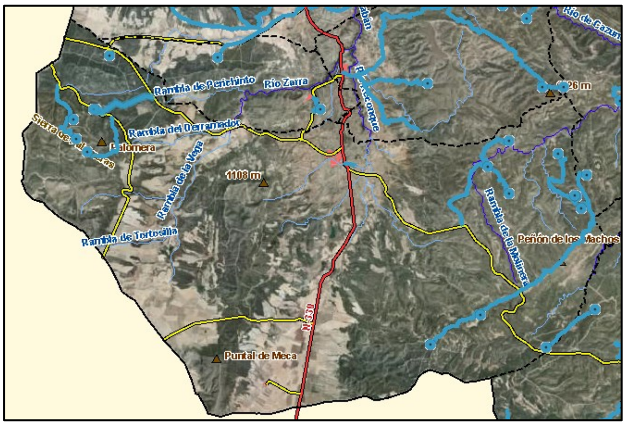


Figure 68: Distribution of water ponds for fire extinction with access roads (SIGIF 2014)

Helicopters are an important mean for fire fighting, however their maintenance is very expensive (image 58). It should be noted that the discussed media such as fire observatories, helicopters, water ponds, and firebreaks increased the organisation and the success of fire extinction. Also according to the report of OECD (2004), the effectiveness of fire fighting has increased, for example fire fighters arrive faster at the fires.

Image 58: Aerial fire fighting (La Moncloa n.d.)

An important tool to prevent and effectively extinct fires is the integrated system on forest fire management (Sistema Integrado de Gestión de Incendios Forestales SIGIF). This Geographic Information System (GIS) was developed within the fire prevention plan of Valencia and provides information on climatic conditions (figure 70) and on the exact location of the fires. Furthermore, the distribution of fire prevention and extinction infrastructure such as water ponds, forest observatories, helicopters, trucks etc. can be displayed on a map (figure 69), which contributes to effective fire extinction (VAERSA n.d.). Notably, in the year 2012 VAERSA started to document and analyse all recent fires within SIGIF.

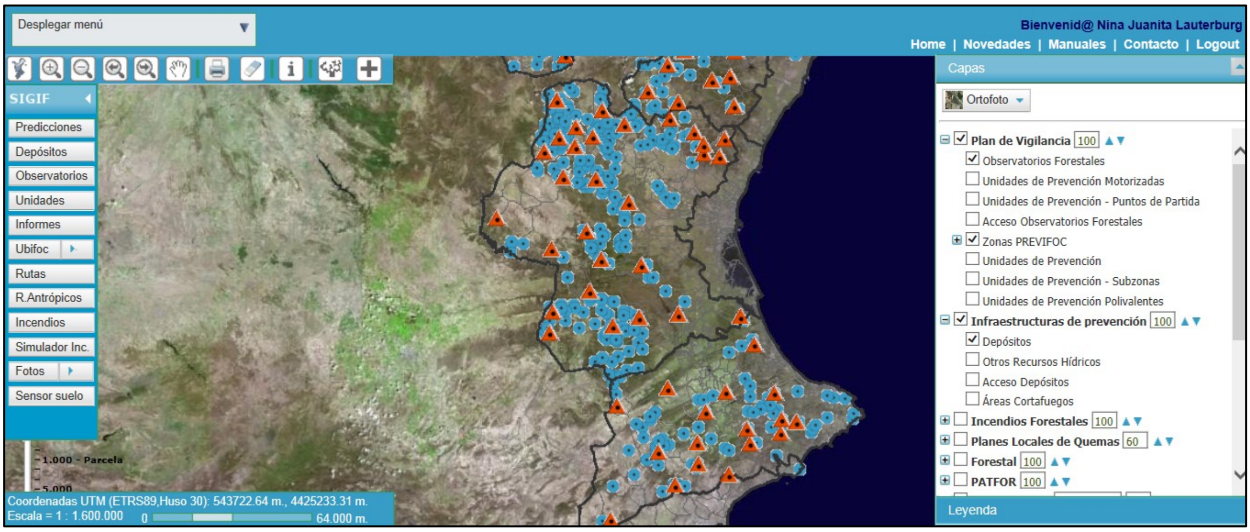


Figure 69: SIGIF: Map of water ponds (blue) and fire observatories (red) (SIGIF 2014)

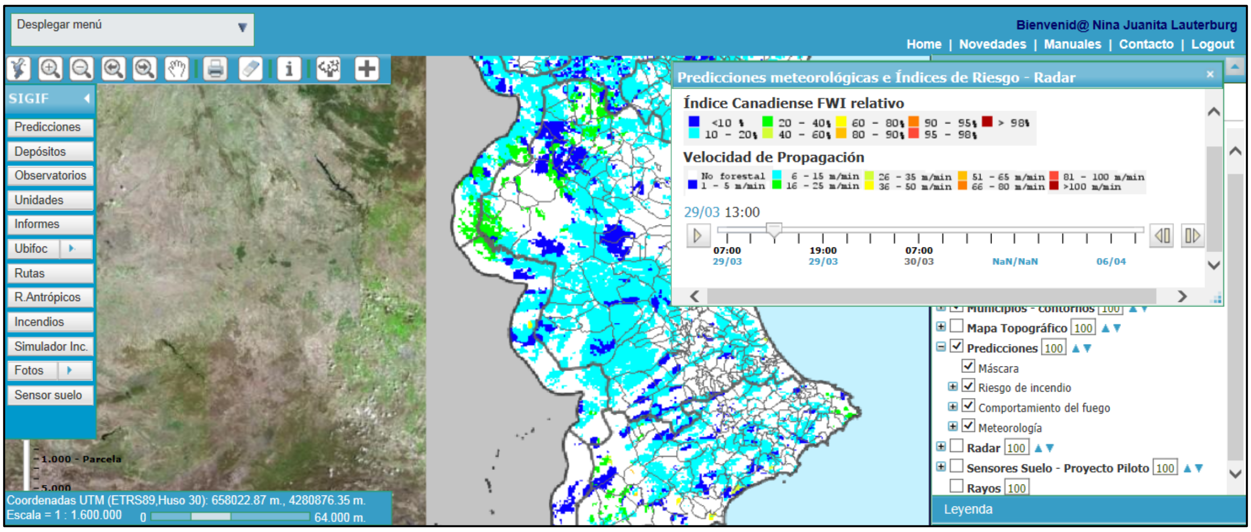


Figure 70: SIGIF: Example of climate data which can be used to calculate the probability of fires (SIGIF 2014)

A further management practice which was not mentioned in this master thesis is prescribed burning. According to FRA (2000) and FAO (2013) prescribed fires are a cost-effective management tool to limit fuel load and to prevent large fires. However, according to Valdecantos et al. (2009: 415) “fuel management through controlled burning results in the elimination of all existing vegetation and is therefore unselective with respect to species of conservation interest”. This management practice is not applied in Ayora. However, further information on prescribed fires is provided in a WOCAT documentation of Portugal.

4.4 Documentation and impact assessment of SLM approaches

This chapter is assessing through which approaches the SLM technologies have been implemented. Within the SLM-DPSIR framework, approaches are understood as responses to degradation. The firebreak establishment was documented with the WOCAT approach questionnaire (the WOCAT documentation can be found in Annex 5). The other SLM technologies are based on forest laws or management plans which were not suitable to be documented in the WOCAT format or where only little information was available. However, some important laws and management plans are mentioned in this chapter, but it should be noted that this list is not complete.

4.4.1 Forestry policy in Spain

According to FAO Forestry (2014) and OECD (2004), the forestry policy of Spain is based on sustainable management. In 1999, the **Spanish Forest Strategy** was formulated in a participatory way, focusing on sustainable forest management and on forest conservation. Some important objectives are to include all forests in the network of protected areas, to restore degraded forests, to revitalise the forestry sector in order to promote rural development, to restructure the forest industry and to improve the marketing of forest products. Furthermore, an important aim is the protection of forests against fires and pests.

In 2002, the **Spanish Forest Plan** was established, focusing on forest biodiversity conservation, reduction of soil erosion, the development of guidelines of land use planning with respect to forests, and prevention of forest fires (OECD 2004).

At the national level, the Ministry of Environment is responsible for forestry issues. However, the autonomous communities (such as the autonomous community of Valencia) decide on their own forest management strategies (FAO Forestry 2014).

4.4.2 Forestry policy in Valencia

In Valencia, the activities in forest management and the planning of fire prevention are defined by different laws (especially the forest law 3/1993) and management plans. Some of them will be mentioned in the following.

As a consequence of the devastating fire in 1994, which burnt more than 10% of the forested area of Valencia, the government decided to focus on a holistic strategy of fire prevention and extinction and elaborated the "**Plan Especial Frente al Riesgo de Incendios Forestales (PEIF)**" ("Special Plan on the Risk of Forest Fires") in 1995. Related to the PEIF, the "**plan de prevención y extinción de incendios** (2001)" ("Plan of Fire Prevention and Extinction") summarizes the most important prevention and extinction actions applied in Valencia. Prevention measures realized through the ministry of environment include issues such as education and awareness raising of villagers, biomass control through controlled grazing within firebreaks (this is not applied in Ayora), agroforestry (investigation on alternatives for burning agricultural residues), improvement of recreation areas, research on causes of fires, the "plan de vigilancia" ("plan of forest observation to detect fires"), network of forest observatories, volunteers, plan of preventive silviculture, network of water ponds and forest roads, communication media, geographic information and statistics. Fire extinction is enabled through the availability of extinction media such as forest brigades, vehicles, and helicopters. Courses on fire extinction further improve the organisation of extinction.

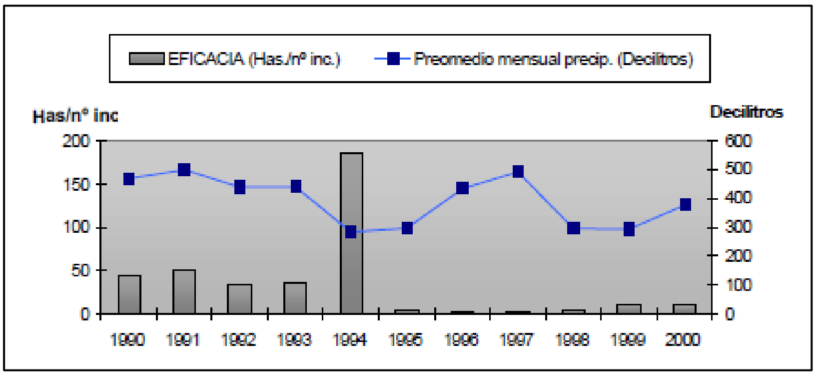


Figure 71: Comparison of burnt area and precipitation in Valencia. The effectiveness of fire prevention and extinction has increased since 1994 (eficacia (has/n inc.)=effectiveness (ha/number of fires), promedio mensual precip.=mean monthly precipitation in deciliters) (GVA 2001: 20)

Figure 71 illustrates that through the improved holistic approach of the PEIF on fire prevention and extinction, the burnt area per number of fires has decreased after 1994, although there were drier periods between 1998 and 2000. The same trend is visible in figures 5 and 6.

Based on the forest law 3/1993, there are two major management plans for fire prevention: The "**Plan de Prevención de Incendios Forestales de Demarcación**" ("Plan of Forest Fire Prevention per Demarcation") and the "**Plan Local de Prevención de Incendios Forestales**" ("Local Plan of Forest Fire Prevention").

The ministry of environment of Valencia is expected to establish a fire prevention plan for each demarcation/region (plan de prevención de incendios forestales de demarcación). Ayora is part of the demarcation Requena. However, this plan is still in process and therefore only a draft version is available on the internet (figure 72). The plan includes general information on all municipalities, a historic analysis of forest fires (1999-2008), an analysis of the fire risk, suggestions to prevent causes of fires, a plan of observation and fire detection, an infrastructure plan, technical norms and instructions, and a synthesis.

Figure 72: Cover page of the Plan of Forest Fire Prevention of Requena which includes Ayora (GVA 2011)

Furthermore, for all municipalities with forested area it is mandatory to establish a local fire prevention plan (plan local de prevención de incendios) to prepare and coordinate activities of fire prevention and extinction. This plan aims to define and manage the means, actions and infrastructure which are required to reduce the number of fires. The main objectives are to reduce the probability of forest fires, the time needed to detect a fire and the response of extinction media.

These local plans, which include the actions defined in the plan de prevención de incendios forestales de demarcación but adapted to the municipality level, provide a description of the muncipality including physical, economic and sociological facts, an inventory of high fire risk areas, areas with special protection and priority of defence, an inventory of available fire extinction media, and norms such as the local "**Plan de Quemas**" ("Plan of burning"). The plan de quemas regulates the use of fire and the traditional burnings of agricultural residues. In general, it is not allowed to use fire in the forest or if the farm is located within 500m distance to the forest between 1st of June until 30 of Septembre (GVA n.d.).

Apart from fire prevention, the **forest law 3/1993** provides the base of forest management in Valencia (BOE 2014). Amongst others, the forest law includes the following issues: Specific areas can be declared to forest intervention areas aiming at forest conservation and restoration (article 24). Furthermore, afforestations are regulated through this law, only allowing the plantation of indigenous species (articles 27-29). Additionnally, the use of forest resources such as wood, fuelwood, bark, pastures, fruits, aromatic plants, medical plants, truffles and mushrooms, honey, hunting etc. is regulated through a permission. The administration is allowed to restrict the use of forest resources if it is too excessive (articles 30-37). In case of a forest fire, it is regulated by law that local people have to contribute to fire extinction (article 55). Furthermore, there are restrictions of land use after a fire: grazing is not allowed for 5 years, agricultural activities for 20 years and extraction of goods (e.g. wood) for 10 years (article 57). There are various extensions of this law, however they will not be mentioned here. Based on the forest law 3/1993, the "**Plan de Acción Territorial Forestal de la Comunitat Valenciana (PATFOR)**" ("Forest Action Plan of Valencia") was developed, however it is still not approved. PATFOR is a tool for future forest management carried out through the government of Valencia following the principles of the forest law, namely sustainable use and management of forest resources, and including numerous maps based on GIS analysis (PATFOR 2011).

Finally, there is the "**Plan de Selvicultura Preventiva de Incendios en los Sistemas Forestales de la Comunidad Valenciana** (1996)" ("Plan of Fire Preventive Silviculture in the Forests of Valencia") which is presented in the next chapter.

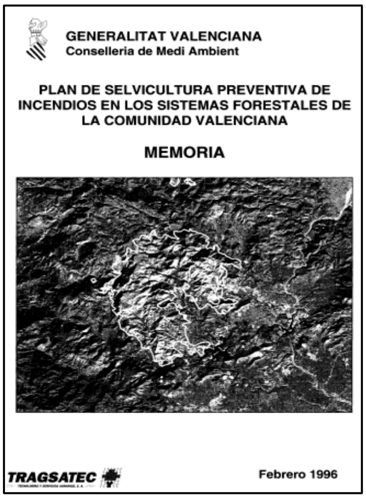
4.4.3 Plan of Fire Preventive Silviculture (PSP): implementation of a firebreak network within a forest intervention area

This approach has been documented with the WOCAT approach questionnaire and explains how the firebreak network has been established.

4.4.3.1 Forest law, forest intervention area (ZAU), and plan of preventive silviculture (PSP)

In the article 24 of the forest law 3/1993 the declaration of special areas to forest intervention areas, so-called "Zonas de Actuación Urgente (ZAU)" ("Zones of Urgent Action") through the regional government of Valencia is defined. Objectives are the protection against natural hazards and the promotion of forest conservation and restoration within a degraded area, which is affected by forest fires, adverse climatic conditions, pests, severe ecological changes, or where fauna or flora of special value can be found.

If the use of the resources is not compatible with the conservation objectives within a ZAU, the ministry of environment has the right to enforce restrictions to the owners of the property. The Ayora region was declared to a ZAU in 1997 due to its high risk of fires. In the "Plan de Selvicultura Preventiva de Incendios en los Sistemas Forestales de la Comunidad Valenciana (PSP)" (figure 73) which became operative in 1996 and whose main objective is the reduction of the fire risk, the ZAU was practically addressed for the first time in the establishment of a firebreak network. Thus, the main objectives of this approach were to reduce the high fire risk and to improve fire prevention and extinction measures to promote conservation of the forest on a large scale.


GENERALITAT VALENCIANA
Conselleria de Medi Ambient

PLAN DE SELVICULTURA PREVENTIVA DE INCENDIOS EN LOS SISTEMAS FORESTALES DE LA COMUNIDAD VALENCIANA

MEMORIA

TRAGSATEC

Febrero 1996

Figure 73: Cover page of the Plan of Fire Preventive Silviculture (GVA 1996)

Figure 74 illustrates the general line of action of the PSP. In green, base data is listed which has been processed and used for the analysis and mapping of historic forest fires in Valencia (1984-1994) and the classification of the forest by quality and fire risk aiming in prioritising actions and establishing local and regional plans to prevent forest fires. Based on this classification and on criteria such as representativity of the forest systems for the whole province and high value for the population, four areas were selected at the province level for the establishment of pilot projects. Additionally, decisions on periodic investment and employment were made and a normative system was established, which orders the recognition of financial resources and which is compatible with the national and European system.

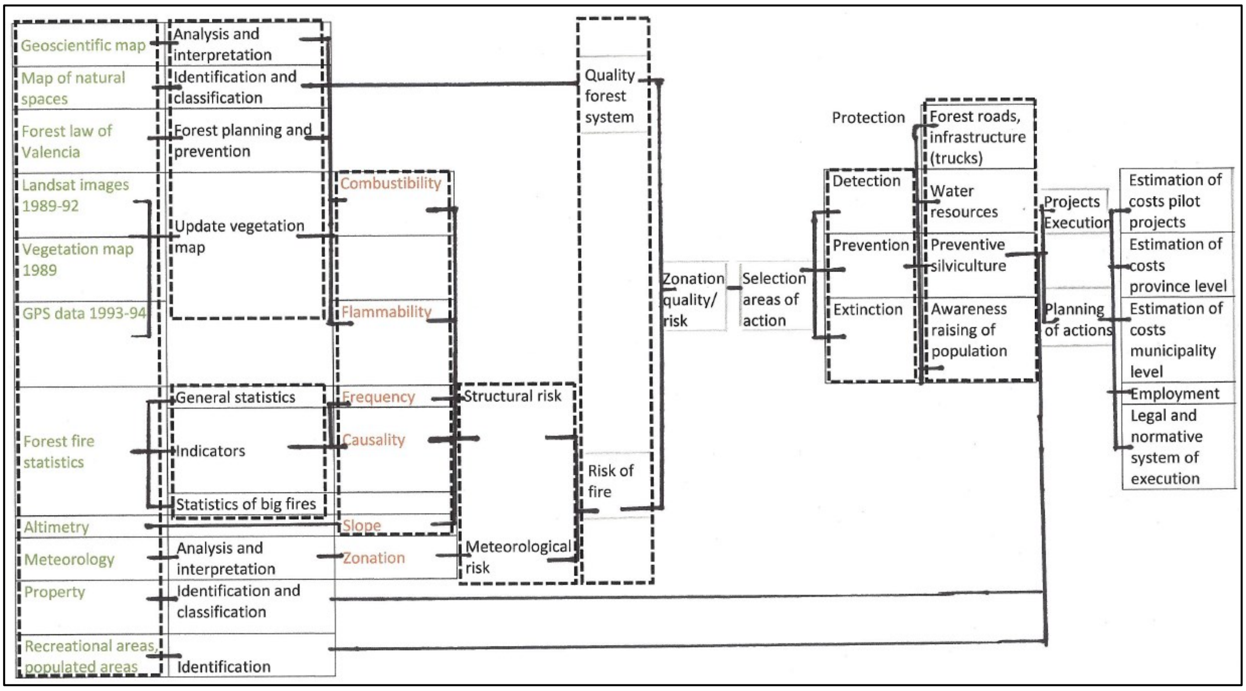


Figure 74: General line of action of the PSP (Nina Lauterburg 2013, data source: GVA 1996)

The four pilot projects were initiated in Los Serranos (17'470 ha), Utiel-Requena (20'966 ha), Valle de Ayora-Cofrentes (33'851 ha) and Sierra de Mariola (11'574 ha). Since the focus of this master thesis is on Ayora, only the pilot project of Ayora-Cofrentes is discussed more in detail in the following chapter. There is a table in Annex 6 which provides general information on all pilot projects.

4.4.3.2 Pilot project Valle de Ayora-Cofrentes

The pilot project Valle de Ayora-Cofrentes includes the municipalities Requena, Cofrentes, Jalance, Jarafuel, Zarra and Ayora. The firebreak network was established between 1998 and 2002. First, the territory was split up based on the quality and the potential fire risk using maps and aerial pictures. After the elaboration of the first draft of the firebreak network, it was checked in the field and digitized in the office to establish the final map, which was also combined with the cadastral land register. Finally, costs were estimated.

There were several stakeholders involved in the set up of the pilot project. Politicians and decision makers from the regional government of Valencia collaborated with SLM specialists and planners from the forest services (forest agents and forest engineers) to design the projects. VAERSA, a public company of the government, executed the pilot projects and was supported by forest engineers, forest agents and the local governments (figure 75).

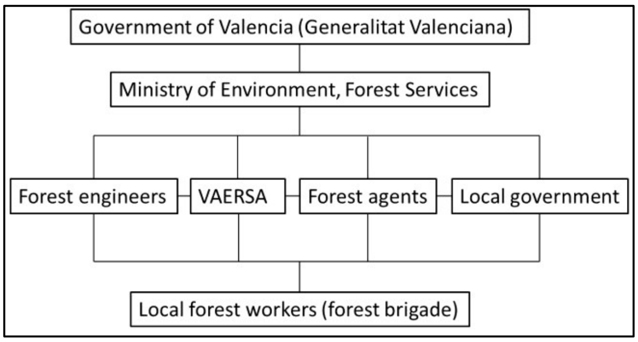


Figure 75: Stakeholders involved in the planning and execution of the pilot project of the PSP (Nina Lauterburg 2013)

Local forest workers were contracted for execution and maintenance work. However, they were not involved in the initiation, planning, monitoring and research activities.

As mentioned in the results on technologies, recurrent maintenance of the firebreaks is required which is also included in the pilot project. The PSP is put into operation each year by the forest services to plan the maintenance of the firebreak network. In the here described project the maintenance was carried out in three phases (2001-2004, 2004-2008 and 2008-2012). Image 59 shows a map of the third maintenance which was carried out between 2008 and 2012.

