FIRE ECOLOGY IN THE CANARY ISLANDS AND CENTRAL CALIFORNIA - A COMPARATIVE OUTLINE

With 3 figures, 1 table and 6 photos

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Zusammenfassung: Feuerökologie auf den Kanarischen Inseln und in Kalifornien, ein vergleichender Überblick

In den Gebirgen der subtropischen Winterregengebiete sind Wald- und Buschbrände von besonderer ökologischer Bedeutung. Unter natürlichen Bedingungen bewirkt das Feuer in Ökosystemen mit saisonaler Trockenheit eine beschleunigte Remineralisierung der Biomasse. Feuer ist sowohl auf den vulkanischen Kanarischen Inseln als auch im „fire country" Kalifornien stets ein natürlicher ökologischer Faktor gewesen. Beide Gebiete weisen eine Flora auf, die an das Feuerrisiko in besonderem Maße angepaßt ist. Heute steht unter den Feuerursachen der Mensch an erster Stelle. Die hypsometrische Verbreitung der Brände wird vornehmlich durch das Klima und die Menge der feueranfälligen Biomasse vorgegeben. So findet sich in der zentralen Sierra Nevada (Kalifornien) die Höhenstufe größter Feuerhäufigkeit bei 1400–2100 m (Koniferen-Mischwald), während auf den Westkanaren die Höhen von 800–1400 m besonders betroffen sind (Kanarischer Kiefernwald und Übergang zum Monte Verde-Gürtel). Insgesamt gesehen erscheinen die geoökologischen Folgeerscheinungen der Brände auf den Kanaren weniger tiefgreifend und langandauernd als in Kalifornien, so daß schwerlich von „ökologischen Katastrophen" gesprochen werden kann. Die Reproduktion der Vegetation nach den Bränden vollzog sich auf den Kanaren rasch, insbesondere an relativ humiden Standorten. Anders als in Kalifornien überwogen auf den Kanaren wenig intensive Grundfeuer. Die Kanarenkiefer gehört zu den am meisten feuerresistenten Koniferen. Es wurden weder ernsthafte Erosionsprobleme noch dauerhafte Störungen des Wasserhaushaltes im Gefolge der Brände beobachtet. Größere Bestandsdichte bzw. Biomasse im kalifornischen Koniferenmischwald (bedingt durch klimatische Faktoren und langandauernde Feuerschutzpolitik) begünstigt intensivere Kronenfeuer und damit weitergehende geoökologische Folgeerscheinungen. Das wesentliche ökologische Problem liegt jedoch nicht im Feuer selbst, sondern in den anthropogenen Eingriffen in die natürlichen Abläufe und Strukturen.

1 Introduction

Wildfires in forest and shrubland ecosystems are of particular ecological significance in subtropical countries with a summer-dry mediterranean type climate. In the Mediterranean countries some 200,000 hectares of land are burnt over year after year with an estimated economic damage of more than 100 Mio US-$ in 1980 prices (LE HOUÉROU 1981, TRABAUD 1981) and with an increasing tendency. Fire is a permanent menace to human property and lives especially in the densely populated regions of California (see e. g. the Oakland-Berkeley firestorm on October 20, 1991, which destroyed more than 3000 homes and took 24 lives). Many fire events which ran out of control were declared as "ecological disasters" in the communication media. Each fire produces a complex of abrupt or lasting changes in the entire environment, regardless of the economic or human aspect. Thus fire patterns and environmental changes following fire are an important object of geoecological studies. The paper will give some comparative reflections on fire ecology, based on case studies in the western Canary Islands (Province Sta. Cruz de Tenerife) and in Central California.

2 Fire distribution patterns and causes of fire origin

In California, the highest number of wildfires per area is concentrated in the Central Sierra Nevada, in the Central Coast Ranges, and in Southern California (Fig. 1)[1]. On the western Canary Islands, six catastrophic fires took place between 1983 and 1990 (Fig. 2), with a total area of more than 16,500 ha (or nearly 5% of the total island area). Taking into account the total number of fires of all dimensions, an annual average of about 80 fires was registered on the Canary Islands for the period 1983–1991 (ICONA 1978 ff.). In California, the annual average of wildfires for the period 1984–91 was calculated at 10,885 with an area of 101,160 ha per annum (California Dept. of Forestry, Wildfire Activity Statistics 1991, S. 46).