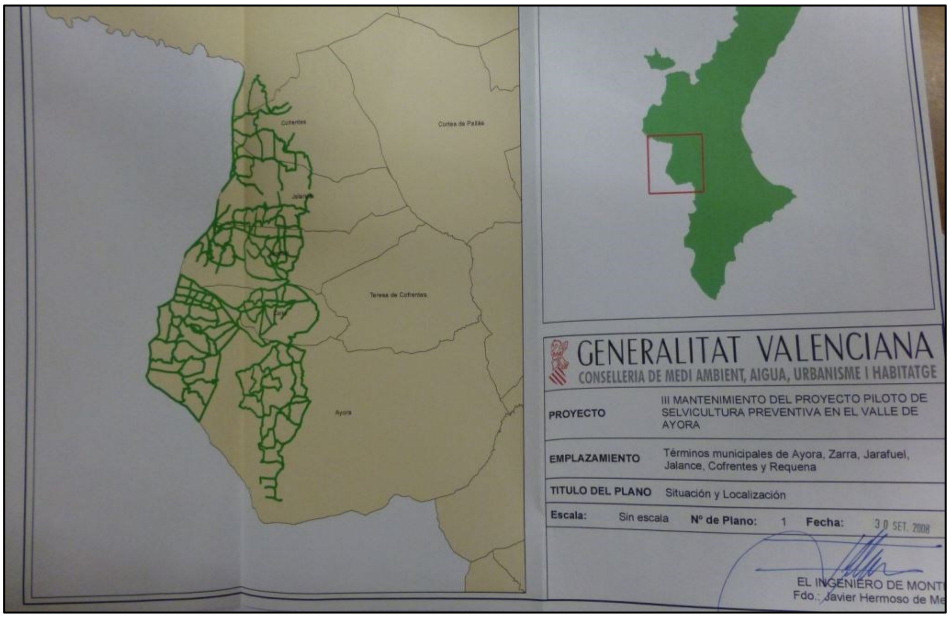


Image 59: Third maintenance of the firebreaks established within the pilot project of the PSP (Nina Lauterburg 2013, data source: Generalitat Valenciana)

4.4.3.3 Benefits and disadvantages

The benefits and disadvantages of firebreaks have already been discussed in the chapter on technologies. However, some additional information of the approach is provided in the following.

Benefits/Strengths

Although some firebreaks already existed before, through the implementation of the pilot project of the PSP the establishment of a whole network of firebreaks was institutionalized and developed based on profound research on where and how to establish the vegetation-free strips.

Furthermore, through the PSP a new type of firebreaks was designed to reduce the visual impact, so-called "áreas cortafuegos" ("firebreak areas"). In some cases, these firebreak areas are five time wider than the usual firebreaks (image 60).

Image 60: Traditional firebreaks (red) and new type of firebreaks (yellow, áreas cortafuegos) (GVA 2011)

Notably, also maintenance activities of the firebreaks are included in the PSP. The pilot project of the PSP and the maintenance activities are fully financed by the government. Furthermore, the local population is benefitting from the establishment and the maintenance activities of the firebreaks through the creation of jobs in forest management.

The project was important to raise awareness on the fire problem and on the importance of forest management. The network is enlarged from time to time whenever forest agents discover a suitable area where a firebreak is still missing. Thus, the approach contributed to the adoption of this technology.

Disadvantages/weaknesses

However, there are also some weaknesses. Local forest workers cannot continue the activities on their own due to the high costs and the required technical assistance of forest services. Once the government will not continue paying the maintenance of the firebreaks the technology will probably not be managed anymore, and future funding of activities is not clear. Furthermore, the projects were designed by the government without including local forest workers.

How to sustain benefits and how to overcome disadvantages

To sustain the benefits and to overcome the disadvantages of this approach, the government should sustain its investment in forest management. Public awareness raising and training of local people through the forest services could also contribute to sustainable forest management. It would be important to work in a participatory way and to include local forest workers already in the planning of forest management activities in order to stimulate their interest.

4.4.4 Public awareness raising

The laws and management plans discussed previously are the reasons why and how forest management and especially fire prevention measures are executed. However, another crucial issue to prevent fires are the efforts of the government of Valencia to improve the consciousness and the education of people. Sustainable development is promoted through dissemination of knowledge (GVA 2012).

The manual of good practices (figure 76) disseminates advices among all land users and forest visitors and explains in a simple manner which activities are allowed and what should not be done in order to prevent forest fires. Furthermore, the most important laws are listed as well.

The following issues are addressed by the manual:

- Forests and their ecosystem services
- Production and propagation of forest fires
- Fire prevention including forest observatories, firebreaks, water ponds, basic norms (e.g. not to throw away cigarettes)
- Norms in forest management work due to the fact that a lot of forest fires originate from management activities. There is an additional manual on security norms how to prevent fires when executing forest management works.
- Norms when spending leisure time in the forest

Figure 76: Cover page of the manual of good practices to prevent forest fires (GVA 2012)

Figures 77 and 78 illustrate the simple way through which the manual seeks to disseminate knowledge among all forest users.

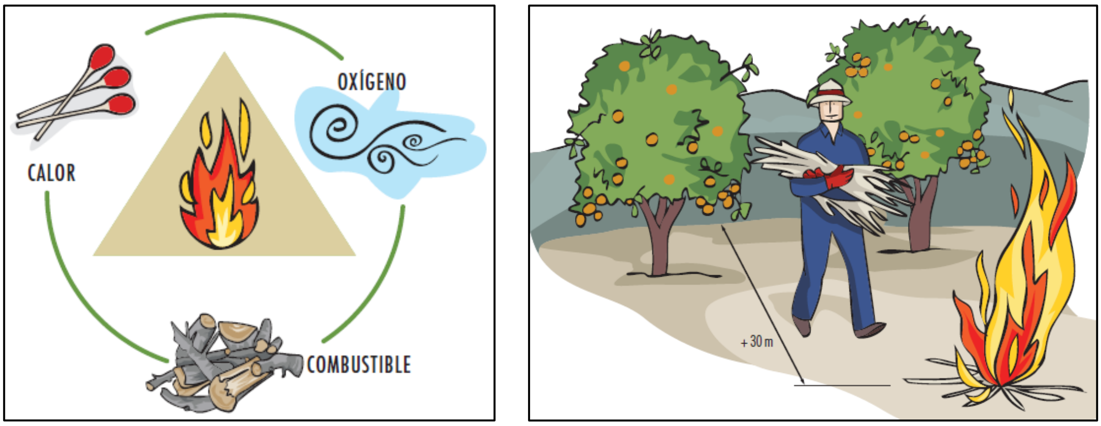


Figure 77: Simple explanations on how a fire is produced (left), and burning instructions (right) (calor=heat, oxígeno=oxygen, combustible=fuel) (GVA 2012)

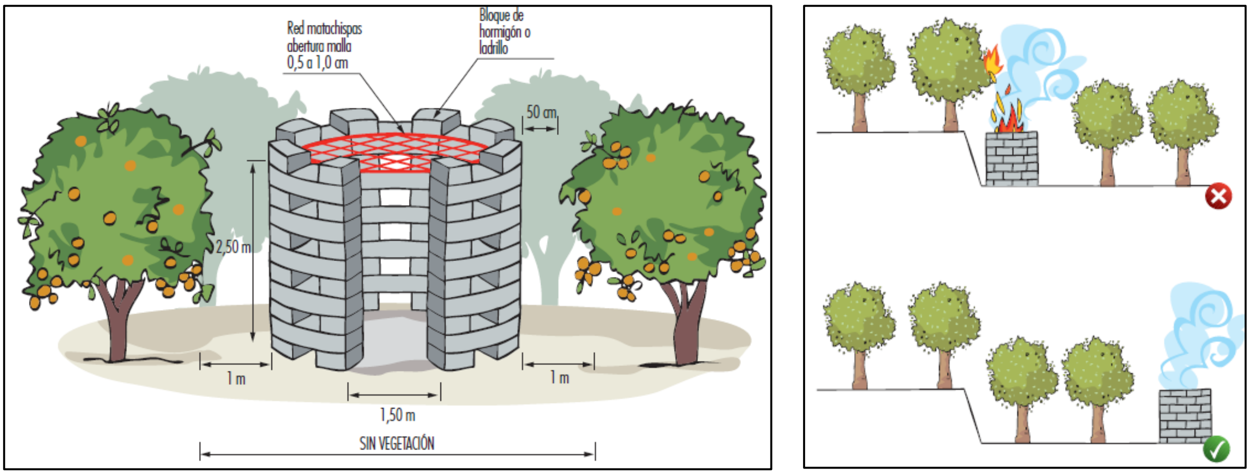


Figure 78: Explanations on how to burn agricultural residues (red matachispas=net against sparks, bloque de hormigón o ladrillo=concrete block, brick, sin vegetación=without vegetation) (GVA 2012)

The information provided in this chapter and further information on laws, regulations and management plans and activities is accessible either on the website of the Generalitat Valenciana (http://www.cma.gva.es/web/indice.aspx?nodo=180&idioma=C) or on the website of emergencies 112 which focuses on fire prevention and extinction (http://www.112cv.com/prevencion/guatlla30/web-2520exportar/indice.aspx@nodo=206&idioma=c .htm).

5. Synthesis

The overall research question of this master thesis asks for causes and consequences of forest fires and deals with the potential of SLM strategies in reducing fires and preventing regime shifts in Ayora. This chapter summarizes the main results and provides an overall synthesis. A brief overview on vegetation degradation and the effectiveness of currently applied SLM practices is followed by a discussion of further options for sustainable land management suggested by stakeholders. Furthermore, a small chapter on methodological reflexions contributes some insights on the suitability of the WOCAT methods for assessing degradation and SLM in this specific context. At the end, an outlook reveals further research required in this field.

5.1 Assessment of overall research question

5.1.1 Regime shifts in Ayora

Ayora has experienced two major regime shifts which have modified the vegetation composition from more fire resistant resprouter species to fire-prone seeder species:

1. Shift from holm oak woodland to pine forests and shrublands of different successional stages
2. Shift from pine forests to shrublands dominated by seeder species

The first shift was mainly driven by cultivations in the past (removal of resprouter species). The disappearance of oaks, combined with land abandonment and the associated lack of management, went along with an increase in the vulnerability of the vegetation to fires; the vegetation is dominated by highly fire-prone seeder species. This in turn has promoted short-interval fire cycles resulting in the disappearance of pines before having been able to produce seeds. Thus, the high fire recurrence caused another shift from pine forest to seeder shrubland. To conclude it can be stated that natural forest fire dynamics and the resilience of the vegetation to fires have been modified by human activities.

Regime shift or possible vegetation regeneration?

When discussing regime shifts in Ayora, there is always the question if with ongoing secondary succession the vegetation will recover or if there is a long-term persistent change in the vegetation composition. Taking into account the natural vegetation regeneration over time, it is crucial to define the temporal scale in which a change is considered as a regime shift. Within the CASCADE project, there is a general agreement that one generation is an appropriate time span. Due to the facts that the impacts of the fire in 1979 are still visible, and that no change is expected for at least the next 20 years, the observed modifications in the vegetation composition can be seen as a regime shift. It is not fully clear how fires will perform in future. However, considering the abundance of fire-prone vegetation and the projections on climate change, it is probable that the high fire recurrence will persist, hindering the recovery of a more fire resistant vegetation due to short-interval fire cycles.

5.1.2 Degradation (state of vegetation)

Regime shifts are highly complex and may have severe impacts on ecosystem functions and services. Therefore, there is a need to understand degradation drivers, impacts and sustainable land management options in order to prevent or reverse such negative regime shifts.

To properly manage degraded areas, it is crucial to have information on where and at what intensity vegetation degradation is taking place. Although there are different regeneration scenarios after land abandonment and fires, through the application of the WOCAT mapping questionnaire it has become obvious that the vegetation degradation has increased in all assessed land use systems in Ayora over the last 34 years (cropland, water and urban areas have not been analysed). Most of the unburnt forests and shrublands are considered as degraded due to the change in species composition and the lack of management, which affects almost the whole region. The high density, the bad vegetation quality, and the huge fuel amount have increased the fire risk. Around one fourth of Ayora has been affected by fires. Thus, at present, not only unburnt forests and shrublands contain a considerable fire risk, but also the burnt vegetation (both forests and shrublands) which regenerated with a high density. A major problem is that a high fire recurrence may promote short-interval fire cycles and lead to a downward degradation spiral. Considering the state of the burnt vegetation it can be concluded that the degree of vegetation degradation is increasing with the number of fires. Furthermore, an increasing number of fires causes negative impacts on productive, ecological and socio-economic ESS.

One main result of the WOCAT mapping is that regime shifts and the impacts of fires are also influenced by the slope aspect (north, south). The highest degradation extent and degree can be found in south exposed shrublands which burnt twice; around 80% of this LUS are considered as heavily degraded. Additionally to vegetation degradation, further degradation may occur, such as erosion, crusting and aridification. In the worst case, a pattern of bare soil with little vegetation cover could arise. This situation may accelerate desertification processes and thus result in a regime shift similar to the shift observed in the Albatera study site (Alicante), which is also part of the CASCADE project and which is threatened by desertification. Notably, the fire risk has actually decreased in the south exposed shrublands which burnt twice due to the sparse vegetation cover and the interruption of the continuity. In contrast, the high amount and density of fire-prone seeder species in north exposed shrublands which burnt twice has increased the fire risk (see figure 48 on impacts of degradation on fire risk).

The north exposed shrubland which burnt three times is not that degraded as expected due to the fact that this area was not cultivated in the past. The presence of resprouter species increases the resilience to fire in this area, and post-fire recovery is faster. Thus, additionally to the influence of the aspect, it is actually the number of perturbations, namely the combination of past cultivations and recurrent fires, which determines the degradation degree, the impact of fires, the regeneration capacity and the probability of a regime shift.

5.1.3 Currently applied SLM practices and their effectiveness

As a consequence of several devastating fires and their negative impacts on productive, ecological and socio-economic ecosystem services, the government of Valencia introduced numerous management plans and interventions in order to improve fire prevention and extinction as well as to promote mature forests. Although there is still a high number of fires and fire prevention stays challenging, the implementation of a holistic approach in fire prevention and extinction resulted in a decrease of the annually burnt area since 1994.

Important SLM practices in Ayora include the establishment of a firebreak network, selective forest clearings and numerous Pinus halepensis afforestations aiming in post-fire rehabilitation or restoration of abandoned fields. These measures, which are considered effective in case of recurrent maintenance, are mainly based on the forest law 3/1993 and on several management plans.

Almost the whole area is covered with and thus protected by firebreaks, however not all of them are well maintained and they only work with human intervention. To fight efficiently against fires, a prepared infrastructure is needed. If firebreaks are maintained and if firefighting is well organized, they indeed contribute in limiting the burnt area and are therefore an effective tool in fire extinction.

Selective forest clearing (thinning and pruning) is applied in unburnt forest (natural and afforested) and forest burnt once (which recovered with a high density), mainly next to roads or within recreation areas, on less than 10% of the forested area. However, this indication should be taken with caution due to the fact that stakeholders were not sure about the extent of this management measure. Notably, this practice is not applied in shrublands. Selective forest clearings contribute effectively to a decrease of the fire risk due to the reduction of the fuel load and the removal of weak or dead plants. With respect to other management practices, it has some advantages, e.g. the possibility of being selective in order to preserve desired species. If selective clearing is repeated several times, the possibility increases that resprouter species again establish which in turn would increase the resilience of the forest to fire. Both the results of this master thesis as well as the findings of the PRACTICE project (Llovet López et al. 2012) allow the conclusion that selective forest clearing is the most sustainable land management practice in Ayora.

Pinus halepensis afforestations which were executed within the considered time span are mainly executed on burnt shrublands. According to area calculations based on the GIS layer provided by the GEORANGE project, afforestations amount to 3101 ha which is 6.9% of the total area of Ayora. Within the shrubland burnt once, 1748 ha have been afforested which is around 30% of the area of this LUS. Within the shrubland burnt twice, the afforested area amounts to 839 ha which is around 20% of this LUS. However, stakeholders argued that most of the afforestations failed and therefore it is possible that the GIS layer illustrates afforestation projects without considering their success.

Through the WOCAT technology questionnaire, one of a few examples of successful Pinus halepensis afforestation trials has been documented. The success becomes evident through the presence of healthy old pines, but also through the growth of young pines and resprouter species such as Quercus which have not been planted. However, many pines are severely degraded due to the high density and competition for resources. In most cases, monoplantations with Pinus halepensis result in the simplification of the landscape, an alteration of habitats, an accumulation of highly flammable and continuous fuel, and an increase in the vulnerability to perturbations such as forest fires or pests. Due to these reasons and the lack of management (thinning, pruning), Pinus halepensis afforestations are not considered as an appropriate management practice in a fire-prone area. Afforestations do not aim in fire prevention but more in rehabilitation of disturbed areas or prevention of soil erosion, nevertheless they need to be managed to decrease the fire risk in the region.

A major concern hindering the effectiveness of applied conservation measures is the lack of investment into maintenance, which is partly driven by the current economic crisis. Missing management activities result in shrub encroachment and an increasing fire risk. In order to ensure the effectiveness of these technologies, there is a need to sustain maintenance activities.

The calculation of the total conserved area (figure 53) leaves the impression that almost the whole area is conserved. However, considering the fact that not all firebreaks are well maintained and that the afforestations failed to a big part, this result does not imply that there is no need for further management practices. Furthermore, Ayora is still threatened by a high fire risk.

5.1.4 Options for SLM in Ayora

To prevent further degradation and to increase the resilience of the vegetation to fires, efforts of sustainable vegetation management practices are a priority.

Due to the fact that vegetation degradation in Ayora is considered as severe, figure 79 presents some options for SLM suggested by stakeholders for areas where currently no or only few management activities are applied. Through stakeholder interviews and through calculations of the absolute degraded area per LUS, it has become evident that not only the south exposed shrublands which burnt twice, but also the other areas need to gain more attention through conservation practices due to their high fire risk. The explanations of figure 80 are following below.

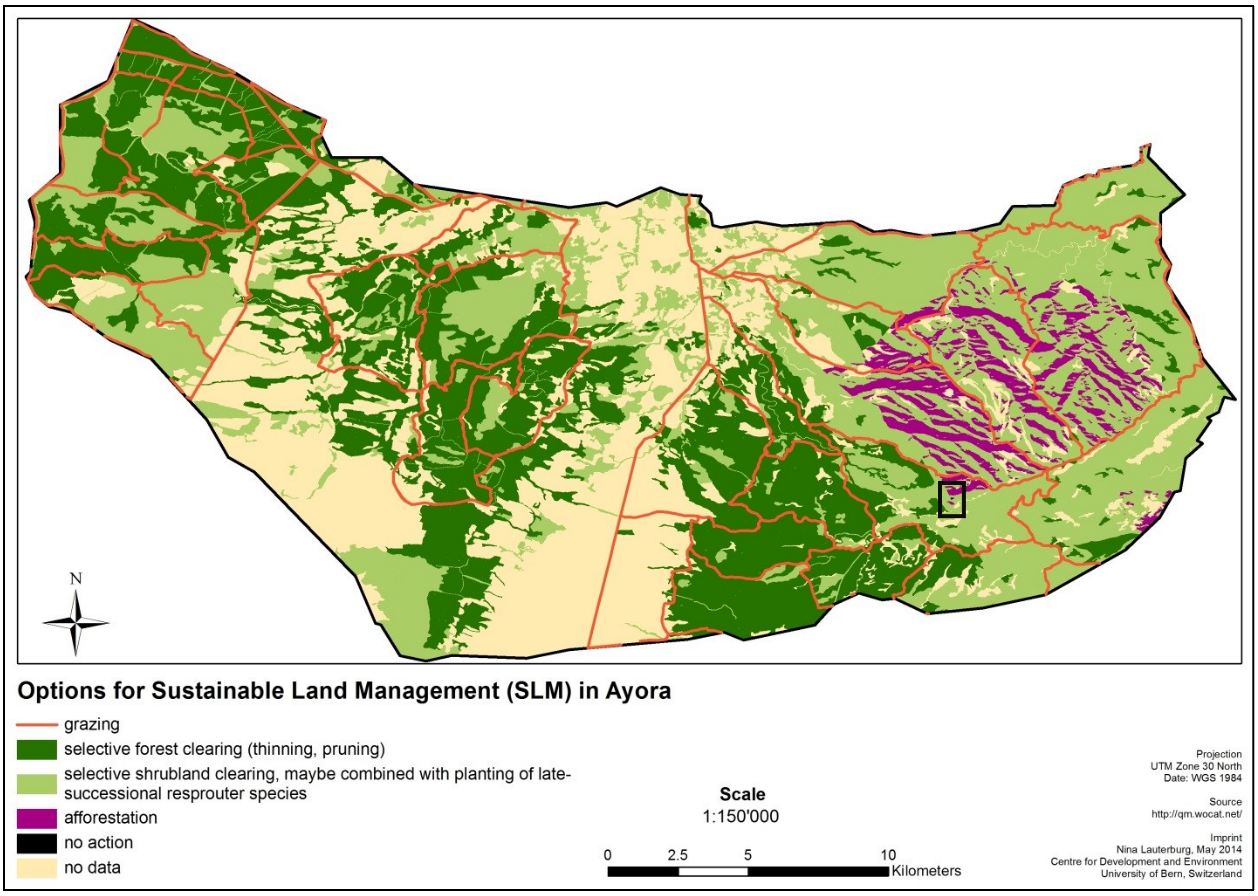


Figure 79: Options for Sustainable Land Management in Ayora, based on stakeholder suggestions. No action is indicated for the small area burnt three times which is located in the black box. No data is available for SLM on cropland, water and urban areas. Grazing refers to firebreak maintenance (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

In forests (both unburnt and burnt, north and south exposed), it would actually be required to apply more selective forest clearings (thinning, pruning) in order to reduce the fuel load, to remove weak or dead plants, to promote healthy forests and maybe even to achieve a reestablishment of resprouter species which in turn would increase the resilience of the forest to fire. Currently, only small areas are managed through this technology; the high costs and a lack of access to the forest may hinder the implementation.

Furthermore, it has been pointed out by stakeholders that management activities are rather applied in forests whereas shrublands are hardly managed; only some firebreaks are located within the shrublands. Notably, especially these areas contain a high fire risk and management is required to decrease the fire hazard. The question on the aim of management in shrublands is crucial. Should the vegetation be restored to a former state of forest land or is there an agreement on the persistence of shrubland? And why should shrubland be considered worse than forest? To answer these questions and to decide on suitable land management practices, the evaluation of ESS becomes an important factor. The major problem is that shrublands composed of seeder species increase the fire recurrence which might lead to a downward degradation spiral. Furthermore, forests are considered as the lungs of the world, contribute to carbon sequestration and stop desertification processes. Therefore, stakeholders argued that, in order to prevent fires effectively and to promote mature forests, there is a need for management, e.g. the application of selective clearings in shrublands (unburnt and burnt once north and south exposed, burnt twice north exposed).

Even more effective but not yet applied on a larger scale is the combination of fuel management and afforestations. CEAM suggests combining selective clearing of seeder species with the plantation of resprouter species in order to accelerate natural succession and to promote resilience to fires. This practice seems to be a suitable way to manage fire-prone areas and it was successful in the reintroduction of native resprouter species. Once established, resprouter species persist for a long time, lowering the impacts of the fire and the fire risk by itself. It should be noted that the application of this practice on a vast continuous area is not the aim, but rather to apply the treatments on some selected spots to reduce the continuity of fire-prone shrubland and to increase the probability of dispersal of resprouters (e.g. by birds), thus to enhance the capacity of the ecosystem to regenerate by itself.