Both regions are characterized by a mediterranean type climate with winter rains and summer aridity. The seasonal cycle of humidity and aridity is even

[1] A high total number of wildfires per area is not necessarily equivalent to massive ecological effects, however. A few high-intensity wildfires out of control generally can be more destructive than many low-intensity fires of local importance only.

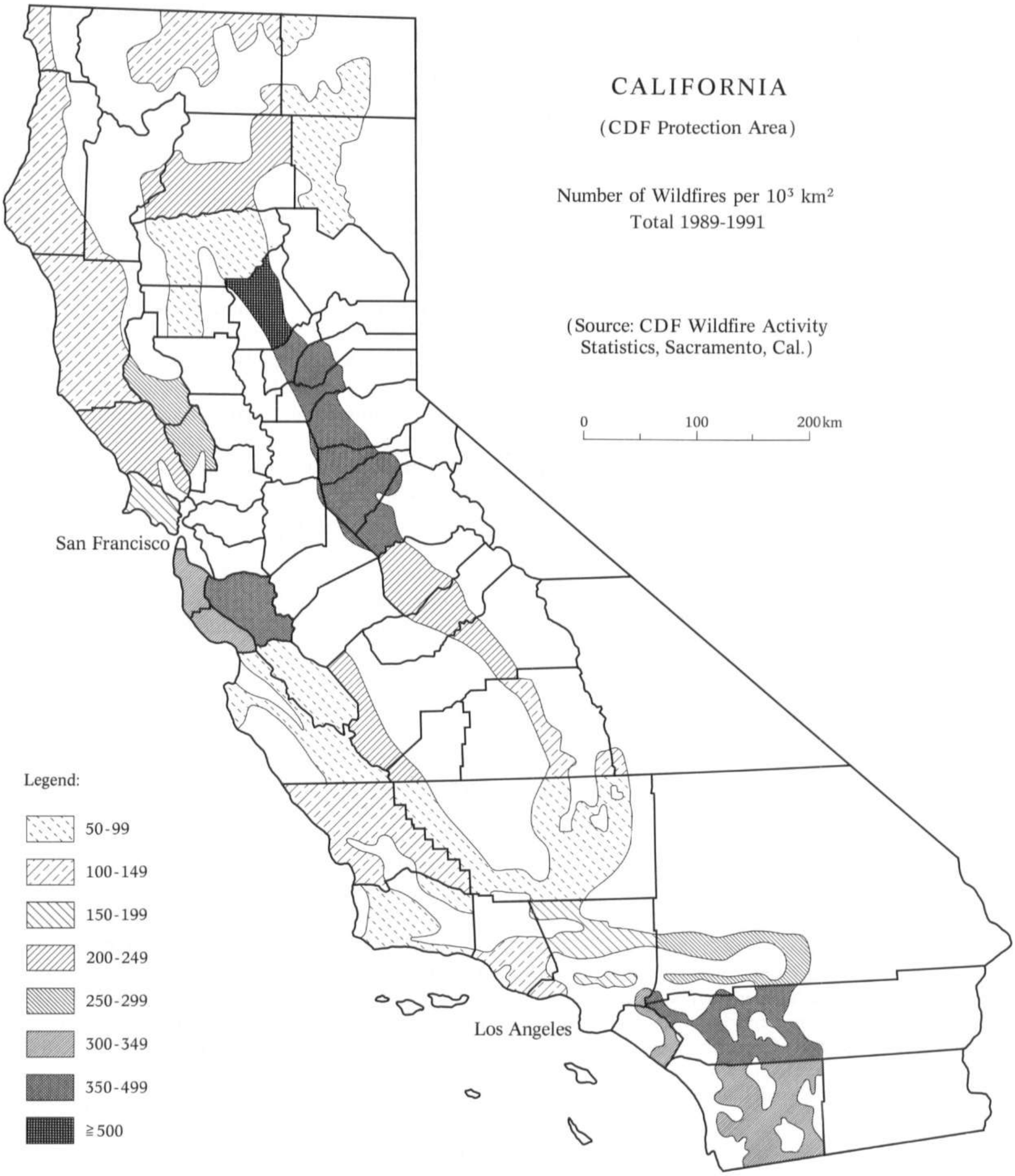


Fig. 1: Number of wildfires per 10^3 km^2 in California, 1989–1991
Zahl der Brände pro 10^3 km^2 für die Periode 1989–1991 in Kalifornien

more pronounced in Central California than on the Canary Islands (Fig. 3, below). In the altitudinal zonation of mountain vegetation the multi-storied forest belt finds its optimal development at medium heights with maximal humidity, i. e. above the arid foot belt and below the cooler high mountain belt. Corresponding to the seasonal climate in both regions, the peak of the fire season culminates in the arid late summer and early fall, when the biomass fuel and litter is dried out and extremely inflammable

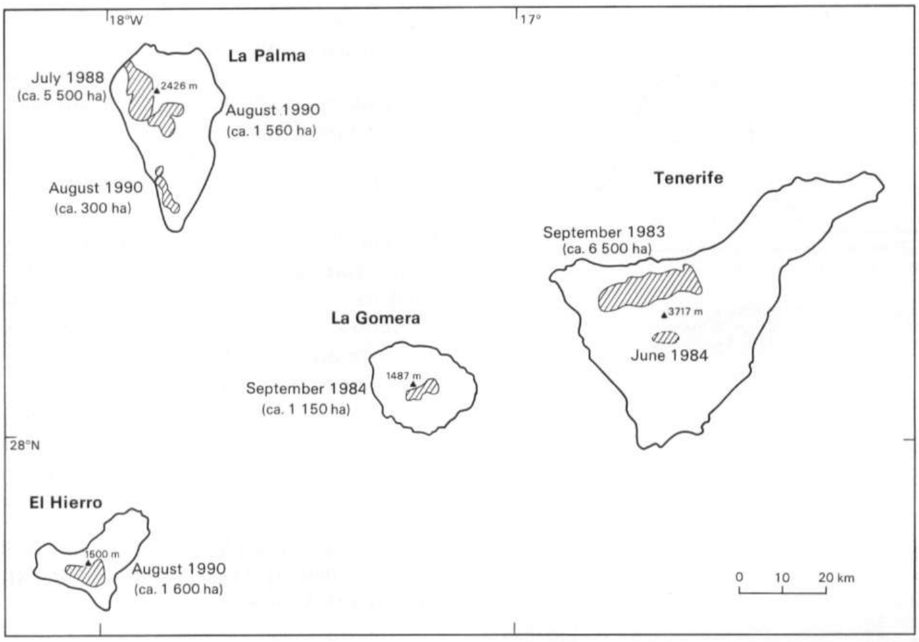


Fig. 2: Large damaging wildfires on the western Canary Islands, 1983–1990
Große Schadensfeuer auf den westlichen Kanarischen Inseln 1983–1990

(Fig. 3, above). Hot spells with gusty winds (e. g. the "tiempo sur" or "scirocco" of the Canaries, or the "Santa Ana winds" in California) promote the uncontrolled spreading of disastrous fires. Nearly all of the recent extensive damaging fires on the Canary Islands developed under "scirocco" conditions with hot and dry air masses spreading from the North African continent over the archipelago.

The great majority of the actual fires are caused by man due to careless handling with fire as well as arson (Table 1). Arson appears to be of greater importance on the Canaries than in California, especially as an estimated half of the unknown causes can be attributed to arson as well. Ignition by lightning is more important in California. In the Sierra Nevada forests hundreds of lightning-set fires occur in summer and may exceed or equal the number of man-caused fires there (KOMAREK 1968). On the Canary Islands the air convection in summer is restricted by the small land area and by the cool marine waters (Canary current and cool upwelling waters). Consequently, the Canarian forest belt has an average of only 2–3 thunderstorms per year, with a maximum in winter time (invasion of cool air masses and frontal activity). Fire has been a natural ecological agent since the origin of the Canary Islands in the Tertiary Period, however, owing to the volcanic environment still active up to the present days (La Palma 1971 and 1949, Tenerife 1909). Otherwise the distinct pyrophytic character of the forest and shrubland species with their genetic adaptions to a fire environment would not be possible.