South exposed shrublands which burnt twice are severly degraded, however the problem is not a high fire risk, but rather the dominance of desertification processes. Therefore, one option would be to afforest these areas with late-successional resprouter species. This in turn would result in a decrease of erosion and aridification, and at the same time in a low fire risk. Notably, this action is expensive and probably not easy to realize. In this case, the costs, benefits, and impacts on ESS have to be evaluated and weighted in order to decide if management is desired and reasonable. Since pine afforestations are not considered as a proper management practice, an alternative suggested by Pausas et al. (2004) is the plantation of both pines and oaks in order to benefit from the fast growth of pines and the high resilience of oaks to fire. This action could promote higher diversity and heterogeneity of the landscape. Mixed plantations as suggested by CEAM or by Pausas et al. (2004) and their potential for managing the shrublands (unburnt and burnt) in Ayora need to be further investigated.

No action is currently required for the shrubland burnt three times. The area is recovering quite well and due to the presence of resprouter species, the fire risk is rather low. However, depending on the future situation, it might be possible that a selective shrubland clearing could contribute to sustainable vegetation management.

The firebreaks which have been established through the pilot project of the PSP are maintained quite recurrently, but there are also firebreaks which are hardly managed. Stakeholders mentioned that the firebreaks could be maintained through grazing. This has been done in other regions and was very successful. However, grazing in the mountains is not cost-effective and thus not attractive for shepherds in Ayora, therefore subsidies from the state would be required to cover the additional costs. The importance of grazing as a contribution to forest management was mentioned several times and could be a simple way to reduce the management costs and the fire risk.

It should be noted that these options are based on suggestions from stakeholders and do not provide a full range of possible SLM practices which could be applied in Ayora. Management activities need to be adapted and designed with respect to the prevailing conditions and in collaboration with stakeholders. In that way, SLM should gain more attention.

5.2 Methodological reflexions (challenges)

The WOCAT programme provides useful and standardized tools to assess land degradation and SLM practices, considering both ecological as well as socio-economic facts and allowing to share the knowledge with other land users. However, there were some challenges to apply the questionnaires in the context of forest fires in Europe. These difficulties are briefly addressed in the following.

Due to the fact that only few land users are still living or working in this abandoned area it was a challenge to find stakeholders with a broad knowledge of the region who could contribute to complete the questionnaires. Furthermore, different from SLM implemented by small-scale farmers in other countries, there is no single person who established a technology and who is able to provide all the required data. Therefore, information had to be collected from many different sources, for example from various stakeholders met in the field, project documents from the government, scientific knowledge from the university, and analysis of existing maps. Unfortunately, this resulted in different indications on the same questions. Furthermore, official project documents are publicly available in the ministry of environment in Valencia, however copying the documents is not allowed. Another general problem of the WOCAT method is to assess a more bio-physical topic with subjective qualitative data; additionally the results should be supported with quantitative data. Researchers from CEAM already conducted studies in this area and could help out with quantitative data on some issues. Once the information was collected, which was highly time intensive, the technology questionnaire was suitable to document the SLM practices comprehensively.

The mapping method was more challenging. The WOCAT mapping of a region threatened by forest fires has never been done up to the present day, therefore it was required to adapt the method in the field. During the mapping it has become obvious that instead of including the last 10 years as proposed in the mapping questionnaire, there is a need to include the time span from 1979 (first fire) until today in order to map the long-term effect of the fires on the vegetation composition. Another difficulty for the stakeholders was to estimate the extent of degradation or to indicate the vegetation dynamics (area trend) due to a lack of knowledge of the situation before the fire in 1979.

To complete the whole mapping questionnaire is a huge work and people got tired and impatient standing in the sun. Due to a lack of availability of stakeholders, the mapping exercise had to be done in only one day, therefore it was not possible to collect all the required data. Thus, the lacking information was completed afterwards through literature review, study of maps (CORINE land cover of 1990, 2000 and 2006) and knowledge collected from other stakeholders or documents. Through the combination of field visits and office work, it was possible to complete the mapping questionnaire and to create maps and charts which are maybe not completely correct, but which clearly show the major problems and SLM practices in Ayora.

The approach questionnaire was not really applicable in the case of Ayora due to the fact that most of the management strategies are based on forest laws or management plans which are not suitable to be documented in the WOCAT format. In my case, only one QA was filled out based on official project documents.

5.3 Outlook

This chapter presents some open questions or tasks which have arisen during this master thesis.

One main objective was the mapping of land use, land degradation and conservation measures, which was done through a qualitative assessment. Although the broad results coincide with the findings of other researchers, unfortunately there was no time to validate the maps in the field. However, during the mapping process, it has become clear that there are some confusing issues in the resulting maps. Due to a lack of cartographic data and missing knowledge of stakeholders, it was not possible to state with certainty which vegetation type was prevalent before the fire in 1979. Thus, it is not clear if a shrubland indicated as burnt once was a forest or a shrubland before the fire. However, to draw a conclusion on degradation and on the impact of fires, it is actually crucial to know whether before the fire an area was covered by forest, or whether there was already shrubland. Furthermore, it would be interesting to map which parts of the land were cultivated in the past to further investigate on the relation between land use, fires and regime shifts. Another confusing issue was the afforestation map which was created using the GIS layer provided by the GEORANGE project. The afforested areas of this layer do not fully match with the forest area indicated in the base map. Thus, it is not sure if today all of these areas are really covered by forest. Since stakeholder explained that many afforestations failed, it is probable that the GIS layer displays the planned and/or executed afforestation projects, however without having been checked in the field with respect to their success. This check would be required in order to draw a conclusion on the effectiveness of this technology and to validate the base map. Unfortunately, this has not been done within this master thesis and would be a further task which should be addressed in future. It would also be interesting to know more about the influence of the aspect on the success of afforestations.

Due to these uncertainties, it has become obvious that a thorough analysis of land use and land cover changes in Ayora using remote sensing and GIS is a pending issue which is addressed more in detail by the on-going master thesis of Camille Flückiger. Furthermore, there are attempts of PhD student Matteo Jucker Riva to analyse the current state and the potential of the vegetation through the application of a remote sensing method which was developed through Hanspeter Liniger of CDE. These remote sensing based results will contribute to the validation of the WOCAT maps.

Through discussions with researchers from CEAM during the mapping process, it has become clear that there would actually be a need to distinguish between seeder and resprouter shrubland (which is not the case in my base map) due to the fact that these shrubland types are very different in terms of fire vulnerability and post-fire regeneration. To map areas with a high degradation and a significant fire risk, and to draw a conclusion on regime shifts, this difference is crucial. However, there is no remote sensing data available so far and a lot of field work and cartography is required to develop a map which distinguishes these shrubland types. This could be addressed by another thesis, ideally through the collaboration of a biologist and a geographer.

Thus, there are still numerous open questions; research on regime shifts and fires will continue within EU-CASCADE and other projects. The role of recurrent fires in diverting the succession of old fields is further investigated within WP6 (CASCADE 2013). Related to that, it is important to note that the WOCAT mapping exercise has shown the possibility of different regeneration scenarios after fires. While in some regions the forest recovers, other burnt areas are covered by shrubland, in some cases with a high percentage of bare soil. A major issue of CASCADE is to find out why in some regions a regime shift occurs (e.g. lack of forest regeneration), while other areas show considerable recovery. Furthermore, to gain knowledge on the consequences of regime shifts in Ayora, CEAM is trying to find out if there is any difference in soil quality between areas that burnt frequently and places that did not burn. It has been pointed out that fires change the nutrient pools in ecosystems, but the extent of this change is still not known. Therefore, within the CASCADE project, CEAM is analysing soil properties in the whole gradient of fire recurrences (0, 1, 2, 3 fires). However, researchers pointed out that the shift between forest and shrubland is not triggered by changes in soil quality or soil fertility. Other factors such as fire intensity, seed dispersal, and post-dispersal rainless period may be more important.

This master thesis will be of further use for the CASCADE project since all study sites have to apply the WOCAT tools to document local SLM practices. Especially the Spanish partner CEAM as well as PhD candidate Matteo Jucker Riva, who evaluates SLM practices of all study sites with respect to their resilience to shocks and shifts, will benefit from the documentations of Ayora.

It is not clear whether people will be able to control the fire in future and if there will be a solution to stop or even reverse degradation. The forest lost a big part of its value and since people are not directly depending on the forest to secure their livelihood, the motivation for SLM is rather low. However, there is growing awareness from the public and policy-makers on the role of forests in providing environmental, economic and social benefits, and there is an agreement on the importance of forest protection measures against devastating fires. It is recognized that the resources are not infinite and that there is a need for sustainable management and use. To reduce the adverse impacts on ecosystems and the livelihoods of local people, it is crucial to further investigate on SLM to control these recurrent fires and to decrease the probability of future regime shifts. In order to sustainably manage fire-prone areas there is a need of profound knowledge on the processes, degradation drivers, and impacts. Thus, the collaboration of researchers, policy makers, local land users and other fire-threatened countries may contribute to identify best practices for sustainable land management. However, this remains a challenge.

Image 61: General view of the Ayora valley including burnt areas in the front (Erik van den Elsen 2013)

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Annex

Annex 1: Climate models on heatwaves

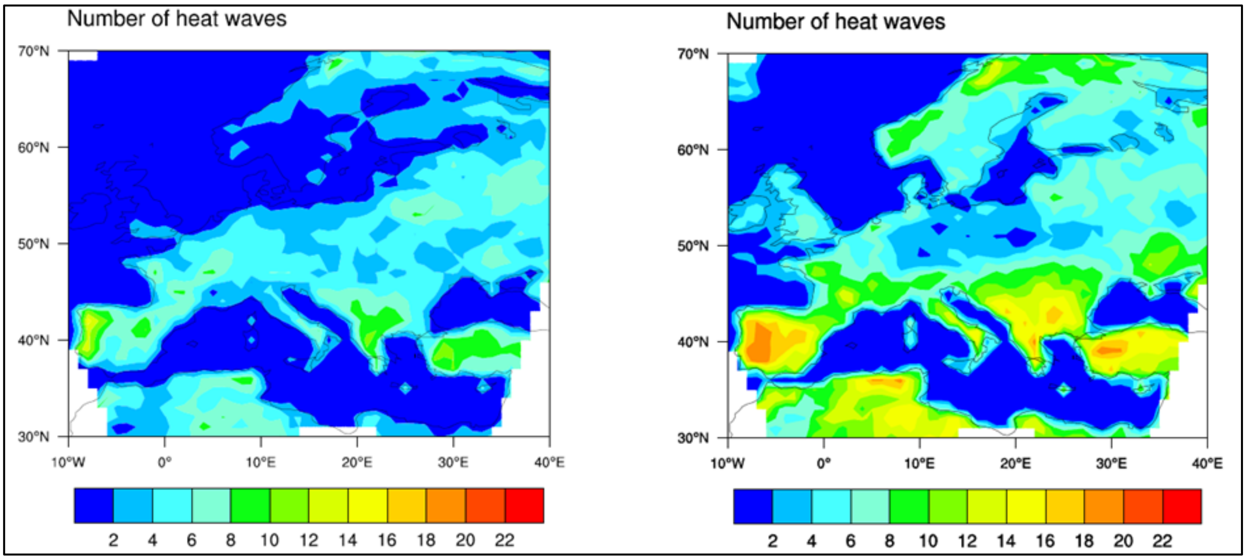


Figure 80: Comparison of the number of heat waves per time period for the years 2001-2010 (left) and 2041-2050 (right) KNMI model (Lauterburg 2012)

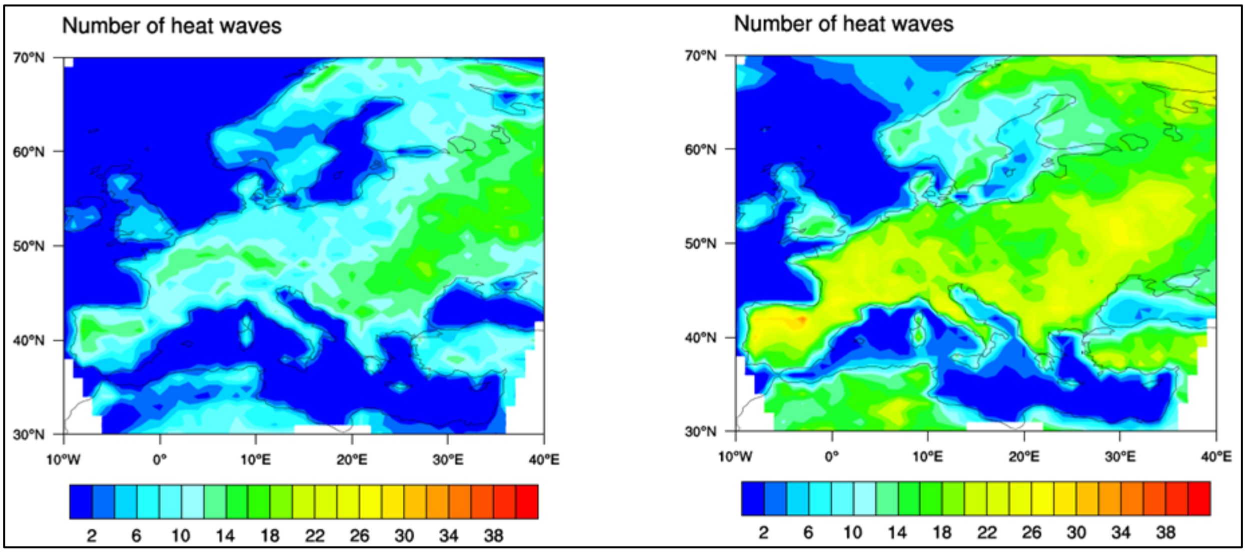


Figure 81: Comparison of the number of heat waves per time period for the years 2001-2010 (left) and 2041-2050 (right) ETHZ model (Lauterburg 2012)

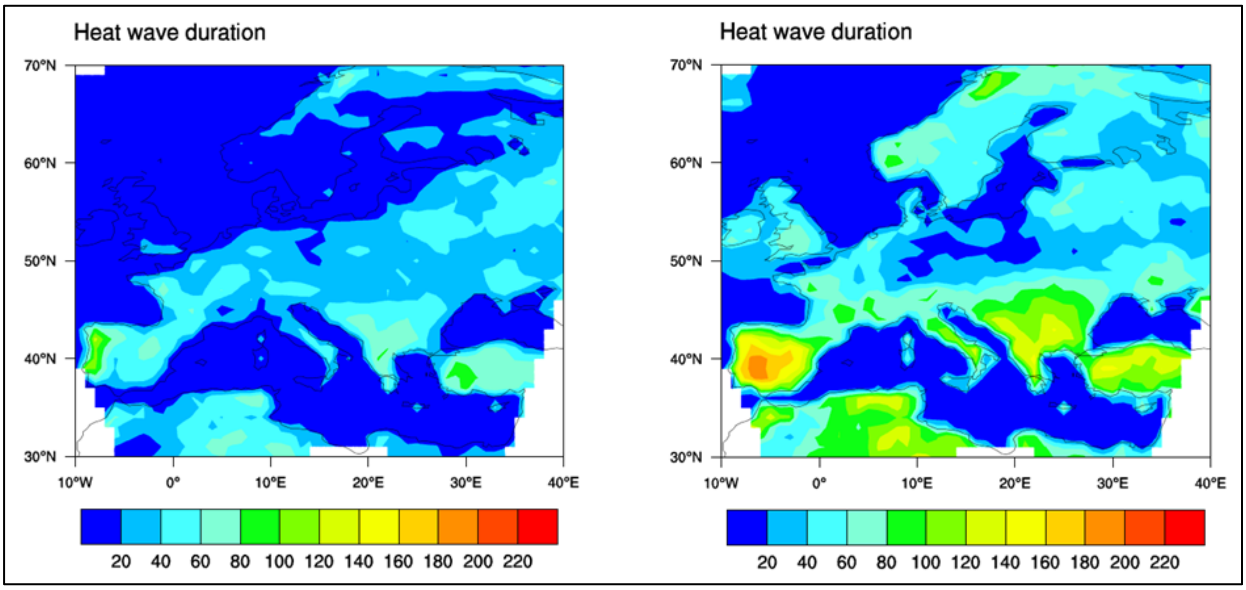


Figure 82: Comparison of the heat wave duration index per time period for the years 2001-2010 (left) and 2041-2050 (right) KNMI model (Lauterburg 2012)

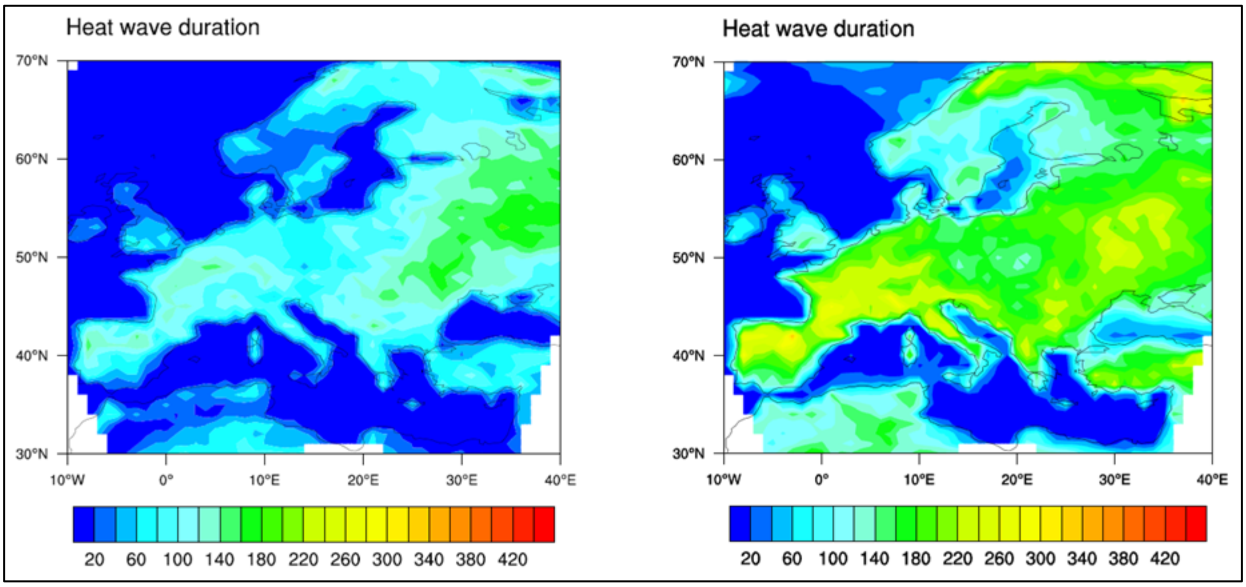


Figure 83: Comparison of the heat wave duration index per time period for the years 2001-2010 (left) and 2041-2050 (right) ETHZ model (Lauterburg 2012)

Annex 2: Data WOCAT mapping questionnaire

Step 2: Land Use System (LUS)

Mapping Unit ID	LUS	Sub Div 1	Sub Div 2	a) LUS area trend	b) LUS intensity trend
100	Water	unknown	unknown	0	0
200	Urban areas	unknown	unknown	0	0
300	Cropland	unknown	unknown	-2	-2
400	Shrubland	north exposed	burnt 0 times	1	-2
401	Shrubland	north exposed	burnt 1 time	1	-2
402	Shrubland	north exposed	burnt 2 times	2	-2
403	Shrubland	north exposed	burnt 3 times	1	-2
410	Shrubland	south exposed	burnt 0 times	1	-2
411	Shrubland	south exposed	burnt 1 time	1	-2
412	Shrubland	south exposed	burnt 2 times	2	-2
500	Forest	north exposed	burnt 0 times	-1	-1
501	Forest	north exposed	burnt 1 time	1	-1
502	Forest	north exposed	burnt 2 times	1	-1
510	Forest	south exposed	burnt 0 times	-1	-1
511	Forest	south exposed	burnt 1 time	1	-1
512	Forest	south exposed	burnt 2 times	1	-1

Step 3: Land degradation

Mapping Unit ID	a) Type			b) Extent	c) Degree	d) Rate	e) Direct causes	f) Indirect causes	g) Impact on ecosystem services
	i	ii	iii						
100	O			100	1	-99			0
200	O			100	1	-99			0
300	O			100	1	-99			0
400	Bs			40	2	2	f3; f6	p; t; h; l; e; g; o	E2+1; E4+1; S2+1; E11-2
401	Bs	Bq		20	1	2	f4	p; t; h; l; e; g; o	P1-1; E1-1; S2+1; E11-2
402	Bs	Bq	Bc	60	2	3	f4	p; t; h; l; e; g; o	P1-1; E1-1; E10-1; S1-2; S2+1; E11-3
403	Bs	Bq	Bc	30	2	2	f4	p; t; h; l; e; g; o	P1-1; E1-2; E2-1; E4-1; E5-1; E6-1; E10-1; S1-1; S2+1; E11+1
410	Bs			40	2	2	f3; f6	p; t; h; l; e; g; o	E2+1; E4+1; S2+1; E11-2
411	Bs	Bq		40	2	2	f4	p; t; h; l; e; g; o	P1-1; E1-1; S1-2; S2+1; E11-2
412	Bs	Bq	Bc	80	3	3	f4	p; t; h; l; r; e	P1-3; E1-3; E2-3; E4-3; E5-2; E6-2; E8-1; E10-3; S1-3; S2+1; E11+2
500	Bs			20	1	1	f3; f6	p; t; h; l; g; o	E1+1; E2+1; E4+2; E5+1; E6-1; E8-1; E10+1; S1-1; S2+1; E11-1
501	Bs	Bp		8	1	1	f4	p; h; g	S2+1; P1-1; E11-1
501	Bs	Bq		20	1	1	f4	p; t; h; l; e; g; o	P1-1; E4+1; E5+1; E6-1; E10+1; S1-1; S2+1; E11-2
502	O			100	1	-99			0
510	Bs			20	1	1	f3; f6	p; t; h; l; g; o	E1+1; E2+1; E4+2; E5+1; E6-1; E8-1; E10+1; S1-1; S2+1; E11-1
511	Bs	Bp		8	1	1	f4	p; h; g	P1-1; S2+1; E11-1
511	Bs	Bq		40	1	1	f4	p; t; h; l; e; g; o	P1-1; E4+1; E5+1; E6-1; E10+1; S1-1; S2+1; E11-2
512	O			100	1	-99			0

Step 4: Conservation measures

Mapping Unit ID	a) Name	b) Group	c) Mesasure	d) Purpose	e) % of area	f) Degradation addressed			g) Effectiveness	h) Effect. Trend	i) Impact on ESS	j) Period
						Deg 1	Deg 2	Deg 3				
100			O		100				1	-99	0	
200			O		100				1	-99	0	
300			O		100				1	-99	0	
400	Firebreaks	AP	V3	P	70	Bf	Bs		2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
401	Firebreaks	AP	V3	P	70	Bs	Bq	Bf	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
401	Afforestation	AP	V1	R	30	Bf	Wt	Bq	1	-1	P1+2, P3-1, E1+1, E2+1, E3+1, E4+2, E5+1, E6+1, E7+1, E8-1, E9+1, E10+2, S1+2, S4+1, S6+1, E11-1	
402	Afforestation	AP	V1	R	19	Bf	Wt	Bc	1	-1	P1+2, P3-1, E1+1, E2+1, E3+1, E4+2, E5+1, E6+1, E7+1, E8-1, E9+1, E10+2, S1+2, S4+1, S6+1, E11-1	
402	Firebreaks	AP	V3	P	70	Bc	Bf	Bs	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
403			O		100				1	-99	0	
410	Firebreaks	AP	V3	P	70	Bf	Bs		2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
411	Firebreaks	AP	V3	P	70	Bf	Bs	Bq	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
411	Afforestation	AP	V1	R	30	Bf	Wt	Bq	1	-1	P1+2, P3-1, E1+1, E2+1, E3+1, E4+2, E5+1, E6+1, E7+1, E8-1, E9+1, E10+2, S1+2, S4+1, S6+1, E11-1	
412	Firebreaks	AP	V3	P	70	Bc	Bf	Bs	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
412	Afforestation	AP	V1	R	19	Bf	Wt	Bc	1	-1	P1+2, P3-1, E1+1, E2+1, E3+1, E4+2, E5+1, E6+1, E7+1, E8-1, E9+1, E10+2, S1+2, S4+1, S6+1, E11-1	
500	Firebreaks	AP	V3	P	90	Bf	Bs		2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
501	Firebreaks	AP	V3	P	70	Bf	Bs	Bq	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
501	Selective forest clearings (thinning, pruning)	AP	V3	P	8	Bs	Bq	Bf	2	1	P1+2, E2+1, E3+1, E6+2, E8+1, E9+2, E10+1, S1+3, S2+1, S3+1, S4+2, S7+1, E11+2	
502			O		100				1	-99	0	
510	Firebreaks	AP	V3	P	90	Bf	Bs		2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	1998
511	Selective forest clearings (thinning, pruning)	AP	V3	P	8	Bs	Bq	Bf	2	1	P1+2, E2+1, E3+1, E6+2, E8+1, E9+2, E10+1, S1+3, S2+1, S3+1, S4+2, S7+1, E11+2	
511	Firebreaks	AP	V3	P	70	Bf	Bs	Bq	2	0	P1+1, E4-1, E6-2, E8+1, E10-1, S1-3, S2+2, S4+2, S7+1, E11+3	
512			O		100				1	-99	0	

Step 5: Recommendation

Mapping Unit ID	Expert recommendation	Remarks and additional information
300	P	Clearing of abandoned fields which are affected by shrub encroachment.
400	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
400	R	In many areas, the species composition has been changed through land use in the past. A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
401	R	In many areas, the species composition has been changed through land use in the past and through fires (interruption of natural succession). A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
401	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
402	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
402	R	In many areas, the species composition has been changed through land use in the past and through fires (interruption of natural succession). High fire recurrence alters the species composition due to the fact that many species could not reach their mature state before being affected by the fire and do therefore disappear (could not establish seed bank). A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
403	R	In many areas, the species composition has been changed through land use in the past and through fires (interruption of natural succession). High fire recurrence alters the species composition due to the fact that many species could not reach their mature state before being affected by the fire and do therefore disappear (could not establish seed bank). A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
403	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
410	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
410	R	In many areas, the species composition has been changed through land use in the past. A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
411	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
411	R	In many areas, the species composition has been changed through land use in the past and through fires (interruption of natural succession). A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
412	P	Prevention of fires through the application of firebreaks and selective clearings of shrubland (remove biomass to reduce the continuity and the amount of fuel).
412	R	In many areas, the species composition has been changed through land use in the past and through fires (interruption of natural succession). High fire recurrence alters the species composition due to the fact that many species could not reach their mature state before being affected by the fire and do therefore disappear (could not establish seed bank). A combination of selective clearing of fire-prone shrubs and planting of late successional, more fire-resilient species could help to increase the resilience of the ecosystem against fires.
500	P	Prevention of fires through the application of firebreaks and selective forest clearings (remove biomass from the understory especially to reduce the continuity and the amount of fuel, branch pruning of large trees to reduce the vertical continuity between forest layers).
501	P	Prevention of fires through the application of firebreaks and selective forest clearings (remove biomass from the understory especially to reduce the continuity and the amount of fuel, branch pruning of large trees to reduce the vertical continuity between forest layers).
510	P	Prevention of fires through the application of firebreaks and selective forest clearings (remove biomass from the understory especially to reduce the continuity and the amount of fuel, branch pruning of large trees to reduce the vertical continuity between forest layers).
511	P	Prevention of fires through the application of firebreaks and selective forest clearings (remove biomass from the understory especially to reduce the continuity and the amount of fuel, branch pruning of large trees to reduce the vertical continuity between forest layers).

Annex 3: Impacts of degradation and conservation on ESS

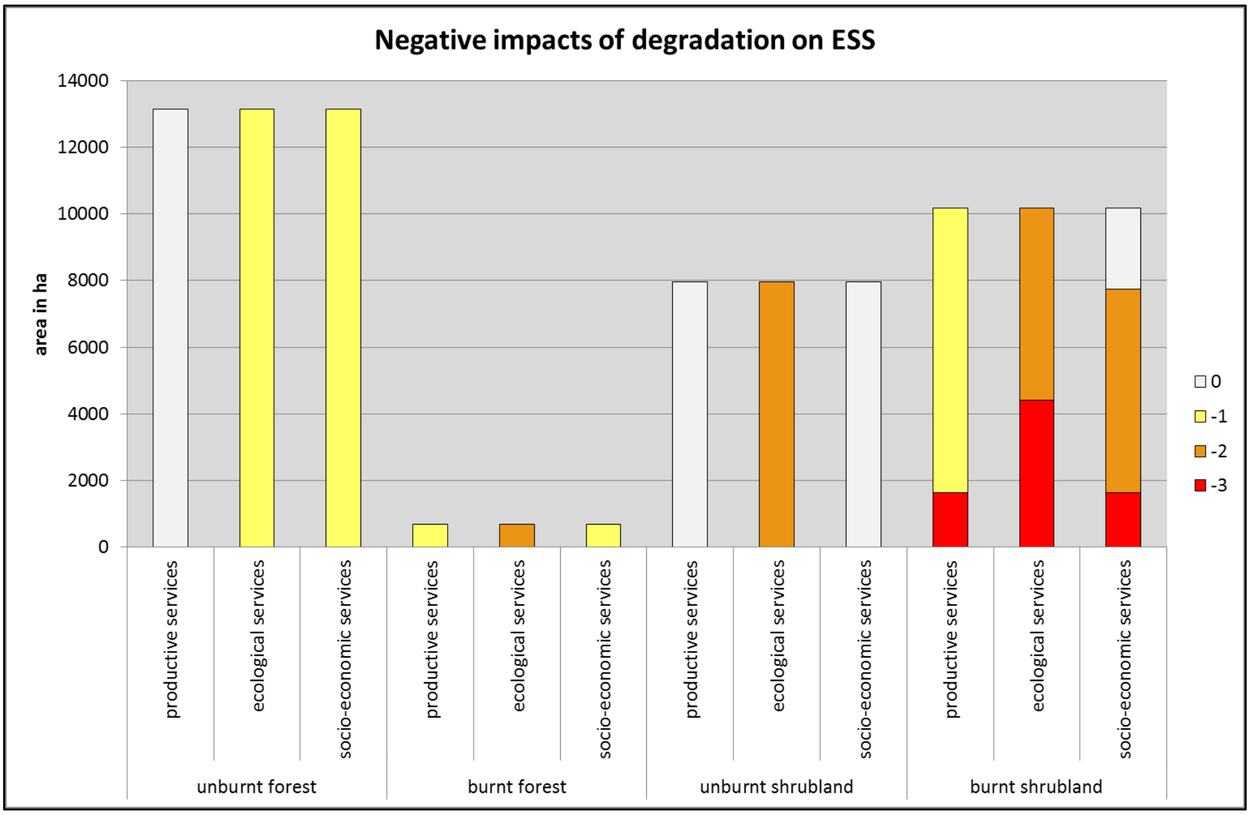


Figure 84: Negative impacts of degradation on ESS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

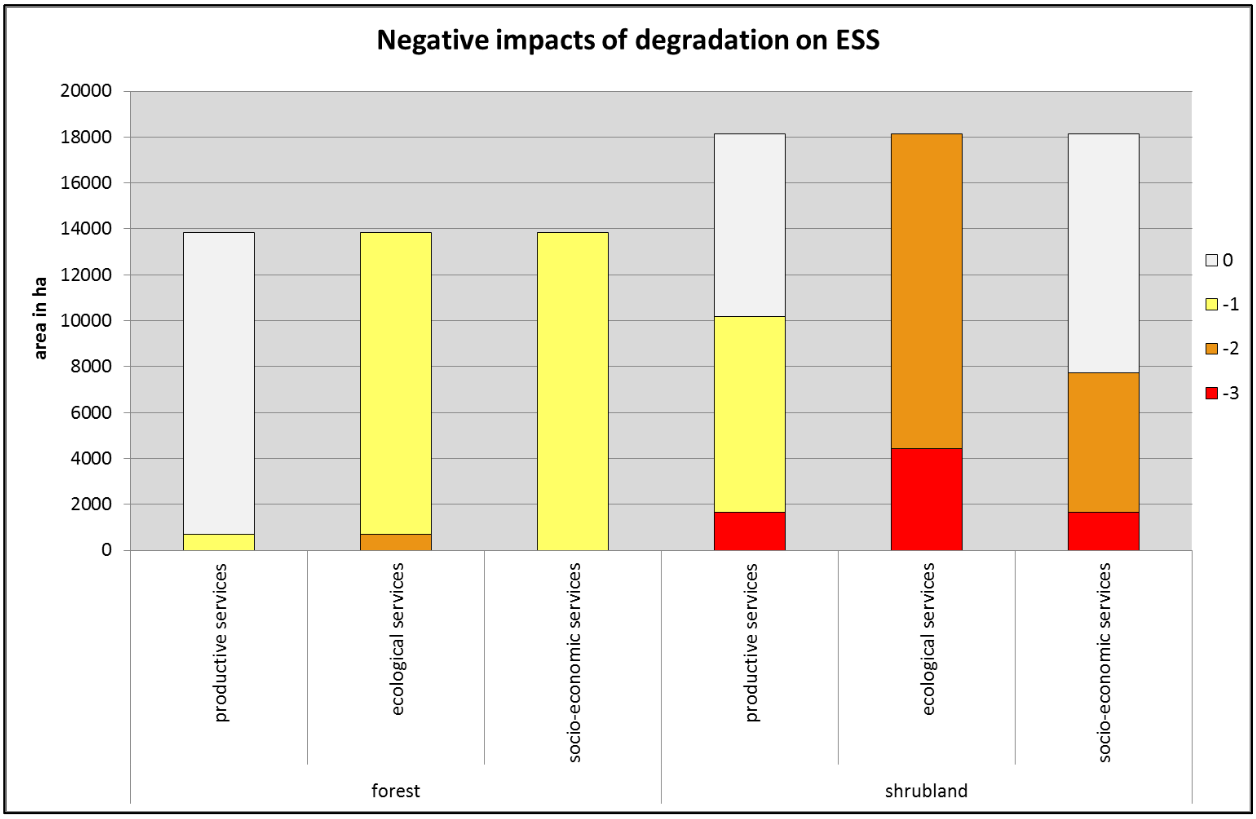


Figure 85: Negative impacts of degradation on ESS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

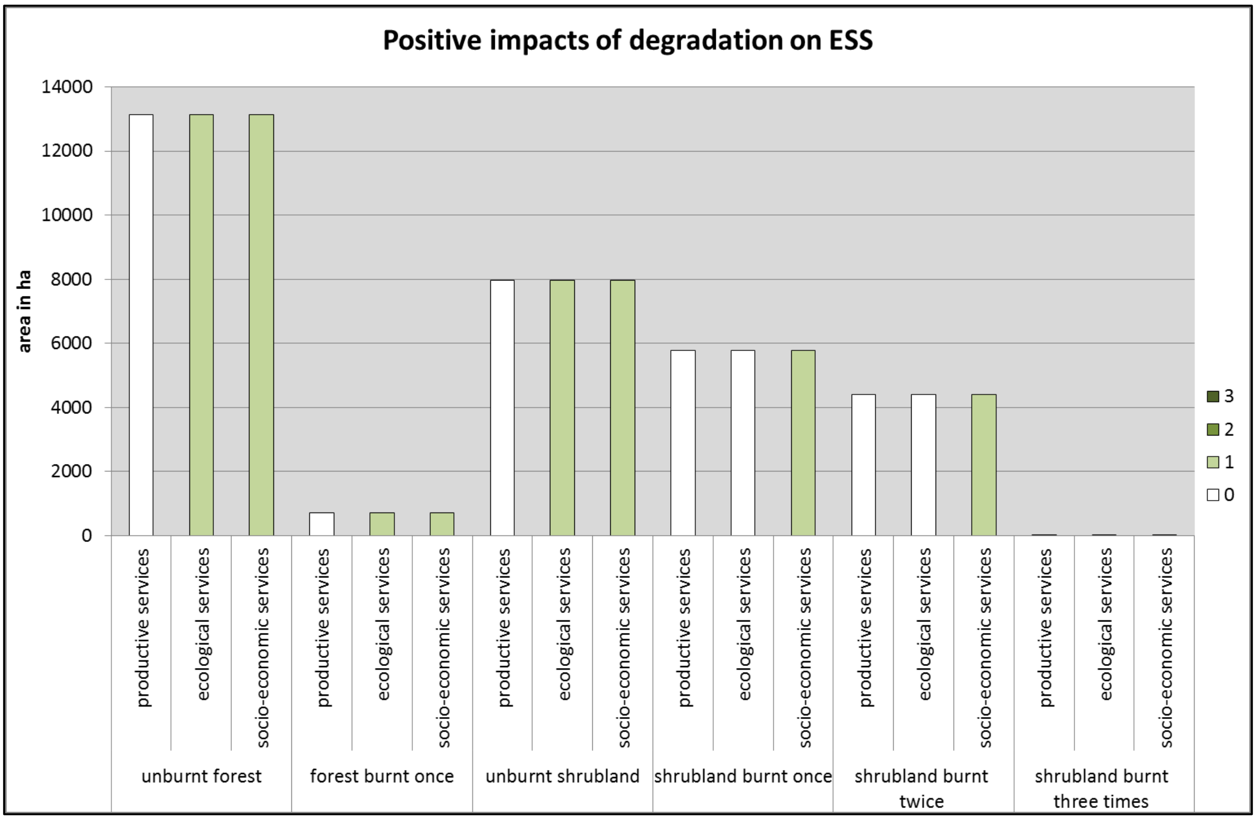


Figure 86: Positive impacts of degradation on ESS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

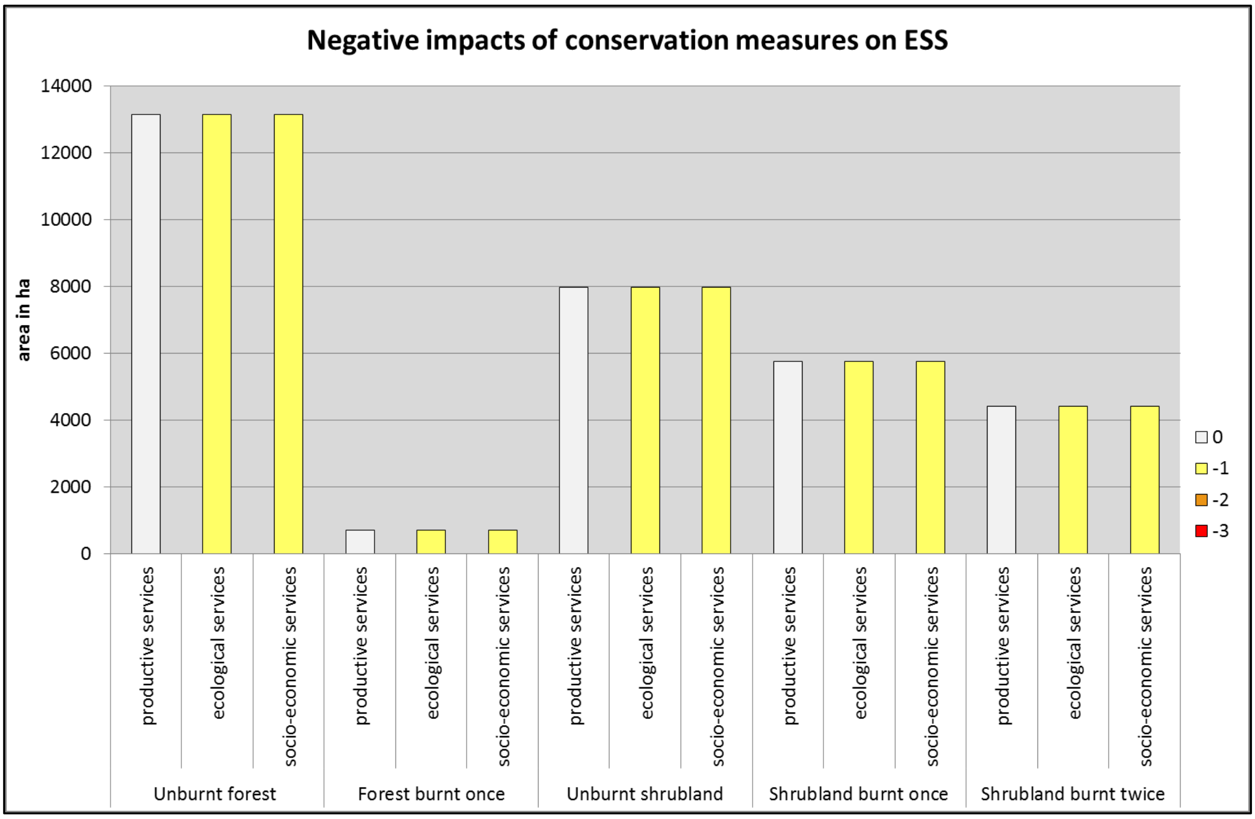


Figure 87: Negative impacts of conservation measures on ESS (Nina Lauterburg 2014, data source: WOCAT mapping questionnaire)

Annex 4: WOCAT Technology Documentations

left: Firebreaks are classified in first, second and third order, together forming a system isolating separate areas by wide strips. This parcelling aims in controlling the spread of large forest fires. (Photo: Nina Lauterburg)
right: Firebreaks are often located along existing roads to guarantee the access for fire-fighting vehicles and to keep the environmental impact limited. (Photo: Nina Lauterburg)

Cleared strip network for fire prevention (firebreaks)

Spain - Área cortafuegos

The basic principle of a firebreak network is to split continuous forest areas (where a lot of fuel is built up) into smaller patches separated by vegetation-free strips in order to prevent large forest fires.

In the forest law 3/1993 the declaration of special areas to “Zonas de Actuación Urgente (ZAU)” (zone of urgent actions) through the regional government of Valencia is defined. Objectives are the protection against natural hazards and the promotion of forest restoration within this area. Ayora was declared to a ZAU in 1997 due to its high risk of fires. In the “Plan de Selvicultura Preventiva de Incendios en los Sistemas Forestales de la Comunidad Valenciana” which became operative in 1996 and whose main objective is the reduction of the fire risk, the ZAU is practically addressed for the first time in the establishment of firebreaks (áreas cortafuegos). Based on this plan, the firebreaks were established within a pilot project “Proyecto Piloto de Selvicultura Preventiva” between 1998 and 2002, carried out by the company VAERSA (public company of the Generalitat Valenciana).

A firebreak is a strategically located strip on which the vegetation cover has been partially or totally removed down to mineral soil with the aim of controlling the spread of large forest fires. The main purposes are 1) to interrupt the continuity of hazardous fuels across a landscape to decrease the area affected by fires, 2) to provide areas where fire fighters are protected and can work more efficiently, 3) to slow down a fire, to reduce the fire intensity and caused damages, and 4) to provide strips where fuel management is facilitated. The total surface protected by the firebreaks is 33’851 ha while the management measures are executed on 1944,81 ha. This technology is also applied in other countries, e.g. Portugal, South Carolina or South Africa.

The establishment and maintenance are labour-intensive and expensive. Firebreaks can range between a protected area of 2000-6000 ha (first order), 500-1500 ha (second order), and 100-300 ha (third order), together forming a system isolating separate areas by wide strips. This parcelling aims in limiting the burnt area to a maximum of 6000 ha. Each firebreak consists of a bare vegetation-free strip (banda decapado). The width of the bare area ranges between 6m (first order), 3m (second order) and 1.5m (third order). Existing vegetation-free areas (e.g. roads) are used to establish firebreaks to have less visual impact. If there is no road, trees and shrubs have to be cleared and chipped entirely using chainsaws and special tractors. On each side of the bare area there is a totally cleared strip (banda de desbroce total). The width depends on the climatic zone, the order and the hazard of fuel, therefore ranging between 28m (first order), 11m (second order) and 6m (third order). Almost all the existing vegetation is cleared, only some isolated mature trees are not cut if they do not contribute to the propagation of a fire. On both sides of these strips there are auxiliary strips (banda auxiliar) where selective clearing is applied until reaching a desired density. Sick trees are cleared with priority. Species of high ecologic value and low flammability level are not cleared, such

Location: Spain, Valencia
Region: Region of Ayora (including the municipalities Requena, Cofrentes, Jalance, Jarafuel, Zarra, Ayora)
Technology area: 338.5 km^2
Conservation measure: vegetative
Stage of intervention: prevention of land degradation
Origin: Developed externally / introduced through project, 10-50 years ago
Land use type:
Forests / woodlands: Natural
Forests / woodlands: Plantations, afforestations
Climate: subhumid, temperate
WOCAT database reference: T_SPA009en
Related approach: Plan of preventive silviculture (PSP): implementation of firebreak network within a forest intervention area (ZAU) (A_SPA002en)
Compiled by: Nina Lauterburg, Centre for Development and Environment (CDE)
Date: 2013-05-06
Contact person: Jaime Baeza, Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), Parque Tecnológico Paterna. C/ Charles Darwin 14, 46980 Valencia, Spain. E-Mail: jaime.baeza@ua.es

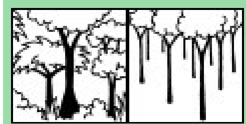
as Juniperus phoenicea, Juniperus oxycedrus and Quercus ilex ssp. rotundifolia. The width of these elements can vary according to the prevalent conditions. A part of the wood generated by the clearings is used as fuelwood, the other part is chipped and distributed on the soil as mulch. Firebreaks are often located on mountain ridges and created with 45° to the dominant wind direction (west) to facilitate fire extinction. The maintenance of firebreaks is extremely important. Without clearing, fire-prone species will encroach which decreases the effectiveness of the firebreak. The maintenance is realized depending on the vegetation, usually in firebreaks of first order the maintenance is done every 2 years ("decapado" and "desbroce total") or every 4 years ("banda auxiliar") while firebreaks of second and third order are cleared every 4 years. In the here described project the maintenance was carried out in three phases (2001-2004, 2004-2008 and 2008-2012).
The region of Ayora is mountainous with a dry subhumid climate (~380 mm annual rainfall). The risk of fire incidence is at its highest from June to September when there are adverse conditions like drought, high temperatures and strong winds (mainly the winds coming from central Spain, called "poniente"). The population density is very low and there are only few job opportunities (e.g. marginal agriculture, grazing, hunting, beekeeping, artisanry, wind mill parc). Most of the inhabitants work in the nuclear power plant. Forest management could be a source for jobs.