The altitudinal zonation of forest fires in the mountains is controlled mainly by the quantity and condition of the fire-susceptible biomass, which is closely related to climatic factors. On the Canary Islands the altitudinal belt of maximal areal distribution of the extensive fires during 1983–1990 is situated between 800 and 1,400 m, which corresponds more or less with the belt of optimal biological net production and biomass concentration. This belt of maximal fire distribution coincides particularly with the lower part of the Canary pine forest belt and the transition zone to the Monte Verde-belt. The structure and areal distribution of the Canary pine forests is well documented by recent publications (DEL ARCO et al. 1990, 1992, 1993; SALAS et al. 1993; BLANCO ANDRAY et al. 1989). The wet Canarian laurel forest is not very fire prone, but the progressive destruction and degradation of the natural vegetation promote flammability. – On the western slope of the Central Sierra Nevada the maximal number of lightning-caused forest fires and the shortest fire cycles concentrate between 1,400 and 2,100 m (REYNOLDS 1959, HÖLLERMANN 1990), in accordance with maximal biomass in the belt of mixed coniferous forests and the upper part of the Yellow Pine belt *(Pinus ponderosa)*. Biomass, vegetation cover, and the fire quota

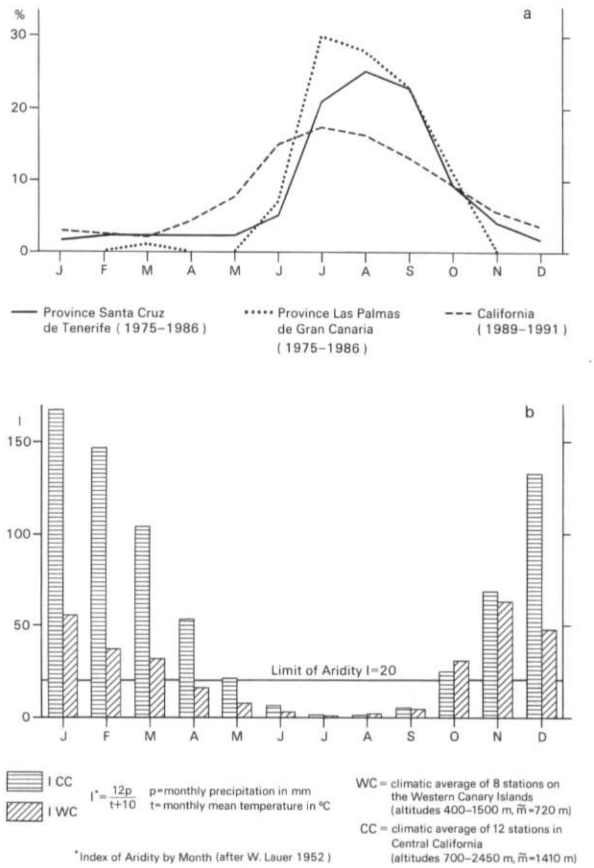


Fig. 3: (a) Annual cycle of wildfires (percentage per month) and (b) of aridity (index by month after LAUER) in the fire-affected forest and shrubland belt on the Canary Islands and in Central California

(a) Jahresgang der Feuerhäufigkeit (monatlicher Anteil in %) sowie (b) Jahresgang der Aridität (monatlicher Ariditätsindex nach LAUER) in den betroffenen Gebieten der Kanarischen Inseln und Zentral-Kaliforniens

decrease to the arid foot belt and to the high mountain belt. Evidently, in subtropical mountains with a mediterranean type climate an altitudinal zone of maximal forest fires (either in number, frequency, or affected area) is a characteristic pattern.

3 *Fire and vegetation*

Both regions possess a vegetation and flora well adapted to the fire risk. Ample scientific literature exists about the fire ecology of vegetation types in California, which needs no special reference here (see e. g. Proceedings, Tall Timbers Fire Ecology Conference, Hoberg Calif. 1967; AGEE et al. 1977, BAR-

Table 1: Causes of fire origin
Ursachen der Brände

California 1989–91 (CDF Protection Area)		Western Canary Islands 1983–91	
Lightning	5.7%	Lightning	0.4%
Arson	6.9%	Arson	23.3%
Equipment use	24.3%	Carelessness (e. g. by debris burning, tourists, smokers, forest workers, charcoal burners)	28.3%
Debris burning	10.6%		
Smokers	8.4%		
Campfires	2.7%		
Play with fire	3.6%		
Miscellaneous	37.8%	Miscellaneous	3.9%
		Unknown causes (an estimated half by arson likewise)	44.1%

Sources: California Dept. of Forestry: Wildfire Activity Statistics 1989–91, Dirección General del Medio Ambiente 1987, ICONA 1978ff.