Classification

Land use problems:

- In Ayora, the prevalent dense shrublands (dominated by seeder species), which resulted from past agricultural land use (changes of the vegetation composition, e.g. removal of key species), land abandonment/rural depopulation and fire occurrence, contain a high fire risk because of both the high fuel loads and their continuity. Also dense forests (either afforestations or natural regeneration) show a high risk for fires. Through the modifications of the vegetation composition in the past (removal of more fire resistant resprouter species (mature forest), whereas fire-prone seeder species are now spreading), the resilience of the ecosystem to fires has decreased. Today a higher fire recurrence can be observed which could still be worsen by future climate change impacts, undermining more and more the ecosystem's capacity to buffer such shocks. Before the implementation of firebreaks, it was almost impossible to stop a fire and it was much more dangerous for fire fighters. There was also no access for fire-fighting vehicles. (expert's point of view)

Land use

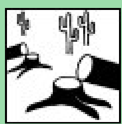


Natural
Plantations, afforestations
selective felling of (semi-) natural forests, plantation forestry

Climate

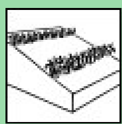
subhumid

Degradation



Biological degradation: detrimental effects of fires

Conservation measure



vegetative: Clearing of vegetation (eg fire breaks/reduced fuel)

Stage of intervention

■ Prevention
□ Mitigation / Reduction
□ Rehabilitation

Origin

▒ Land users initiative: traditional (>50 years ago)
□ Experiments / Research
■ Externally introduced: 10-50 years ago

Level of technical knowledge

■ Agricultural advisor
□ Land user
■ Engineer

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Indirect causes: population pressure, poverty / wealth, labour availability

Main technical functions:
___- control of fires

Secondary technical functions:
___- reduction of dry material (fuel for wildfires)

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000 mm
- 3000-4000 mm
- 2000-3000 mm
- 1500-2000 mm
- 1000-1500 mm
- 750-1000 mm
- 500-750 mm
- 250-500 mm
- < 250 mm

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Soil texture: fine / heavy (clay)
Soil fertility: medium
Topsoil organic matter: low (<1%)
Soil drainage/infiltration: medium

Soil water storage capacity: high
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), floods
Sensitive to climatic extremes: seasonal rainfall increase, wind storms / dust storms, droughts / dry spells
If sensitive, what modifications were made / are possible: The technology was not modified. The firebreaks are quite resistant against climate change or weather extremes. Only if there will be more rainfall the vegetation might grow faster and the maintenance costs could increase. Furthermore, if there are heavy windstorms the effectiveness of firebreaks is undermined because strong winds result in faster spreading fires.

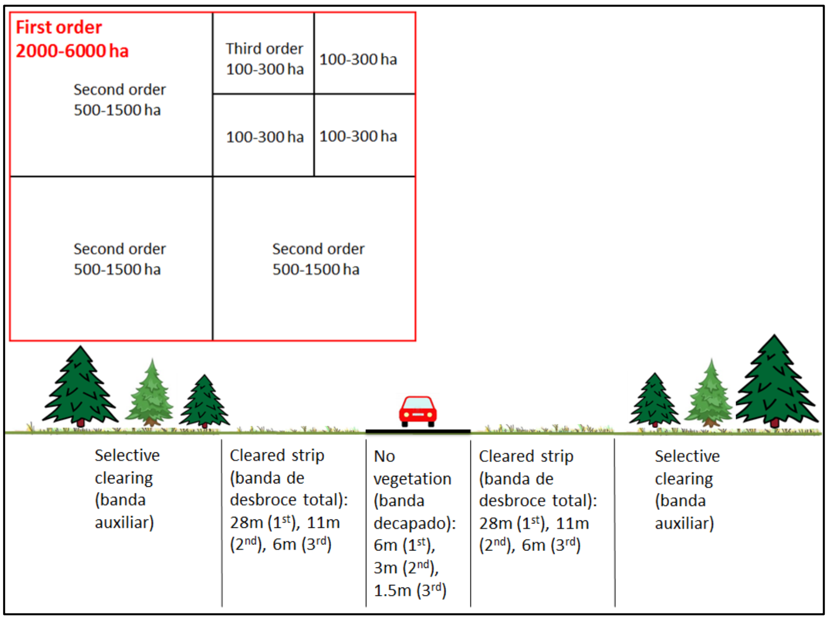
Human Environment

Forests / woodlands per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: employee (company, government), common / average land users, mainly men
Population density: < 10 persons/km2
Annual population growth: negative
Land ownership: state, individual, titled
Land use rights: individual, open access but organised (e.g. wood, hunting)
(There is some public land, controlled by the state. But there is also some private land. The access to the public land is open but organized. Permission is needed from the government to cut trees, to build a house or to hunt. There are some private hunting areas for which the hunting association has to pay a fee.)

Market orientation: mixed (subsistence and commercial)
Purpose of forest / woodland use: timber, other forest products / uses (honey, medical, etc.), recreation / tourism



Technical drawing

Firebreaks can range between a protected area of 2000-6000 ha (first order), 500-1500 ha (second order), and 100-300 ha (third order), together forming a system isolating separate areas by wide strips. This parcelling aims in limiting the burnt area to a maximum of 6000 ha. Each firebreak consists of a bare strip (banda decapado) ranging between 6m (first order), 3m (second order) and 1.5m (third order). On both sides of the bare area there is a totally cleared strip (banda de desbroce total) whose width ranges between 28m (first order), 11m (second order) and 6m (third order). On both sides of these strips there are auxiliary strips (banda auxiliar) where selective clearing is applied. The width of these elements can vary according to the prevalent conditions. (Nina Lauterburg)

Implementation activities, inputs and costs

Establishment activities

- Project planning and design of firebreak system
- Adaption of the agricultural tractors with forest management machinery (wheels, protection of the machine against stones, clearing machinery with chains)
- Cutting and chipping (in-situ) of trees and shrubs (execution of firebreak network)
- Transport of wood (fuel wood)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	1095.00	0%
Equipment		
- machine use	675.00	0%
TOTAL	**1770.00**	**0.00%**

Maintenance/recurrent activities

- Clearing of firebreaks of first order (every 2 years)
- Clearing of firebreaks of second and third order (every 4 years)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	557.00	0%
TOTAL	**557.00**	**0.00%**

Remarks:
The costs of the establishment of firebreaks can be affected by numerous factors, such as slope (if the slope is steep, the work is much more difficult and takes more time, because machines cannot be used on steep slopes), vegetation density (it takes more time to clear a dense area), stone content of the soil (if there are many stones the work is much more difficult for the machines and more dangerous for the workers), availability of a road (where a firebreak can be established, costs can be saved). Important to note is that maintenance costs could increase with an increase in rainfall because the vegetation will grow faster (otherwise firebreaks are quite resistant against climate change or weather extremes). Furthermore, modifying a normal tractor for forest management can be extremely expensive.
The total costs of the firebreaks (establishment and maintenance) were calculated for the application of the technology on one hectare, based on the indications given in the official project documents of the regional government (Generalitat Valenciana) and information from different stakeholders (e.g. forest agent, university staff, employee of VAERSA). The whole project costs were around 3 Mio Euro for the establishment and around 1.5 Mio Euro for the maintenance phase. The maintenance costs refer to the third maintenance phase taking place from 2008 to 2012. The costs of the execution of the project were 1312 Euro/ha (1770 Dollar) and the costs of the maintenance were 82.03 Euro/ha (110 Dollar, after 2 years) and 331.37 Euro/ha (446 Dollar, after 4 years). The currency rate (Euro-Dollar) was calculated on November 16th, 2013.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- ++ increased wood production
- \+ increased fodder production
- \+ increased fodder quality
- \+ increased animal production

Production and socio-economic disadvantages

- ++ high establishment and maintenance costs
- \+ loss of land
- \+ job uncertainty

Socio-cultural benefits

- ++ improved conservation / erosion knowledge
- ++ improved situation of disadvantaged groups
- ++ Increase of the security for fire fighters
- \+ conflict mitigation
- \+ improved food security / self sufficiency

Socio-cultural disadvantages

- \+ loss of recreational opportunities
- \+ socio cultural conflicts
- \+ increased health problems

Ecological benefits

- ++ reduced hazard towards adverse events
- ++ reduced fire risk
- \+ reduced emission of carbon and greenhouse gases

Ecological disadvantages

- \+ increased surface water runoff
- \+ decreased soil cover
- \+ decreased soil organic matter
- \+ increased soil erosion locally
- \+ increased habitat fragmentation

Off-site benefits

- ++ reduced risk of wildfires
- \+ reduced downstream flooding
- \+ reduced downstream siltation
- \+ reduced damage on neighbours fields
- \+ reduced damage on public / private infrastructure

Off-site disadvantages

Contribution to human well-being / livelihoods

\+ Through the establishment and the maintenance of firebreaks it is easier to control fires and protect people. Furthermore it created jobs for the unemployed. But it seems that in general forest management is not something people want to do, they work in this sector only if there are no other job opportunities. Forest management means a hard job and this kind of work is not well-respected in society

Benefits /costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very positive	very positive
Maintenance / recurrent	very positive	very positive

Both the short-term and the long-term benefits are very positive assuming that maintenance is done. Together with the creation of jobs, directly after establishing the firebreaks there is firewood and timber available and a reduced risk of wildfires. But it should also be considered that the establishment costs are high. If maintenance is not done the long-term returns will be very negative because an increase in the risk of fire will occur again (without management, there will also be no firewood, no timber and no jobs). The maintenance costs increase the longer you wait because the vegetation will grow again densely.

Acceptance / adoption:

There is little trend towards (growing) spontaneous adoption of the technology. The existing firebreak network system was established within the pilot project. Other firebreaks were created afterwards by the regional government of Valencia or already existed before. Maybe the network is enlarged in some areas from time to time. This technology is also applied in other countries/regions, amongst others in Portugal, South Carolina and South Africa.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
There is a reduction of fuel load within the firebreaks and therefore they contribute to fire prevention. →The maintenance of firebreaks is crucial	Firebreaks are a strong disturbance of the natural environment. People often criticise the negative aesthetic/visual impact which results in a decline of the recreational value. →This problem is difficult to overcome, but the technology helps to prevent an even bigger disturbance of the forest caused by a fire. Even though criticising the firebreaks due to its visual impact people know about the importance of this measure and are also concerned with the devastating effects of a forest fire. There is always the question of what is better: to establish firebreaks and disturb nature, or to experience a large fire.
A firebreak does not stop a fire but facilitates the access for fire fighters (and vehicles) and guarantees a higher security for people, thus increasing the possibility to control/slow down a fire. By arranging the territory in different parcels (firebreaks of first, second and third order) the spread of large forest fires is less probable → The maintenance of firebreaks is crucial. Furthermore, there must be a good coordination and organisation within the fire fighter staff in case of an emergency.	
There are both social and economic benefits for local people. The establishment and the maintenance of firebreaks provide jobs for rural people which allows them to increase their livelihood conditions. A part of the extracted wood is used for biomass, fertilizers, pellets, or firewood. Furthermore there would be improved conditions for grazing. → More investment in forest management is required to sustain these benefits. Furthermore, many local stakeholders mentioned the importance of reactivating traditional activities (such as grazing, agriculture, wood gathering) and that the villagers should get economic compensation to maintain the forest in a good state.	The establishment and the maintenance activities are expensive and labour-intensive. Without management the firebreaks are not effective anymore. It would be necessary to extract biomass from the forest to decrease the continuity of the trees and shrubs. In case of a lack of management the risk of fires increases. →Management is crucial. It should be noted that prevention measures are often less expensive than rehabilitation activities after a fire. More investment in forest management and fire prevention is required. Managing the forest would not only decrease the risk of fire but also generate benefits (e.g. wood, biomass). Furthermore, jobs would be generated which is especially important during the current economy crisis in Spain. There are some good practices found in other regions to cover the maintenance costs: In Jarafuel (next to Ayora) a part of the rent paid by the wind mill company to the state is reinvested in forest management. Or in Andalucia, the government launched a project to invest subventions in maintenance of firebreaks through grazing and this was very successful. This could be a good alternative to expensive management measures. It was also mentioned by many stakeholders that traditional activities (such as grazing, agriculture, wood gathering) should be reactivated and that the villagers should get economic compensation to maintain the forest in a good state
Vegetation removal produces fresh vegetation growth, therefore more diverse and nutritious fodder is available for animals (game and livestock) in the cleared areas. Game/wildlife and livestock are better because there is an increase in fodder quantity and quality. →The maintenance of firebreaks is crucial.	
Due to the high stone content of the soil, and due to mulching through in-situ brush-chipping of the cleared material, the firebreaks are not that prone to erosion as in other regions/countries (e.g. Portugal). →	
Improvement and maintenance of the forest paths and streets to establish firebreaks and to guarantee access for fire fighter vehicles but also for recreational activities (rural tourism). →Establishment and maintenance of the firebreaks can improve the forest track network.	Firebreaks are not that efficient because after clearing, the first plants which grow are Ulex parviflorus and Cistus albidus which are fire-prone species. Furthermore, if you cut them each 4 or 5 years there will only be grassland which is not natural in Mediterranean region. A fire could be caused more easily due to the high amount of thin and dead material. →CEAM suggests to plant more fire-resistant species (late successional stages) within some spots in the firebreaks to increase the resilience of the ecosystem. Green living plants have a higher humidity content which slows down a fire (oxygen is consumed). The issue is not to cover the whole firebreaks with plants but to establish some green spots. By planting late-successional species densely you don't allow seeders to grow. This measure could also decrease management costs. People keep in their minds the idea of having to clear all the vegetation in order to not have fires or to stop them, but it is not really the most sustainable one. The idea of green firebreaks is already common in some other countries but you need to ensure water availability for irrigation.
Fewer fires result in a decrease of the destroyed area, less money will have to be invested in restoration or fire extinction. Furthermore, farmers, hunters and honey producers will experience fewer losses. →The maintenance of firebreaks is crucial.	
In Jarafuel where most of the land is public retired people receive the firewood gained by forest clearings for free. They can use the wood for cooking and heating and save a lot of money. →People from the region (outside of Jarafuel) like this idea that villagers benefit from what is removed from the forest. More mechanisms like this should be developed so that people recognize that they also benefit from forest management, which in turn would ensure a sustainable forest management.	
There are also off-site benefits. Fewer fires will result in a reduction of downstream flooding, downstream siltation and damage on neighbours' fields. When fire removes less vegetation the soil is less vulnerable to erosion → The maintenance of firebreaks is crucial.	In some areas, the implementation of firebreaks can occupy productive land which means a loss of land →The main objective of this technology is to provide protection from forest fires instead of creating productive land
	The work is dangerous and there is a high risk to harm

oneself when clearing and chipping the vegetation. It is also a physical stress due to the exhausting work →

When there is a strong and dry wind from the inland (poniente) the smaller firebreaks are useless because the fire just passes over. It should also be noted that without human intervention the firebreaks do not stop a fire → Establish big firebreaks and ensure maintenance.


Afforestation with Pinus Halepensis after the fire of 1979 (La Molinera)

Spain - Repoblación "La Molinera" con Pino Halepensis después del incendio del año 1979 (Spanish)

Post-fire afforestation with Pinus Halepensis to reduce soil erosion and to enhance forest growth.

left: The Pinus Halepensis seedlings were planted linearly which is still visible from the distance. (Photo: Nina Lauterburg)
right: The success of this Pinus Halepensis afforestation is not only proved by the occurence of healthy old pines, but also by the growth of young pines and resprouter species such as Quercus which have not been planted. (Photo: Nina Lauterburg)

As a consequence of the devastating fire of the year 1979 which destroyed 33'000 ha of forest, strong erosion processes occurred on the bare soil and hindered the vegetation to regrow. Furthermore, this region was already abandoned (rural exodus) and missing management practices increased the problem of erosion. Therefore the government mandated to afforest the burnt areas in 1985.
The main purpose of the afforestation was to reduce the soil erosion (which was severe at that time) by planting trees, which increases soil stability and enables forest growth again. But the state also wanted to ensure wood extraction in the future. Furthermore, the visual impact was an important driver for afforesting this area.
The afforestation was executed in the winter of 1985 (November-February/March) by the regional forest services (Conselleria de agricultura). Forest engineers, who worked for the state and planned the project, collaborated with forest agents whereas the involved forest agents contracted local villagers to help afforesting these areas. The forest agent acted as a link between engineer and forest brigade and controlled if the brigade executed what the engineer proposed. He also provided assistance to the workers. The forest brigade was paid by day-if it was raining, people did not work and did not get any salary. Nobody could provide direct information on the afforestation process in 1985 but there are not many differences of how they did it in the past and how it works today. The planting holes (60cm x 60cm x 60cm) were created with a machine (Caterpillar) using a "spoon" to open a hole and cover it again. This process loosens the soil (only possible in soils which are free from big stones). It should be noted that they did not use a ripper, they knew that the soil is destroyed using this technique. The seedlings were planted manually by the forest workers and arranged linearly because this facilitated the handling of the machines. Since the soil had a low stone content, it was suitable for the establishment of a forest. The afforested area covered around 100 ha (not continuously). Today, the costs of an afforestation are around 1500 Euro per ha, but in the past it was less expensive. They only planted Pinus Halepensis. Today, a seedling of this tree species costs between 20 and 60 Cents. If the regional forest services have their own nurseries, they do not need to spend money to buy seedlings. The success of an afforestation depends on numerous factors such as aspect and humidity (better on north-facing slopes), soil amount/fertility (better conditions on former cultivated fields), origin of the seedlings (adapted to the local climatic conditions), variability/uncertainty of the weather conditions (e.g. droughts, freezing). Usually a plantation is done in October/November and therefore especially the first summer determines the success. If it is too dry the plant will not grow (roots are too short to reach the humidity deeper in the ground). Further, the availability of trained people and the selection of appropriate machines are crucial. The documented afforestation is one of a few examples of afforestation trials which

Location: Spain, Valencia
Region: Ayora, La Molinera
Technology area: 1 km^2
Conservation measure: vegetative
Stage of intervention: rehabilitation / reclamation of denuded land
Origin: Developed externally / introduced through project, 10-50 years ago
Land use type:
Forests / woodlands: Natural
Forests / woodlands: Plantations, afforestations
Land use:
Other: Other: wastelands, deserts, glaciers, swamps, recreation areas, etc (before), Forests / woodlandsrests / woodlands: Plantations, afforestations (after)
Climate: subhumid, temperate
WOCAT database reference: T_SPA012en
Related approach:
Compiled by: Nina Lauterburg, Centre for Development and Environment (CDE)
Date: 2013-06-01
Contact person: Vicente Colomer, Forest Agent Generalitat Valenciana (Conselleria de infraestructura, territorio y medio ambiente). Phone: +34 669 819 522 E-mail: colomer.vju@gmail.com

succeeded. Today there is a forest where young pines are growing naturally ("children" of the planted ones), but also resprouter species (e.g. Quercus) can be found, which regenerated without having been planted and apparently were dispersed by birds. But there are also some problems related to this afforestation. The forest agent explained that there is a high pest risk since monoplantations are less resilient to diseases (sick or dead plants in turn increase the fire risk). Another problem is that the trees were planted too densely (800-1000 plants per ha with a spacing of 5-10m) which requires recurrent management of the forest. Knowing about this problem, around the year 2003 they managed the area doing a selective clearing to reduce both the continuity and the competition between the species and thus also reduced the fire risk (“ayuda regeneración”). But the forest has become extremely dense again, thus increasing the risk of fires. There is a need to manage this area again and to extract biomass (selective clearing), but unfortunately no management project is planned for the near future.
The region of Ayora is mountainous with a dry subhumid climate (~380 mm annual rainfall). The risk of fire incidence is at its highest from June to September when there are adverse conditions like drought, high temperatures and strong winds (mainly the winds coming from central Spain, called “poniente”). The population density is very low and there are only few job opportunities (e.g. marginal agriculture, grazing, hunting, beekeeping). The plantation provided jobs for rural people. Also today forest management could be a source for jobs.

Classification

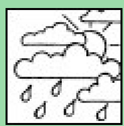
Land use problems:

- The past land use resulted in a change of the vegetation composition (e.g. through removal of resprouter species). Due to rural exodus and land abandonment, the natural succession took place and fire-prone early-successional species colonized the abandoned fields. The vegetation grew without any control which seems to have caused the devastating fire of the year 1979 which destroyed 33’000 ha of forest. As a consequence of this fire, strong erosion processes occurred on the bare soil and hindered the vegetation to regrow. Furthermore, people which still lived there lost their properties after the fire and moved away as well. A consequence of the depopulation was a lack of management practices which increased the problem of post-fire erosion. (expert's point of view)

Land use

Natural
Plantations, afforestations
Other: Other: wastelands, deserts, glaciers, swamps, recreation areas, etc (before)
Forests / woodlandsrests / woodlands: Plantations, afforestations (after)
plantation forestry

Climate

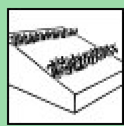


subhumid

Degradation

Soil erosion by water: loss of topsoil / surface erosion, Biological degradation: detrimental effects of fires

Conservation measure



vegetative: Tree and shrub cover

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land users initiative
Experiments / Research
Externally introduced: 10-50 years ago

Level of technical knowledge

Agricultural advisor
Land user
Engineer

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Indirect causes: population pressure, land tenure, labour availability, inputs and infrastructure

Main technical functions:
____- control of raindrop splash
____- control of dispersed runoff: retain / trap
____- control of dispersed runoff: impede / retard
____- control of concentrated runoff: retain / trap
____- control of concentrated runoff: impede / retard

Secondary technical functions:
____- increase of surface roughness
____- increase in organic matter
____- increase in nutrient availability (supply, recycling,…)
____- increase of infiltration
____- promotion of vegetation species and varieties (quality,

____- improvement of ground cover
____- stabilisation of soil (eg by tree roots against land slides)
____- sediment retention / trapping, sediment harvesting
____- increase of biomass (quantity)

eg palatable fodder)

Environment

Natural Environment

Average annual rainfall (mm)

- [ ] > 4000 mm
- [ ] 3000-4000 mm
- [ ] 2000-3000 mm
- [ ] 1500-2000 mm
- [ ] 1000-1500 mm
- [ ] 750-1000 mm
- [ ] 500-750 mm
- [x] 250-500 mm
- [ ] < 250 mm

Altitude (m a.s.l.)

- [ ] > 4000
- [ ] 3000-4000
- [ ] 2500-3000
- [ ] 2000-2500
- [ ] 1500-2000
- [ ] 1000-1500
- [x] 500-1000
- [ ] 100-500
- [ ] <100

Landform

- [ ] plateau / plains
- [ ] ridges
- [x] mountain slopes
- [ ] hill slopes
- [ ] footslopes
- [ ] valley floors

Slope (%)

- [ ] flat
- [ ] gentle
- [ ] moderate
- [ ] rolling
- [x] hilly
- [ ] steep
- [ ] very steep

Soil depth (cm)

- [x] 0-20
- [ ] 20-50
- [ ] 50-80
- [ ] 80-120
- [ ] >120

Soil texture: fine / heavy (clay)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m, > 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall increase, heavy rainfall events (intensities and amount)
Sensitive to climatic extremes: seasonal rainfall decrease, droughts / dry spells, decreasing length of growing period, fires, temperature decrease, hail/snow
If sensitive, what modifications were made / are possible: The technology was not modified but it is important to add some notes to the above stated reactions to climatic extremes. If the temperature is decreasing to -15°C the pines are sensitive because they freeze. But they are tolerant against temperature increase always when there is water available (Pinus Hal. is more tolerant to temperature increase than Pinus Pinaster). Afforestations are more sensitive to droughts than natural forests because the afforested trees are not used to these hard conditions. If the pines are mature, they are more tolerant than young pines because their roots are longer and reach deeper into the ground. If there is a drought when pines are still young it can increase the risk of a fire. The pines are also sensitive to hail and snow.

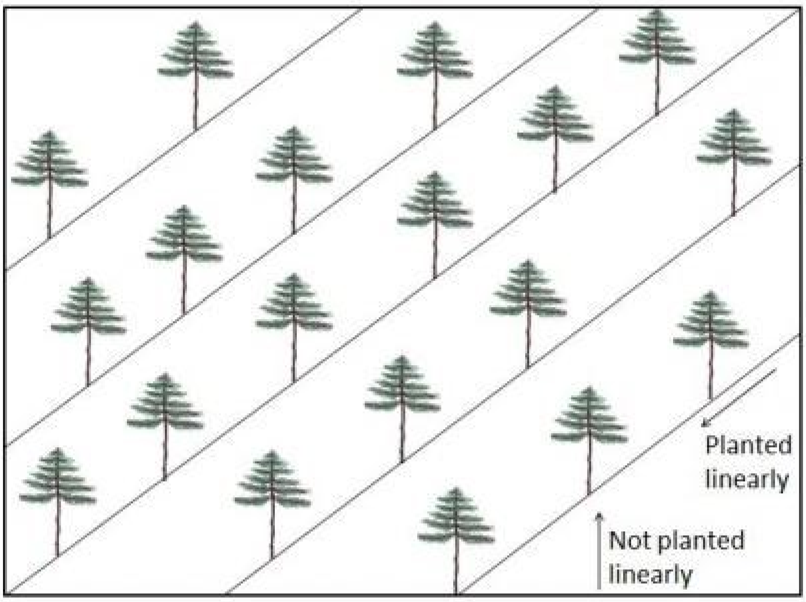
Human Environment

Forests / woodlands per household (ha)

- [ ] <0.5
- [ ] 0.5-1
- [ ] 1-2
- [ ] 2-5
- [ ] 5-15
- [ ] 15-50
- [ ] 50-100
- [ ] 100-500
- [ ] 500-1,000
- [ ] 1,000-10,000
- [ ] >10,000

Land user: employee (company, government), common / average land users, mainly men
Population density: < 10 persons/km2
Annual population growth: negative
Land ownership: state, individual, titled
Land use rights: individual, public/open access but organised (e.g. hunting)
(In the region, there is some public land, controlled by the state. But there is also some private land. The access to the public land is open but organized. Permission is needed from the government to cut trees, to build a house or to hunt. There are some private hunting areas for which the hunting association has to pay a fee.)

Market orientation: mixed (subsistence and commercial)
Purpose of forest / woodland use: nature conservation / protection, protection against natural hazards



Technical drawing

The Pinus Halepensis seedlings were planted on a line in order to facilitate the operation of machines. The linear arrangement is still visible when observing the plantation from the distance, but when finding oneself within the forest this alignment is not visible anymore since the forest grew very densely. A part of today's forest grew naturally after planting the trees - some young pines but also some resprouters (e.g. Quercus) can be found which is pleasant and shows the success of this plantation effort. However, it would have been better to plant less trees with a bigger distance between the individuals. To reduce the high density and continuity of the forest (and thus to reduce the fire risk) a selective clearing would be required but currently the state does not invest money in forest management practices. Without extraction of biomass this dense forest contains a high risk of fire. (Nina Lauterburg)

Implementation activities, inputs and costs

Establishment activities

- Digging holes (60cm x 60cm x 60cm)
- Plantation of the seedlings (pinus halepensis)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	4857.00	0%
TOTAL	**4857.00**	**0.00%**

Maintenance/recurrent activities

- Selective clearing "ayuda regeneración" (only done once in 2003 but should be done again to decrease the risk of fires and competition between species)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	2428.00	0%
TOTAL	**2428.00**	**0.00%**

Remarks:
The costs of a plantation can be affected by numerous factors, such as slope (if the slope is steep, the work is much more difficult and takes more time, also because machines cannot be used on steep slopes), distance from a street (people can work less in a day if they have to walk far to plant), stone content of the soil (if there are many stones the work is much more difficult for the machines), soil type (plantations work much better on previous cropland because the soil is more fertile), origin of the seedlings (adapted to the local climatic conditions), variability/uncertainty of the weather conditions (e.g. droughts, freezing). If there are adverse climatic conditions or other negative circumstances the afforestation will not work well and this might cause higher costs.
The costs were calculated for the application of the technology on one hectare. Furthermore, the total costs of the afforestation were calculated with today’s costs because the costs at the time it was implemented are not known.
The currency rate (Euro-Dollar) was calculated on November 16th, 2013.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- +++ increased wood production
- ++ increased product diversification

Production and socio-economic disadvantages

- ++ loss of land
- + reduced animal production

Socio-cultural benefits

- ++ improved conservation / erosion knowledge
- ++ improved situation of disadvantaged groups
- + increased recreational opportunities

Socio-cultural disadvantages

Ecological benefits

- ++ improved harvesting / collection of water
- ++ increased soil moisture
- ++ reduced surface runoff
- ++ improved excess water drainage
- ++ improved soil cover
- ++ increased biomass above ground C
- ++ increased nutrient cycling recharge
- ++ increased soil organic matter / below ground C
- ++ reduced soil loss
- ++ Reduction of soil surface temperature
- + reduced evaporation
- + recharge of groundwater table / aquifer
- + reduced wind velocity
- + reduced soil crusting / sealing
- + increased animal diversity
- + increased plant diversity
- + Increase in shade

Ecological disadvantages

- ++ increased fire risk
- ++ increased niches for pests

Off-site benefits

- + reduced downstream flooding
- + reduced damage on neighbours fields
- + reduced damage on public / private infrastructure
- + Reduced amount of sediments in the water ponds for fire extinction

Off-site disadvantages

Contribution to human well-being / livelihoods

+ In the year 1985 the afforestation created jobs for the unemployed. But it seems that in general forest management is not something people want to do, they work in this sector only if there are no other job opportunities. Until today this attitude did not change much. Forest management means a hard job and this kind of work is not well-respected in society.

Benefits /costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	negative	positive
Maintenance / recurrent	neutral / balanced	neutral / balanced

Short-term returns are negative because the management practice is expensive and until the trees reach a mature state, there are not many returns (in terms of wood and biomass). In the long-term this management practice shows a positive result because compared to bare soil or shrubland it has ecological benefits such as the reduction of soil erosion, and it also provides wood and biomass which could be extracted. Currently there is no management project because the state does not invest money but it would actually be required in order to maintain the healthy state of this forest patch and to control the fire risk. If there is money invested by the state they can do a selective clearing which will result in short-term returns, e.g. wood (but also in the long-term they will be able to extract wood).

Acceptance / adoption:

There is no trend towards (growing) spontaneous adoption of the technology. In Spain a lot of afforestation trials have been realized in the past but only a few of them succeeded.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
The afforestation allowed the rehabilitation of an area affected by a devastating wildfire. It is an example out of many afforestation trials which succeeded. The success of this Pinus Halepensis afforestation is not only shown by the occurrence of healthy old pines, but also by the growth of young pines and resprouter species such as Quercus which were not planted. →Recurrent management, e.g. selective clearing, is crucial to ensure a healthy forest	It would be necessary to extract biomass from the forest to decrease the continuity of the trees and shrubs. Due to the lack of forest management (the management activities are expensive and labour-intensive) there is an increased risk of fires. →More investments in forest management such as selective forest clearings are required. Managing the forest would not only decrease the risk of fire and the competition between the species but also generate benefits such as timber or biomass for bioenergy production. Furthermore, jobs would be generated. In general, after afforestations, it would be required that people manage the forest. Nowadays, there is only limited use of the forest – in the past people lived of the land, but today this is not the case anymore. E.g. grazing is almost not existing anymore but in fact this would be really important for the reduction of the fire risk.
Through the plantation of pines, the soil cover and stability was improved which in turn led to a decrease of soil erosion. The reduction in soil erosion (less transported sediments) also resulted in a decrease of damages of the infrastructure (such as streets or water ponds for fire extinction). →There is no need to plant more trees or shrubs because the ecosystem regenerated well. But recurrent management, e.g. selective clearing, is crucial to ensure a healthy forest	It is not fully clear whether Pinus Halepensis plantations are a useful tool for restoration and it is also questioned whether it is sustainable to plant only Pinus Halepensis. Monoplantations result in the simplification of the landscape and alterations of habitats. One of the reasons why they used this species is that planting pines is kind of a tradition: it was always used for economic purposes because in earlier times the wood had a higher value. Furthermore, Pinus Halepensis seedlings grow faster and show a higher survival rate than other species, and since the aim of the afforestations was to have forest again in a short period of time, this species seemed to be the most suitable. But often in Pinus Halepensis Monoplantations other species do not grow (which is not the case in the documented afforestation). →Research carried out on this topic showed that it would be good to increase the diversity (e.g. with carrasca, sabina, enebros, madroños), to combine the plantation of pines with the plantation of broad-leaved resprouting species (such as holm oak), in order to take advantage of both the fast-growth features of pines and the high resilience of oaks. This also provides higher diversity and landscape heterogeneity
There are also economic benefits for local people. The afforestation provided jobs for rural people. Furthermore, Pinus Halepensis seedlings grow faster and show a higher survival rate than other species, therefore the natural process of forest growth is increased which in turn results in the possibility to use the forest after some years again, e.g. extraction of wood/biomass for bioenergy or timber. But unfortunately this is not done frequently because it is expensive to clear the forest (located in a remote area). →Also today forest management could be a source for jobs. It was also mentioned by many stakeholders that traditional activities (such as grazing, agriculture, wood gathering, selective clearings) should be reactivated and that the villagers should get economic compensation to maintain the forest in a good state	Monoplantations are more vulnerable to perturbations such as forest fires or pests. If there is a high amount of one specific species the spread of a pest is facilitated. Sick or dead trees in turn increase the fire risk. →It would be good to increase the diversity (e.g. with carrasca, sabina, enebros, madroños), to combine the plantation of pines with the plantation of broad-leaved resprouting species (such as holm oak), in order to take advantage of both the fast-growth features of pines and the high resilience of oaks.
Many stakeholders mentioned the positive visual impact. They prefer to have a forest instead of bare soil or shrubland, and it reminds them of how the state of the forest was before the fire. Trees have a higher value for them than shrubs. They supported the fact that the afforestation helped the environment to regenerate. → Recurrent management, e.g. selective clearing, is crucial to ensure a healthy forest.	Additional information: The here documented afforestation was successful, but usually many plantations of Pinus Halepensis failed (low seedling survival rate) →Seedling survival can in some cases (has also be questioned) be enhanced through preconditioning, water harvesting techniques (micro-catchments), tree-shelters (protective tubes), fertilisation, application of mulch, using facilitating effects (planting close to a resource island or a nurse plant, to benefit from shade, change in soil properties, retention of soil and nutrients, protection from grazers), perch effect (providing
Compared to the situation after the fire there is a higher biodiversity due to the afforestation. →Recurrent management, e.g. selective clearing, is crucial to ensure a healthy forest.	
The afforestation contributed to rural development →	

	bird perches e.g. dead trees, artificial woody structures, in old fields to accelerate colonisation rates (bird-mediated restoration))
	The area which was afforested is now not available anymore for agriculture. There is therefore a loss of agricultural land, but it is not sure either whether there would be a farmer using this land since it is located in a remote area. →
	The area is now less accessible for hunters because of the density of the forest which allows animals to hide themselves →Local hunters are cultivating cereals next to the forest to attract the animals. This is also important for the animals because without these fields, they would probably have to leave this area due to the scarce fodder supply
	Some stakeholders criticized the linear planting. This is not like nature "would do it". →
	There are many stakeholder who said that it was an error to do so many afforestations with Pinus Halepensis because in many regions nature would have regenerated by itself. It would have been possible to save a lot of money. A plantation causes high costs. →
	Due to the lack of management and because there is almost no use of the forest by the local population, there is a high amount of shrubs which increases the fire risk and hinders from walking through the forest →In the opinion of the villagers it would be important to promote the relationship between humans and nature and to find a balance between forest use and natural processes. The consciousness of the patrimonial value of the forest should also be promoted.

left: Cleared forest with chipped material applied as mulch and fresh grasses providing fodder to animals. (Photo: Nina Lauterburg)
right: The residues generated by forest clearings are chipped in-situ using brushcutters (motodesbrozadoras). The chipped material protects the soil as a mulch layer. Forest management provides jobs - many forest workers were unemployed before. (Photo: Nina Lauterburg)

Selective forest clearing to prevent large forest fires

Spain - Clareo selectivo para la prevención de incendios (tratamientos selvícolas) (Spanish)

Selective forest clearing aims in reducing the connectivity and the amount of (dead standing) fuel, as well as reducing the competition between regenerating pines, in order to prevent forest fires and to ensure the growth of a healthy forest.

The forests in the Ayora region experienced a huge disturbance in the past, such as deforestations, removal of key species, land abandonment, dense growth of fire-prone seeder species (high continuity of dead standing fuel), missing management, wildfires and dense afforestations. These disturbances resulted in the degradation of the vegetation, the reduction of the resilience of the ecosystem against fires and thus an increasing risk of wildfires. After fires, many landscapes regenerated with a high and continuous fuel accumulation with few native resprouter species, which made it extremely difficult to control forest fires. The dense growth not only increased the risk of wildfires but also the competition between different species (nutrients, light, space). Therefore appropriate vegetation management to increase the resilience of the ecosystem to fires and to reduce competition is crucial.
These problems are approached by selective forest clearing. The main purposes of thinning dense pine forests are the prevention of fires by reducing the fuel load and its continuity, and to improve pine regeneration by eliminating the competition between different species. As a result, the quality of the plants is improved and the amount of dead or sick plants is reduced, which is essential to ensure a healthy forest. This also leads to a higher resistance to pests which in turn again decreases the risk of fire (less dead plants). Vegetation removal produces fresh vegetation growth, therefore more diverse and nutritious fodder is provided to animals (game and livestock) in the cleared areas which is a benefit for herders. Also wild animals use this fodder supply which in turn hinders them to destroy cultivated fields of the farmers. Furthermore, honey producers make use of the enhanced growth of shrubs and the additional space created by selective clearing to place their beehives and to increase honey production. Especially during the current economic crisis forest management is an important source for jobs - most of the workers were unemployed before working in the selective clearing. Through the clearings, fuelwood is gained and offered to retired people for free for cooking and heating, allowing them to save money. Additionally, almost all villagers like to have a cleared forest due to its high aesthetic and recreational value.
In order to be selective and to preserve desired species, the clearing is done with small machines such as brushcutters and chainsaws. On average the forest is thinned until reaching a density of 800-1200 trees/ha. Species such as Juniperus, Rhamnus al., Quercus rotundifolia, Quercus faginea or Fraxinus ornus are not removed which increases the probability to have a more fire-resistant vegetation composition in future. Dead or sick plants and also a part of fire-prone shrubs such as Ulex parv. and Cistus alb. are removed. If there are both Pinus pinaster and Pinus halepensis. Pinus halepensis is cleared because they compete with each other. The roots are not removed which ensures the stability and productivity of the soil. The remaining species are pruned ("poda") until a

Location: Spain, Valencia
Region: Ayora/Jarafuel
Technology area: 0.5 km^2
Conservation measure: vegetative
Stage of intervention: prevention of land degradation
Origin: Developed externally / introduced through project, recent (<10 years ago)
Land use type:
Forests / woodlands: Natural
Forests / woodlands: Plantations, afforestations
Climate: subhumid, temperate
WOCAT database reference: T_SPA010en
Related approach:
Compiled by: Nina Lauterburg, Centre for Development and Environment (CDE)
Date: 2013-05-11
Contact person: Vicente Colomer, Forest Agent Generalitat Valenciana (Conselleria de infraestructura, territorio y medio ambiente). Phone: +34 669 819 522 E-mail: colomer.vju@gmail.com

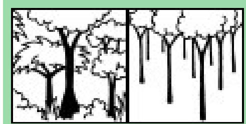
maximum height of 2.5m to improve the conditions of the species. Around each tree they should clear an area of 2m. After felling trees and shrubs a part of the residues is chipped in-situ and covers the soil as mulch, which results in ecological benefits (e.g. increase in soil moisture, prevention from erosion, enhancement of nutrient cycling, reduction of the soil surface temperature). If the slope is steep, it takes more time to do the clearing and it might also increase the risk of erosion afterwards. Under the best conditions (e.g. good access and terrain), 0.8ha per day are cleared (calculated for a group of 9 persons working 7 hours). In this case the costs are paid by the municipal council, which receives a part of the money from the rental fee paid by the wind mill company. The cleared areas have to be maintained depending on the speed of the vegetation growth (which amongst others depends on the soil, slope and humidity). If the clearings are done regularly, it takes less time and it is cheaper than the first clearing. It should be noted that recurrent maintenance is crucial to ensure the effectiveness of the technology.
The region of Ayora is mountainous with a dry subhumid climate (~380 mm annual rainfall). The risk of fire incidence is at its highest from June to September when there are adverse conditions like drought, high temperatures and strong winds (mainly the winds coming from central Spain, called “poniente”). The population density is very low and there are only few job opportunities (e.g. marginal agriculture, grazing, hunting, beekeeping). Most of the inhabitants work in the nuclear power plant. Forest management could be a source for jobs.

Classification

Land use problems:

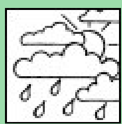
- The prevalent dense shrublands (dominated by seeder species), which resulted from past agricultural land use (changes of the vegetation composition, e.g. removal of key species), land abandonment/rural depopulation and fire occurrence, contain a high fire risk because of both the high fuel loads and their continuity. Also dense forests (either afforestations or natural regeneration) show a high risk for fires. Through the modifications of the vegetation composition in the past (removal of more fire resistant resprouter species, whereas fire-prone seeder species are abundant), the resilience of the ecosystem to fires has decreased. Today a higher fire recurrence can be observed which could still be worsen by future climate change impacts, undermining more and more the ecosystem’s capacity to buffer such shocks. Furthermore, the high density of the forest results in a competition between different species which increases the amount of dead or thin material. (expert's point of view)

Land use



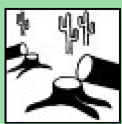
Natural
Plantations, afforestations
selective felling of (semi-) natural forests, plantation forestry

Climate



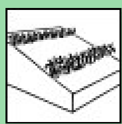
subhumid

Degradation



Biological degradation: detrimental effects of fires, quality and species composition /diversity decline

Conservation measure



vegetative: Clearing of vegetation (eg fire breaks/reduced fuel)

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land users initiative
Experiments / Research
Externally introduced: recent (<10 years ago)

Level of technical knowledge

Agricultural advisor
Land user
forest engineer

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires)
Indirect causes: population pressure, poverty / wealth, labour availability

Main technical functions:
___- control of fires
___- reduction of dry material (fuel for wildfires)
___- reduction of fire-prone species

Secondary technical functions:
___- increase in nutrient availability (supply, recycling,…)
___- promotion of vegetation species and varieties (quality, eg palatable fodder)

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000 mm
- 3000-4000 mm
- 2000-3000 mm
- 1500-2000 mm
- 1000-1500 mm
- 750-1000 mm
- 500-750 mm
- 250-500 mm
- < 250 mm

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Soil texture: fine / heavy (clay)
Soil fertility: low
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: > 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: temperature increase, seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic extremes: seasonal rainfall increase
If sensitive, what modifications were made / are possible: The technology was not modified but it is important to add some notes to the above stated reactions to climatic extremes. The cleared areas are quite resistant against climate change or weather extremes. Only if there will be more rainfall the vegetation might grow faster and the maintenance costs could increase.

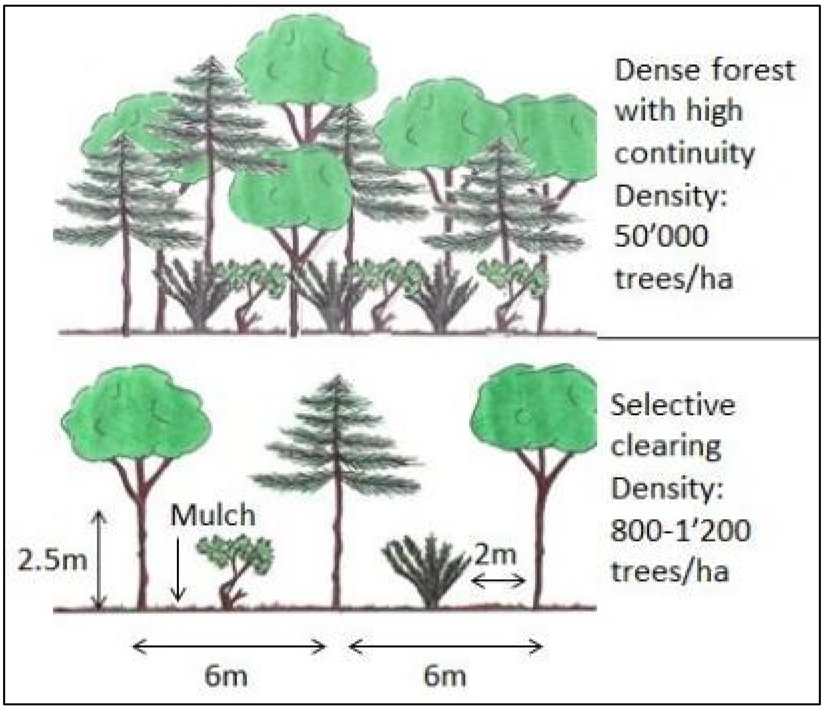
Human Environment

Forests / woodlands per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: employee (company, government), common / average land users, mainly men
Population density: < 10 persons/km2
Annual population growth: negative
Land ownership: state, individual, titled
Land use rights: individual, public/open access but organised (e.g. wood, hunting) (There is some public land, controlled by the state. But there is also some private land. The access to the public land is open but organized. Permission is needed from the government to cut trees, to build a house or to hunt. There are some private hunting areas for which the hunting association has to pay a fee.)