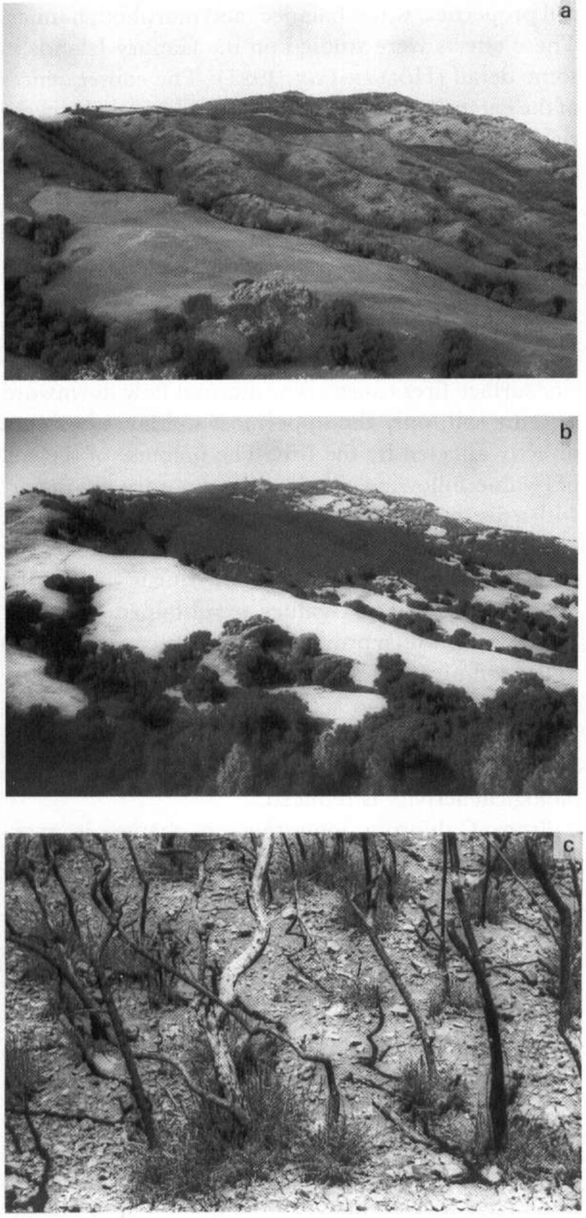
BOUR a. MAJOR 1977, HANES 1971, HÖLLERMANN 1990, KILGORE 1973, KILGORE a. TAYLOR 1979, REYNOLDS 1959). In the Californian Chamise Chaparral the usual fire cycle is about 10 years. Following fire, new sprouts from the base of the burnt stems come up very soon, and after 8–10 years the shrub formation has recovered (Photos 1 a–c). In the Yellow Pine Forest *(Pinus ponderosa)* periodic low intensity surface fires were frequent under natural conditions, thus creating open park-like forest stands. In the mixed coniferous forest of the Sierra Nevada the Giant Sequoia *(Sequoiadendron giganteum)* needs fire for reproduction by seedlings, a process which is supported by controlled burning nowadays. In the open subalpine forest belt fires are rare. All the different vegetation formations have a particular fire regime and specific adaptions of survival or recovery.

The open stands of the Canary pine look very similar to the Ponderosa pine forest of California. Mature specimen of the endemic *Pinus canariensis* are protected by a heat-insulating thick bark. Our fire simulation experiments exposed the surface of the pine bark with temperatures of about 400 °C for a time span of 45 minutes, but the cambium tissue on the inside of the dry bark (2.5 cm thick) was not endangered by lethal temperatures above 55 °C. Following fire, the Canary pine develops many new sprouts from the base of the stem or from dormant buds of the trunk and branches. The fire-stimulated resprouting brings about strange looking fire-column shapes of heavily burnt trees. Furthermore, great numbers of pine seedlings follow a burn and find favourable conditions for establishment in the ash bed and upper soil layer with a concentration of available nutrients. The dominating species of the heath forest or shrub, namely *Erica arborea* and *Myrica faya*, have the ability for rapid basal sprouting following fire. The sprouting Monte Verde shrubs attain a height of 1 m in 2 years and 3–4 m in 7–8 years from the burn. Most woody shrubs on the forest floor reproduce from seeds stimulated by fire (e. g. *Adenocarpus, Chamaecytisus, Cistus,* or *Echium*). Herbaceous geophytes recover from underground bulbs or tubers (e. g. *Asphodelus, Habenaria*). Anthracophytes are attracted by the availability of nutrients in the ash layer (e. g. many *Gramineae* and *Leguminosae*).