Market orientation: mixed (subsistence and commercial)
Purpose of forest / woodland use: timber, other forest products / uses (honey, medical, etc.), recreation / tourism



Technical drawing

The main purposes of thinning dense forests (some 50'000 individuals per ha) are the prevention of fires by reducing the fuel load and its continuity (both vertical and horizontal), and to improve regeneration by eliminating the competition between different species. On average the forest is thinned until reaching a density of 800-1200 trees/ha. Species such as Juniperus, Rhamnus al., Quercus rotundifolia, Quercus faginea or Fraxinus ornus are not removed which increases the probability to have a more fire-resistant vegetation composition in future. Dead or sick plants and also a part of fire-prone shrubs such as Ulex parv. and Cistus alb. are removed. The remaining species are pruned ("poda") until a maximum height of 2.5m to improve the conditions of the species. Around each tree they should clear an area of at least 2m but ideally there should be a distance of 6m between different individuals. After felling trees and shrubs a part of the residues is chipped in-situ and covers the soil as mulch, which results in ecological benefits and provides fodder to livestock and game.
(Nina Lauterburg)

Implementation activities, inputs and costs

Establishment activities

- Cutting and chipping (in-situ) of trees and shrubs (selective clearing)
- Transport of wood (fuel wood)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Labour	404.00	0%
Equipment		
- machine use	2024.00	0%
TOTAL	**2428.00**	**0.00%**

Maintenance/recurrent activities

- Cutting and chipping (in-situ) of trees and shrubs (selective clearing)
- Transport of wood (fuelwood)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	446.00	0%
TOTAL	**446.00**	**0.00%**

Remarks:
The costs of selective forest clearing can be affected by numerous factors, such as slope (if the slope is steep, the work is much more difficult and takes more time), vegetation density (it takes more time to clear a dense area) and vegetation type (pine forest or shrubland), distance from a street (people can work less in a day if they have to walk far to clear). Important to note is that maintenance costs could increase with an increase in rainfall because the vegetation will grow faster.
The costs were calculated for the application of the technology (selective clearing) on one hectare. In this case, 9 people are working as a team. If the site is accessible and if the terrain is good for clearing work they can clear 0.8 ha per day. It should be noted that clearing with small machines such as brushcutters and chainsaws is much more expensive than clearing with tractors, but often it is only possible to clear with small machines (e.g. removal of trees

is not possible with tractors). A tractor costs more or less 500 Euro per ha (674 Dollar per ha). A clearing of a pine forest with manual machines costs around 1800 Euro per ha (2428 Dollar per ha). The costs of the maintenance activities (e.g. second clearing) are much lower because the area was cleared already some years before. Therefore more ha per day can be cleared. In Jarafuel, a part of the costs are covered by the rental fee paid by the windmill company. The currency rate (Euro-Dollar) was calculated on November 16th, 2013.

Assessment

Impacts of the Technology

Production and socio-economic benefits

++	increased wood production
+	increased fodder production
+	increased fodder quality
+	increased animal production
+	reduced expenses on agricultural inputs
+	increased farm income
+	increased production area
+	increased product diversification

Production and socio-economic disadvantages

++	high establishment and maintenance costs
+	reduced animal production
+	job uncertainty

Socio-cultural benefits

+++	improved cultural opportunities
+++	increased recreational opportunities
++	improved conservation / erosion knowledge
++	improved situation of disadvantaged groups
+	conflict mitigation
+	improved food security / self sufficiency

Socio-cultural disadvantages

Ecological benefits

+++	reduced fire risk
++	increased soil moisture
++	reduced hazard towards adverse events
++	increased biological pest / disease control
+	reduced evaporation
+	improved soil cover
+	increased biomass above ground C
+	increased nutrient cycling recharge
+	increased soil organic matter / below ground C
+	reduced emission of carbon and greenhouse gases
+	reduced soil crusting / sealing
+	increased animal diversity
+	reduction of soil surface temperature

Ecological disadvantages

+	increased soil erosion locally
+	increased habitat fragmentation

Off-site benefits

++	reduced risk of wildfires
+	reduced downstream flooding
+	reduced downstream siltation
+	reduced damage on public / private infrastructure

Off-site disadvantages

Contribution to human well-being / livelihoods

(+) Through the clearings it is easier to control fires and protect people. Furthermore it created jobs for the unemployed. In general forest management is not something people want to do, they work in this sector only if there are no other job opportunities. Forest management means a hard job and this kind of work is not well-respected in society.

Benefits /costs according to land user

Benefits compared with costs	short-term:	long-term:
Establishment	very positive	very positive
Maintenance / recurrent	very positive	very positive

Both the short-term and the long-term benefits are very positive assuming that maintenance is done. It contributes to prevent devastating fires and to guarantee a healthy forest. Together with the creation of jobs, directly after clearing there is firewood and timber available and a reduced risk of wildfires. But it should also be considered that the establishment costs are high. If maintenance is not done the long-term returns will be very negative because an increase in the risk of fire will occur again (without management, there will also be no firewood, no timber and no jobs). The maintenance costs increase the longer you wait because the vegetation will grow again densely.

Acceptance / adoption:

There is no trend towards (growing) spontaneous adoption of the technology. Clearings are only done when the state has money. Selective clearing is also applied in other countries/regions, e.g. in California.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Through selective forest clearing the fuel amount and connectivity (vertical/horizontal) is reduced which is crucial for preventing the occurrence and spread of large forest fires. →Recurrent maintenance is crucial to ensure the effectiveness of the technology. Especially the fire-prone seeder species (e.g. Ulex parviflorus, Cistus albidus) should be removed frequently. CEAM suggests to plant more fire-resistant species (late successional stages) within some spots to accelerate the natural succession and to increase the resilience of the ecosystem to fires. Green living plants have a higher humidity content which slows down a fire (oxygen is consumed). By planting late-successional species really densely you don't allow seeders to grow. This measure could also decrease management costs and create Jobs.	The establishment and the maintenance activities are expensive and labour-intensive. Without management the technology is not effective anymore. It would be necessary to extract biomass from the forest to decrease the continuity of the trees and shrubs. In case of a lack of management the risk of fires increases. →Management is crucial. Prevention measures are often less expensive than rehabilitation activities after a fire. The state should therefore invest more money in forest management and fire prevention. Managing the forest would not only decrease the risk of fire but also generate benefits (e.g. wood, biomass, fuelwood). Instead of getting unemployment pay people could get jobs in forest management. Stakeholders mentioned that it would be important to promote the forest as a sustainable economic resource and that the relation between the villagers and the forest should be enhanced. Furthermore it was mentioned that traditional activities (such as grazing, agriculture, wood gathering) should be reactivated and that the villagers should get economic compensation to maintain the forest in a good state. Especially the promotion of grazing was stressed many times. Also planting of more fire-resistant species (late successional stages) in some spots as suggested by CEAM could increase the resilience of the ecosystem and decrease management costs.
There is a reduction of competition between plants which is essential to ensure a healthy forest (more nutrients, light, space). This also leads to a higher resistance against pests which in turn again decreases the fire risk (less dead or sick plants). →Recurrent maintenance is crucial to ensure the effectiveness of the technology.	The clearing of forests has potential to prevent fires and therefore degradation. But there are also a lot of highly connected shrublands with a high fuel load which are not addressed by this management practice. →Shrublands need to be cleared as well since they constitute a huge risk for wildfires.
Fuel management through vegetation clearing presents some positive aspects with respect to other techniques, e.g. the possibility of being selective in order to preserve desired species or individuals. Furthermore, after felling trees and shrubs a part of the vegetation is chipped in-situ and covers the soil as mulch. This results in ecological benefits (e.g. increase in soil moisture, prevention from erosion, enhancement of nutrient cycling, reduction of the soil surface temperature and evaporation loss). →Recurrent maintenance is crucial to ensure the effectiveness of the technology.	If there is more space after clearing the first shrubs which will grow will be fire-prone early successional species, such as Cistus albidus and Ulex parviflorus. Without management, they will increase the risk of fires. → Recurrent maintenance is crucial to ensure the effectiveness of the technology. Management through grazing could be a simple way to reduce the costs and the risk. By planting resprouter species really densely seeders would not grow anymore in those spots which would also decrease the fire risk and the management costs.
The trees/shrubs are cut but the roots are not removed. This ensures the stability and productivity of the soil. →	When the clearing is done on extremely steep slopes there might be an increase in erosion. →Before clearing the soil erosion risk should be calculated.
Fewer fires result in a decrease of the destroyed area, less money will have to be invested in restoration or fire extinction. Furthermore, farmers, hunters and honey producers will experience fewer losses. →Recurrent maintenance is crucial to ensure the effectiveness of the technology.	In some areas there will be less shade which could harm
There are both social and economic benefits for local people. The selective clearings provide jobs for rural people, which allows them to increase their livelihood conditions. People do not depend on unemployment pays and are therefore more accepted in society. A part of the extracted wood is used for biomass, fertilizers, pellets, or	

firewood. Furthermore there would be improved conditions for grazing. Therefore forest management contributes to rural development. →Actually there is still a lot of management required in the forest of this region which would provide jobs in the longer term.Furthermore, many local stakeholders mentioned the importance of reactivating traditional activities (such as grazing, agriculture, wood gathering) and that the villagers should get economic compensation to maintain the forest in a good state.

There are also off-site benefits. Fewer fires will result in a reduction of downstream flooding, downstream siltation and damage on neighbours' fields. When fire removes less vegetation the soil is less vulnerable to erosion. → Recurrent maintenance is crucial to ensure the effectiveness of the technology.

In Jarafuel where most of the land is public retired people receive the firewood gained by forest clearings for free. They can use the wood for cooking and heating and save a lot of money. →People from the region (outside of Jarafuel) like this idea that villagers benefit from what is removed from the forest. More mechanisms like this should be developed so that people recognize that they also benefit from forest management, which in turn would ensure a sustainable forest management.

Almost all villagers like to see a cleared forest. It has a high aesthetic and recreational value (it is possible to walk through the forest). They are also aware that the risk of wildfires is reduced through this technology. → Recurrent maintenance is crucial to ensure the effectiveness of the technology. Villagers and state need to work together to ensure a long-term forest management.

Shepherds, hunters and farmers benefit from forest clearings. Vegetation removal produces fresh vegetation growth, therefore more diverse and nutritious fodder is available for animals (game and livestock) in the cleared areas. Game/wildlife and livestock are better because there is an increase in fodder quantity and quality. Wild animals benefit from this food source which in turn hinders them to destroy cultivated fields of the farmers. Also honey producers benefit from the cleared areas since bees can fly better and there is more place to put the beehives, furthermore the growth of shrubs is enhanced. →Recurrent maintenance is crucial to ensure the effectiveness of the technology.

some species. →

left: Different vegetation treatments were examined on four plots in three study sites. 1)Control (no action), 2)clearing, 3)clearing and planting, and 4)planting within the shrubland. (Photo: CEAM)
right: The combination of clearing fire-prone and planting more fire resistant species is an appropriate management practice of fire-prone shrubland. (Photo: CEAM)

Selective clearing and planting experiment to promote shrubland fire resilience

Spain - Experimento para aumentar la resiliencia del matorral contra incendios (Spanish)

The combination of clearing of fire-prone seeder species and planting of more fire resistant resprouter species directs the vegetation to later successional stages which increases the resilience to fires

The forests and shrublands in Ayora experienced a series of disturbances in the past (such as deforestation and land use), which resulted in the degradation of the vegetation and the reduction of the resilience to fires. At present, there is a high fire incidence. Post-fire landscapes regenerated with a high and continuous fuel accumulation with few native resprouter species. Therefore appropriate vegetation management is crucial. For management the major goals are to reduce the fuel load and its continuity and to increase the resilience of the vegetation to fires. Within this experiment carried out by CEAM (Centro de Estudios Ambientales del Mediterráneo, University of Valencia) different fuel management techniques were examined. They selected three study sites (Morera, Roñoso, Gachas) with a similar history of land use, vegetation composition, soil characteristics, and a typical post-fire scenario whith scarce occurrence of resprouter species. In each site, four plots were established to test the effect of the following management techniques: 1) control (no action), 2) clearing, 3) planting (within the shrubland) and 4) the combination of clearing and planting.
The main purpose of this experiment was to find out which management technique is the most appropriate to prevent fires and it was shown that the combination of selective clearing of fire-prone shrubs (fuel control) and planting of more resistant resprouter species can increase the resilience to fires and is therefore a suitable management practice. Compared to the other management techniques, there are some advantages. Clearing the vegetation (either by hand or mechanically) reduces the fire risk and enhances seedling establishment and growth. Furthermore, the cleared vegetation is chipped and applied in-situ as mulch, which protects the soil from erosion, reduces soil temperature and moisture loss, and enhances carbon conservation. Additionnally, selective clearing allows to preserve desired species and by planting resprouter species the natural processes can be accelerated. Once established, resprouter species persist for a long time which promotes an increase of the vegetation resilience. In this documentation, only the combination of clearing and planting is evaluated since this action is considered as the most appropriate management practice.
In each study site, the experimental area covered about 5000m2 (3 plots of 1000m2 each, one plot of 2000m2). To test the effect of the combination of clearing and planting, a clearing machine was used to clear a plot of 1000 m2 in all three sites. The few resprouting individuals such as Juniperus oxycedrus and Quercus ilex and also some seeder trees such as Pinus halepensis and Pinus pinaster were left standing. The planting holes (0.35 m2) were created with a tractor using a backhoe. The slash and brush chips generated by the clearing were reused in the planting holes as mulch which resulted in ecological benefits. In February 2003, native resprouters of late successional stages with a low amount of dead fuel were planted, such as Quercus ilex, Rhamnus alaternus and

Location: Spain, Valencia
Region: Ayora
Technology area: 0.015 km^2
Conservation measure: vegetative
Stage of intervention: prevention of land degradation, mitigation / reduction of land degradation
Origin: Developed through experiments / research, recent (<10 years ago)
Land use type:
Forests / woodlands: Natural
Forests / woodlands: Plantations, afforestations
Climate: subhumid, temperate
WOCAT database reference: T_SPA011en
Related approach:
Compiled by: Nina Lauterburg, Centre for Development and Environment (CDE)
Date: 2013-04-26
Contact person: Alejandro Valdecantos, Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), Parque Tecnológico Paterna. C/ Charles Darwin 14, 46980 Valencia, Spain. Phone: +34 609 183 599 E-Mail: a.valdecantos@ua.es

INSTITUTO UNIVERSITARIO CEAM CENTRO DE ESTUDIOS AMBIENTALES DEL MEDITERRÁNEO

CASCADE Catastrophic shifts in drylands: How can we prevent ecosystem degradation?

Pistacia lentiscus, all protected by a plastic tree shelter to prevent browsing. The seedlings were grown for 8 months in a nursery in Santa Faz (Alicante) and then transferred to a nursery in La Hunde (Ayora) one month before planting. The Regional Forest Services of Valencia provided seeds as well.
The region of Ayora is mountainous with a dry subhumid climate (~380 mm annual rainfall). The risk of fire incidence is at its highest from June to September when there are adverse conditions like drought, high temperatures and strong winds (mainly the winds coming from central Spain, called "poniente"). The population density is very low and there are only few job opportunities (e.g. marginal agriculture, grazing, hunting, beekeeping). Most of the inhabitants work in the nuclear power plant. Forest management could be a source for jobs.

Classification

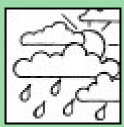
Land use problems:

- In Spain the prevalent dense shrublands (dominated by seeder species), which resulted from agricultural land abandonment and fire occurrence, contain a high fire risk because of both the high fuel loads and their continuity. Resprouter species have been removed in the past and are therefore scarce, whereas seeder species are abundant and increase the risk of fires. (expert's point of view)

Land use

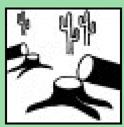
Natural
Plantations, afforestations
selective felling of (semi-) natural forests, plantation forestry

Climate



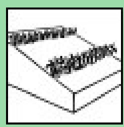
subhumid

Degradation



Biological degradation: detrimental effects of fires, quality and species composition /diversity decline

Conservation measure



vegetative: Tree and shrub cover
vegetative: Clearing of vegetation (eg fire breaks/reduced fuel)
vegetative: Others (Introduction of fire resistant species)

Stage of intervention

Prevention
Mitigation / Reduction
Rehabilitation

Origin

Land users initiative
Experiments / Research: recent (<10 years ago)
Externally introduced

Level of technical knowledge

Agricultural advisor
Land user

Main causes of land degradation:
Direct causes - Human induced: deforestation / removal of natural vegetation (incl. forest fires), other human induced causes, change of vegetation composition to fire-prone shrubland
Indirect causes: population pressure, poverty / wealth, labour availability

Main technical functions:
____- control of fires
____- reduction of dry material (fuel for wildfires)
____- Promotion of vegetation species and varieties (more fire resistant vegetation composition)

Secondary technical functions:
____- increase / maintain water stored in soil

Environment

Natural Environment

Average annual rainfall (mm)

- > 4000 mm
- 3000-4000 mm
- 2000-3000 mm
- 1500-2000 mm
- 1000-1500 mm
- 750-1000 mm
- 500-750 mm
- 250-500 mm
- < 250 mm

Altitude (m a.s.l.)

- > 4000
- 3000-4000
- 2500-3000
- 2000-2500
- 1500-2000
- 1000-1500
- 500-1000
- 100-500
- <100

Landform

- plateau / plains
- ridges
- mountain slopes
- hill slopes
- footslopes
- valley floors

Slope (%)

- flat
- gentle
- moderate
- rolling
- hilly
- steep
- very steep

Soil depth (cm)

- 0-20
- 20-50
- 50-80
- 80-120
- >120

Soil texture: fine / heavy (clay)
Soil fertility: medium
Topsoil organic matter: medium (1-3%)
Soil drainage/infiltration: medium

Soil water storage capacity: medium
Ground water table: 5 - 50 m
Availability of surface water: poor / none
Water quality: good drinking water
Biodiversity: medium

Tolerant of climatic extremes: seasonal rainfall decrease, heavy rainfall events (intensities and amount), wind storms / dust storms, floods, droughts / dry spells
Sensitive to climatic extremes: temperature increase, seasonal rainfall increase, temperature decrease, snow, frost

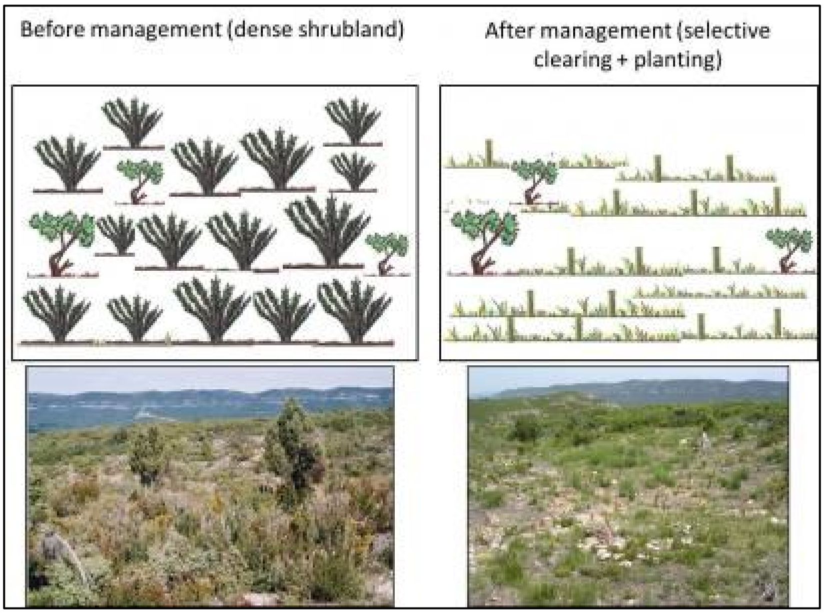
Human Environment

Forests / woodlands per household (ha)

- <0.5
- 0.5-1
- 1-2
- 2-5
- 5-15
- 15-50
- 50-100
- 100-500
- 500-1,000
- 1,000-10,000
- >10,000

Land user: employee (company, government), mainly men
Population density: < 10 persons/km2
Annual population growth: negative
Land ownership: state, individual, titled
Land use rights: individual, public/open access but organised (e.g. wood, hunting) (There is some public land, controlled by the state. But there is also some private land. The access to the public land is open but organized. Permission is needed from the government to cut trees, to build a house or to hunt. There are some private hunting areas for which the hunting association has to pay a fee.)

Market orientation: mixed (subsistence and commercial)
Purpose of forest / woodland use: timber, other forest products / uses (honey, medical, etc.), recreation / tourism



Technical drawing

On the left, the situation before management is illustrated. Dense shrublands contain a high fire risk due to their high fuel amount and continuity. On the right, the situation after management is shown. The combination of selective clearing of fire-prone seeder species and planting of more fire resistant resprouter species (illustrated by tree shelters in the drawing) promotes shrubland resilience to fires. (Nina Lauterburg)

Implementation activities, inputs and costs

Establishment activities

- Cutting and chipping (in-situ) trees and shrubs (removed species: ulex parviflorus, rosmarinus officinalis, cistus albidus. Natural regenerated species which are not cleared: pinus halepensis, pinus pinaster, quercus ilex, juniperus oxycedrus)
- Planting (planted species: pistacia lentiscus, quercus ilex, rhamnus alaternus)

Establishment inputs and costs per ha

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	3089.00	0%
- tree shelters	945.00	0%
Agricultural		
- seedlings	4587.00	0%
TOTAL	**8621.00**	**0.00%**

Maintenance/recurrent activities

- There is no maintenance, but in case of maintenance they would do selective clearings (using machines)

Maintenance/recurrent inputs and costs per ha per year

Inputs	Costs (US$)	% met by land user
Equipment		
- machine use	446.00	0%
TOTAL	**446.00**	**0.00%**

Remarks:
Slope (if the slope is steep, the work is much more difficult and takes more time), distance from a street (people can work less in a day if they have to walk far to clear/plant), vegetation density (it takes more time to clear a densely vegetated area).
The costs were calculated for the application of the technology (combination of clearing and planting) on one hectare. The costs can vary depending on the amount of vegetation which has to be cleared (site specific). The costs of the clearing amount to 1090 Euro per ha (1470 Dollar). The costs of the plantation (both labour and machines) are approximately 5300 Euro per hectare (7150 Dollar). But it should also be noted that the application of the selective clearing and planting on a vast continuous area is not the aim of this technology, but rather to apply the treatments on some selected spots to reduce the continuity of fire-prone seeder species and to increase the probability of dispersal of resprouter species (e.g. by birds). Therefore the costs would be lower than indicated here. The currency rate (Euro-Dollar) was calculated on November 16th, 2013.

Assessment

Impacts of the Technology

Production and socio-economic benefits

- + increased fodder production
- + increased fodder quality
- + increased animal production
- + increased wood production

Production and socio-economic disadvantages

- + reduced animal production

Socio-cultural benefits

- ++ improved cultural opportunities
- ++ increased recreational opportunities
- ++ improved conservation / erosion knowledge
- ++ improved situation of disadvantaged groups
- + conflict mitigation

Socio-cultural disadvantages

Ecological benefits

- +++ reduced fire risk
- ++ increased soil moisture
- ++ increased plant diversity
- ++ increased biological pest / disease control
- ++ reduction of germination of competing seeds
- ++ reduction of soil surface temperature
- + reduced evaporation
- + improved soil cover
- + increased biomass above ground C
- + increased nutrient cycling recharge
- + increased soil organic matter / below ground C
- + reduced emission of carbon and greenhouse gases
- + reduced soil loss
- + reduced soil crusting / sealing
- + increased animal diversity

Ecological disadvantages

Off-site benefits

- ++ reduced risk of wildfires and damage of villages

Off-site disadvantages

Contribution to human well-being / livelihoods

Not applicable since it was only an experiment, but for sure it would contribute to improve livelihoods and human well-being, forest and shrubland management could provide jobs and would also decrease the risk of fires.

Benefits /costs according to land user

Benefits compared with costs	**short-term:**	**long-term:**
Establishment	slightly negative	very positive
Maintenance / recurrent	very positive	very positive

Short term returns are slightly negative because the management practice is expensive and until the trees reach a mature state, there are not many returns (in terms of wood and biomass). In the long term this management practice has very positive results because it increases the resilience to fires and can be seen as a sustainable management of fire-prone areas. Additionally, wood and biomass can be extracted. The idea is not to apply any maintenance in the first 10 years after the establishment.

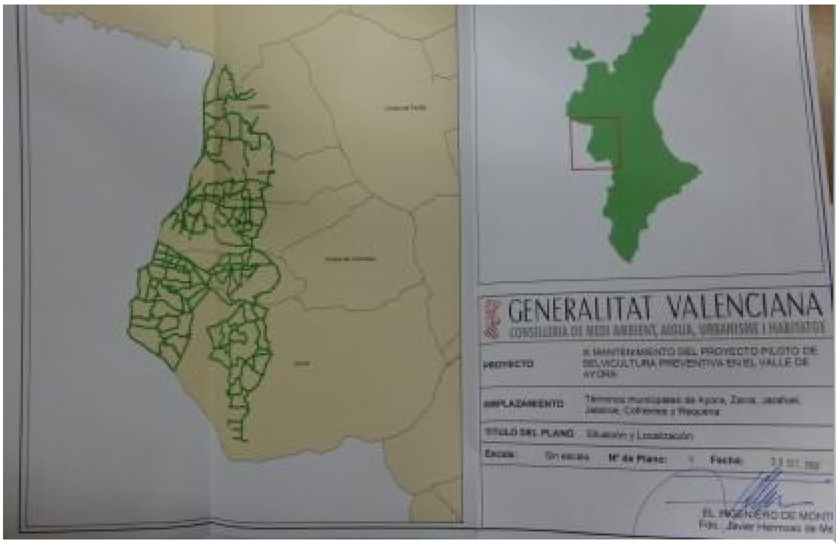
Acceptance / adoption:

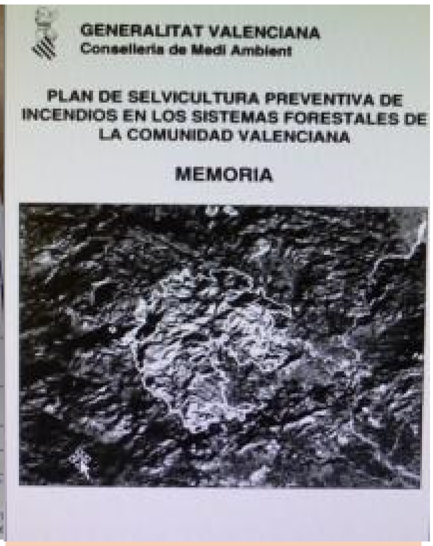
There is no adoption trend since this was only an experiment, but maybe there will be the possibility to upscale this technology in a regional project.

Concluding statements

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
After fires, the natural landscape regenerated with a high and continuous fuel amount and a scarce occurrence of native resprouter species. It is crucial to apply management actions to reduce the fire hazard. The experiment demonstrated that it is possible to accelerate the post-fire vegetation response (which promotes ecosystem resilience). →Clearing of fire-prone species and planting of late-successional species. The management of these areas is crucial – the clearings must be repeated from time to time.	The management activities are expensive and labour-intensive. The state does not invest much money in prevention of forest fires but focuses more on fire extinction. →More investment in prevention of forest fires is required and this management practice could increase the ecosystem resilience against fires in the long term in a sustainable way. This would also generate jobs. This technology implies a combination of techniques (selective clearing and planting). Costs may be reduced by implementing individual techniques but positive results may also be reduced.
Planting of resprouting species in post-fire areas can accelerate the natural process. Clearing of the vegetation reduces the fire risk, but this treatment may also enhance seedling establishment and growth. →	The technology could result in a reduction of the animal production because grazing should be restricted after planting to ensure the growth of the planted seedlings. → Since the technology would not be applied over vast areas but only locally on some plots, the fodder supply would probably still cover the needs of the animals.
The slash and brush chips generated by the clearings can be reused in the planting holes. This mulch layer protects the soil surface and reduces both the soil surface temperature and the germination of competing seeds while increasing the soil moisture content, especially in the driest periods. →Recurrent maintenance is crucial to ensure the effectiveness of the technology.	Depending on the site, some soil may be exposed to erosion due to mechanical clearing. →Mulching with brush chipping can minimize or even solve this problem.
The combination of clearing and planting resprouting species seems to be an appropriate option for managing these areas because, once established, the resprouting species persist for a long time and lead to an increase of the ecosystem resilience. →Recurrent maintenance is crucial to ensure the effectiveness of the technology.	After clearing, an increase in wind velocity might occur. →The planted trees will grow which will again result in the reduction of this problem.
Social and economic benefits for the locals. Especially during the economic crisis the forest management is an important source for jobs. →Actually there is still a lot of management required in the forest of this region which would provide jobs in the longer term.	
Almost all villagers prefer a managed forest. It has a high aesthetic and recreational value. Through the application of this technology the awareness of the risk of wildfires would probably increase. →Recurrent maintenance is crucial to ensure the effectiveness of the technology. Villagers and state need to work together and ensure a long-term forest management.	
Shepherds and farmers benefit from forest clearings. There are more young grasses in the forest which provides fodder for livestock. Also wild animals benefit from this food supply which in turn hinders them to destroy cultivated fields of the farmers. →Recurrent maintenance is crucial to ensure the effectiveness of the Technology.	

Annex 5: WOCAT Approach Documentation





left: Third maintenance of the firebreaks established through the pilot project of the plan of preventive silviculture (Photo: Generalitat Valenciana)
right: Project documents of the plan of preventive silviculture (Photo: Generalitat Valenciana)

Plan of preventive silviculture (PSP): implementation of firebreak network within a forest intervention area (ZAU)

Spain - Plan de selvicultura preventiva de incendios en los sistemas forestales de la Comunidad Valenciana (Spanish)

Through the declaration of Ayora to a forest intervention area (ZAU) and the implementation of the pilot project of the PSP, a preventive silviculture was promoted through the establishment of a firebreak network.

Location: Spain, Valencia, Los Serranos, Utiel-Requena, Valle de Ayora-Cofrentes, Sierra de Mariola
Approach area: 838.61 km^2
Type of Approach: project/programme based
Focus: mainly on conservation with other activities
WOCAT database reference: A_SPA002en
Related technology(ies): Cleared strip network for fire prevention (firebreaks)
Compiled by: Nina Lauterburg, Centre for Development and Environment (CDE)
Date: 2013-09-09
Contact person: Jaime Baeza, Fundación Centro de Estudios Ambientales del Mediterráneo (CEAM), Parque Tecnológico Paterna. C/ Charles Darwin 14, 46980 Valencia, Spain. / Departamento de Ecología, Universidad de Alicante, Ap. 99, 03080 Alicante, Spain. jaime.baeza@ua.es

Aim/objectives: Forest fire is the main degradation driver in Ayora. In the article 24 of the forest law 3/1993 the declaration of special areas to forest intervention areas, so-called "Zonas de Actuación Urgente (ZAU)" through the regional government of Valencia is defined. Objectives are the protection against natural hazards and the promotion of conservation/restoration within a area which is degraded, affected by a forest fire (and natural regeneration is not probable), adverse climatic conditions, pests, severe ecological change, or fauna or flora of special value. If the use of the resources is not compatible with the conservation objectives within a ZAU, the administration has the right to enforce restrictions. The Ayora region was declared to a ZAU in 1997 due to its high risk of fires. In the "Plan de Selvicultura Preventiva de Incendios en los Sistemas Forestales (PSP)" ("plan of preventive silviculture to prevent forest fires") which became operative in 1996 and whose main objective is the reduction of the fire risk, the ZAU was practically addressed for the first time in the establishment of a firebreak network (áreas cortafuegos). The PSP constitutes an important part of the "plan de protección contra incendios forestales" ("plan of protection against forest fires") and has the following main objectives: The analysis/mapping of historic forest fires in Valencia (1984-1994) to support decision-making in silvicultural issues, the classification of the forest by quality and fire risk to establish local/regional plans to prevent fires (through silvicultural actions), selection of areas (province level) for the establishment of pilot projects (to apply silvicultural actions), decision on periodic investment and level of employment.

Methods: Within the PSP, 4 pilot projects were initiated in Los Serranos (17'470 ha), Utiel-Requena (20'966 ha), Valle de Ayora-Cofrentes (33'851 ha) and Sierra de Mariola (11'574 ha) to promote a preventive silviculture which aims in modifying the amount of fuel in the forest through the establishment of a firebreak network and to limit the burnt area. The pilot areas were selected (in collaboration with the forest administration of Valencia) by the following criteria: representativity for the whole province, high value for the population, high potential risk of fire. In T_SPA009en the pilot project of Ayora-Cofrentes (Cofrentes, Jalance, Jarafuel, Zarra, Ayora) is described in detail and this approach focuses on the Ayora site as well. The firebreak network was established between 1998 and 2002, carried out by the company VAERSA and executed on both public and private land. Since the old firebreaks (established before the project) had a strong visual and ecological impact, the PSP designed a new type called “área cortafuego”. The continuous maintenance of the firebreaks is required which is also included in the pilot project. The total area protected by the firebreak network amounts to 33’851 ha while the management measures were executed on 1944,81 ha. The costs of the execution were 1312 Euro per ha, the maintenance 82.03 Euro per ha (all 2 years) and 31.37 Euro per ha (all 4 years).

Stages of implementation: After the establishment of the PSP (1996) and the declaration of Ayora to a ZAU (1997) the implementation of the pilot project was realized in the following phases: 1) splitting up of the territory based on the quality and the potential risk (using maps and aerial pictures), 2) field work (to examine the first draft of the firebreak network elaborated in the office), 3) office work (digitizing), 4) final map, 5) estimation of costs, 6) combination of firebreak plan with the cadastral land register.

Role of stakeholders: The PSP, the ZAU and the pilot projects were set up by the regional government of Valencia, in collaboration with the forest services. The PSP is put into operation each year by the forest services to plan the maintenance of the firebreak network. The effect on the local population is the creation of jobs in forest management.

Problem, objectives and constraints

Problems

High amount of continuous fuel due to lack of management which increases the risk of vast and devastating fires, lack of fire prevention and extinction measures, ecological and visual impact of old firebreaks.

Aims/Objectives

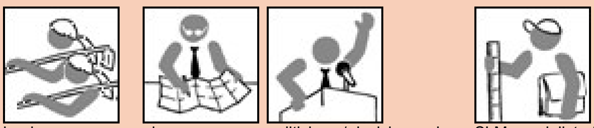
Research on historic fires to support decision-making in silvicultural practices, fire risk reduction, reducing the burnt area through splitting up the forest, improvement of fire prevention and extinction measures (e.g. improvement of access for fire-fighting vehicles and protection of fire fighters), establish local/regional plans to prevent fires (through silvicultural actions), promote conservation of the forest on a large scale

Constraints addressed

	Constraint	Treatment
financial	There was a lack of money to implement silvicultural measures	The pilot project of the PSP was fully financed by the government
institutional	Laws on forest management existed already before the implementation of the PSP but the idea of establishing a firebreak network was not available	With the pilot project of the PSP the firebreak network was carefully assessed and implemented

Participation and decision making

Stakeholders / target groups



land users, groups · planners · politicians / decision makers · SLM specialists / agricultural advisors

Approach costs met by:

government (government of Valencia)	100%
Total	**100%**

Annual budget for SLM component: US$ 100,000-1,000,000

Decisions on choice of the Technology(ies): Politicians in collaboration with SLM specialists

Decisions on method of implementing the Technology(ies): Politicians in collaboration with SLM specialists

Approach designed by: national specialists

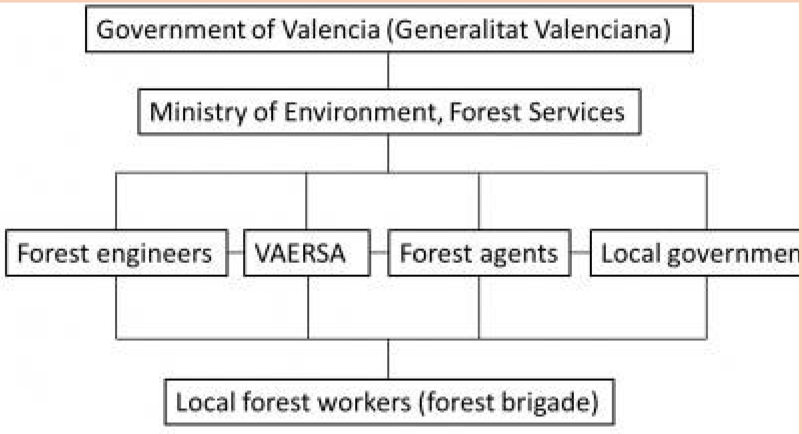
Implementing bodies: government (Regional government of Valencia (Generalitat Valenciana), forest services), local government (district, county, municipality, village etc) (Probably the local governments helped in the implementation of the pilot projects, e.g. provision of maps.)

Land user involvement

Phase	Involvement	Activities
Initiation/motivation	None	By government of Valencia
Planning	None	By government of Valencia
Implementation	Payment/external support	local people working in the execution and maintenance of the firebreak network, led by forest agents and forest engineers of the government of Valencia
Monitoring/evaluation	None	By government of Valencia
Research	None	By government of Valencia

Differences between participation of men and women: Yes, moderate
Usually men are involved in the forest sector

Involvement of disadvantaged groups: Yes, little
In the execution and the maintenance of the firebreak network unemployed local people were/are included. But in the development of the PSP this was not the case.



Organogram: The PSP and the pilot projects were set up by the regional government of Valencia in collaboration with the forest services. Forest engineers and forest agents are employed at the forest services and helped to design the projects. VAERSA, a public company of the Generalitat Valenciana, executed the pilot projects and was supported by forest engineers, forest agents and the local governments. Local forest workers were contracted (by VAERSA) for execution and maintenance work and controlled by forest agents. (Nina Lauterburg)

Technical support

Training / awareness raising:
Training provided for land user
Training was on-the-job
Training focused on Training of local people in the use of machinery in forest management (execution and maintenance of firebreaks)

Advisory service:

The extension system is quite adequate to ensure continuation of activities. The maintenance of the pilot projects is included in the PSP and is planned and executed by the government of Valencia. Already three maintenance projects followed after the execution of the pilot projects (2000-2004, 2004-2008, 2008-2012). Future funding of activities is not clear.

Research:
Yes, moderate research. Topics covered include technology, economics / marketing, ecology

Mostly on station and on-farm research.
analysis/mapping of historic forest fires in Valencia (1984-1994) to support decision-making in silvicultural practices, classification of the forest by quality and fire risk, research on causes of forest fires

External material support / subsidies

Contribution per area (state/private sector): Yes. state (government of Valencia)

Labour: Paid in cash. execution and maintenance of firebreak network (forest management)

Inputs:
- Equipment (machinery, tools, etc) - machinery for forest management. Fully financed
- Infrastructure (roads, schools, etc) - roads . Fully financed

Credit: Credit was not available

Support to local institutions: No

Monitoring and evaluation

Monitored aspects	Methods and indicators
technical	Regular observations by project/programme based recent local initiative / innovative - Observations of built-up of fuel to decide when and where maintenance is required

Changes as result of monitoring and evaluation:
There were no changes in the approach.

There were few changes in the technology. The technology is the same since the execution of the project but maintenance (e.g. clearing of firebreaks) is applied. Some more firebreaks were established where it was still required and not covered by the pilot project.

Impacts of the Approach

Improved sustainable land management: Yes, moderate; Improvement of fire extinction and prevention

Adoption by other land users / projects: Yes, few; Within the PSP they carried out 4 pilot projects, and after the projects more firebreaks were established

Improved livelihoods / human well-being: Yes, little; Reduction of the risk of fire and the loss of land through fires. Furthermore jobs were created by this project.

Improved situation of disadvantaged groups: Yes, little; More jobs provided through this approach of forest management

Poverty alleviation: Yes, little; More jobs provided through this approach of forest management

Training, advisory service and research:

- Training effectiveness

  Land users* - good

- Research contributing to the approach`s effectiveness: Moderately
  The development of the firebreak network is a complex process and was planned in detail.

Land/water use rights:
None of the above in the implementation of the approach. The firebreak network was implemented on both public and private land and the government of Valencia is allowed to establish a ZAU by law.

Long-term impact of subsidies:
Once the government will not be able to continue paying the maintenance of the firebreaks the technology will probably not be managed anymore

Concluding statements

Main motivation of land users to implement SLM:

Fire prevention and extinction

Sustainability of activities:

No the land users can`t sustain the approach activities without support.
The maintenance is expensive and has to be financed by the state. Furthermore, forest services need to provide technical assistance.

Strengths and →how to sustain/improve	Weaknesses and →how to overcome
Before the implementation of the pilot projects of the PSP there was a lack of money and no institutional base. The pilot project allowed to establish a firebreak network (fully financed by the government of Valencia) →The government should sustain its investment in forest management.	Land users cannot continue the SLM approach/ technology on their own. The maintenance is expensive and has to be financed by the state. Once the government will not continue paying the maintenance of the firebreaks the technology will probably not be managed anymore. Furthermore, forest services need to provide technical assistance →The government should sustain its investment in forest management. More trainings could be provided to local land users by the government of Valencia
The maintenance of the firebreak network is included in the PSP. →The government should sustain its investment in forest management.	Little involvement of the local population. The projects were designed by the government without including local land users →Include local land users in the planning of forest management. Work in a transdisciplinary way.
The firebreak network facilitates the access for fire fighters (and vehicles) and guarantees a higher security for people, thus increasing the possibility to control/slow down a fire. By arranging the territory in different parcels (firebreaks of first, second and third order) the spread of large forest fires is less probable →The maintenance of firebreaks is crucial. Furthermore, there must be a good coordination and organisation within the fire fighter staff in case of an emergency	Firebreaks do mainly work in fire extinction and less in fire prevention →Investigation of other management practices and approaches. An integrative way of forest management could be the clearing of fire-prone species and the planting of more fire-resistant species as suggested by CEAM.
There are also firebreaks which were not established within the pilot project but due to a request of forest agents. The project was important to upscale this technology and to get people's attention for the problem of forest fires. →Public awareness raising.	
There are both social and economic benefits for local people. The establishment and the maintenance of firebreaks provide jobs for rural people, which allows them to increase their livelihood conditions. People do not depend on unemployment payments and are therefore more accepted in society. →The government should sustain its investment in forest management and include the local population	

Annex 6: Information on pilot projects of the PSP

PROYECTO PILOTO	LOS SERRANOS	REQUENA	VILLARGORDO DEL CABIEL	AYORA	MARIOLA	MEDIA
ZONA METEOROLOGICA	3	3	3	3	5	
AREA DE ESTUDIO (HA)	17.470	8.879	12.087	33.851	11.574	
SUPERFICIE FORESTAL (HA)	14.840	8.064	9.986	28.496	9.701	
SUPERFICIE FORESTAL ARBOLADA (HA)	13.013	4.834	7.791	17.979	8.610	
LONGITUD DE ACTUACIONES (m)	189.795	157.848	204.038	498.584	100.255	
SUPERFICIE APERTURA ELEMENTOS (HA)	1.517,03	730,98	751,36	2.075,10	490,42	1.113
COSTE TOTAL EJECUCION (pta)	392.028.325	147.305.999	166.983.274	464.302.219	113.941.892	
DENSIDAD DE ELEMENTOS (m/Ha)	12,79	19,58	20,43	17,50	10,33	16,13
SUPERFICIE DE ACTUACION (%)	8,68	8,23	6,22	6,13	4,24	
COSTE DE HA DE ACTUACIÓN (Pta/HA)	258.418	201.518	222.241	223.750	232.337	227.653
COSTE DE HA FORESTAL PROTEGIDA (Pta/Ha)	26.417	18.268	16.722	16.293	11.745	

Figure 88: Information on the four pilot projects of the PSP. Costs are indicated in pesetas (source: GVA 1996)

ORDEN	PRESUPUESTO	LOS SERRANOS	REQUENA (1ª Y 2ª)	AYORA	MARIOLA	MEDIA
1	EJECUCION	264.992	219.928	221.852	200.631	225.466
	MANTENIMIENTO 2 AÑOS	6.527	12.568	20.558	16.910	13.826
	MANTENIMIENTO 4 AÑOS	57.312	51.921	53.598	49.192	52.789
2	EJECUCION	231.605	203.492	230.068	300.113	233.753
	MANTENIMIENTO 2 AÑOS	4.812	13.711	25.728	10.706	13.733
	MANTENIMIENTO 4 AÑOS	42.670	56.388	64.648	59.699	5.959
3	EJECUCION	193.165	160.884	217.339	246.425	195.739
	MANTENIMIENTO 2 AÑOS	9.913	13.512	23.764	6.759	13.492
	MANTENIMIENTO 4 AÑOS	59.758	53.818	59.481	56.422	56.659

Figure 89: Information on the four pilot projects of the PSP. Costs are indicated in pesetas (source: GVA 1996)

Annex 7: Annex on attached CD

Content of data CD

1. GIS Data
2. KMZ files
3. QM
4. Maps
5. Statistics
6. Master Thesis
7. Powerpoint Presentations

Erklärung

Gemäss Art. 28 Abs. 2 RSL 05

Name/Vorname:	Lauterburg Nina
Matrikelnummer:	08-116-444
Studiengang:	Master of Science in Geography

Bachelor ☐ Master ☑ Dissertation ☐

Titel der Arbeit:	Forest fires and related regime shifts in Ayora, Spain. An assessment of land use, land degradation and sustainable land management practices.
Leiter/-in der Arbeit:	Prof. Dr. Hans Hurni Co-Leitung: Dr. Hanspeter Liniger

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28.5.2014

Ort/Datum

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Unterschrift