On favourable sites in the humid cloud belt the post-fire reproduction and regeneration proceeded very fast due to the sprouting of the Canary Pine and some Monte Verde shrubs (Photos 2a–c). On more arid sites in southern aspect or at higher elevations the regeneration of the burnt vegetation is retarded. Furthermore, the re-establishment of the vegetation structure and cover depends on fire intensity. The predominance of low intensity surface fires in the Canary pine forests restricted the environmental consequences in most areas. The regeneration of a burnt Canary pine forest with a substory of heath shrubs needs about 8–10 years, as a rule, while shrubland formations recover in 5–8 years. Reforestations with the Californian Monterey pine *(Pinus radiata)* became mostly killed by intense fires and will be replaced by the native Canary pine. The post-fire regeneration of Canarian forest and shrubland communities can be documented by series of photographs (e. g. Photos 2a–c) as well as by diagrams of vegetation structure pyramids, figuring stratification and coverage.

4 Fire geoecology on the Canary Islands and in California

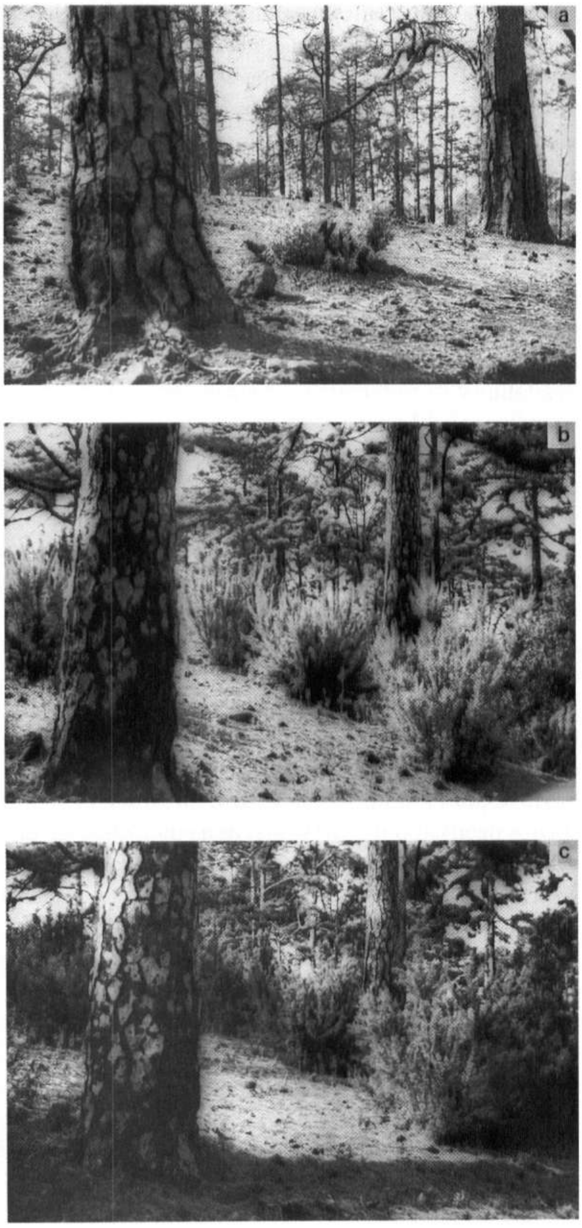
It is well known that wildfires cause complex geoecological changes in the environmental systems, affecting the vegetation, animal life, microclimate,



Photos 1a–c: Vegetation pattern and post-fire regeneration in the Central Coast Ranges, California
a: Southern slope of Mount Diablo (Diablo Range) with burnt chaparral, grassland, and oak woodland (fire in summer 1968, photo taken in December 1968)
b: Idem (photo taken in July 1992). The vegetation structure is completely restored (see especially the dense chaparral formation above the center of the photo)
c: Burnt chamise chaparral *(Adenostoma fasciculatum)* with basal sprouts one year after the fire of summer 1968 (photo taken in July 1969). Location at southern slope of Mount Diablo, about 900 m a. s. l.

Vegetationsmuster und Regeneration nach dem Feuer im mittleren Küstengebirge, Kalifornien

a: Südabdachung des Mount Diablo (Diablo Range) mit verbranntem Chaparral, Grasland und Eichengehölz (Feuer im Sommer 1968, Photo im Dezember 1968)
b: Gleiches Gebiet (Photo im Juli 1992). Die Struktur der Vegetation ist völlig wiederhergestellt (vgl. besonders die dichten Chaparral-Flächen oberhalb der Bildmitte)
c: Verbrannter Chamise-Chaparral *(Adenostoma fasciculatum)* mit basalen Sproßausschlägen ein Jahr nach dem Feuer im Sommer 1968 (Photo im Juli 1969). Lage an der Südabdachung des Mount Diablo um 900 m Höhe



Photos 2 a–c: Regeneration of a Canary pine forest with an understorey of heath shrub *(Erica arborea, Myrica faya)* after the fire of July 1988. Location near Puntagorda, La Palma, Canary Islands, northern aspect, about 860 m a. s. l.

a: Photo 31. December 1988

b: Photo 21. November 1991

c: Photo 7. April 1993

Fortschreitende Regeneration im Kanarischen Kiefernwald mit Heidebusch-Unterwuchs *(Erica arborea, Myrica faya)* nach dem Brand vom Juli 1988. Lage nahe Puntagorda, La Palma, Kanarische Inseln, Nordauslage um 860 m Höhe

a: Photo vom 31. Dezember 1988

b: Photo vom 21. November 1991

c: Photo vom 7. April 1993

soil properties, water balance, and morphodynamics. These effects were studied on the Canary Islands in some detail (Höllermann 1993). The consequences of the extensive fires for animal life – especially on the rich invertebrate fauna of the forest belt – were less radical than expected (Machado 1983). On the burnt soil surface the daily temperatures and radiation balance are increased, and the seasonal variation of soil moisture proved to be more extreme than on unburnt sites. In the fresh ash layer and upper soil the supply of available nutrients and the soil pH are raised by mineralization of biomass. Since low intensity surface fires cause a low thermal flow downward into the soil, only the uppermost soil layer becomes directly affected by the fire. The increase of the soil pH-value following fire has a temporary character, with a distinct decrease near the soil surface in the first six months and a more gradual reduction in the following years. 10 cm below the burnt surface the maximal post-fire pH-values are obtained after only 2 or 3 years, which proves that the fire-caused change in the soil nutrient status persists over several years. Fire brings about an accelerated remineralization in the nutrient cycle of ecosystems in seasonal arid climate, where the normal decomposition and microbiological activity is reduced.

From California mountains a change in morphodynamics with increased runoff, landslides, mudflows, dry erosion and floods after fire was reported (see e. g. Mooney a. Parsons 1973, Bauer 1978, Fuller 1991). In the Canary Islands the detrimental consequences following fires were by far less important. No serious soil erosion problems or lasting disturbances of the water balance by fire were observed. Any sites of accelerated runoff and erosion in burnt-over land were generally due to human disturbance, and not to fire. Even heavy rainstorms with precipitation levels of 300 mm and more within three days in December 1991 on La Palma did not result in accelerated erosion on slopes affected by the fires of 1990.

Thus the geoecological consequences following fire were less detrimental and long lasting on the western Canary Islands than in Central and Southern California, as a rule. The longterm geoecological and environmental consequences of the forest and shrubland fires on the Canaries may, on the whole, not be classed as disastrous or as "ecological catastrophes".

This can be partly explained by the dominance of less intensive surface fires in the Canary pine forest. About 90% or even more of the burnt areas in the Canary pine forest were exposed to surface fires of low or medium intensity only, while less than 10% were affected by intense crown fires. The intense and damaging fires were mainly concentrated on steep slopes, ridges and mountain tops. The dominant low-intensity surface fires were unable to totally destroy the organic matter of the upper soil layer, which generally retains a high infiltration capacity controlling runoff and erosion. Furthermore, the mature Canary pine is one of the most fire-resistant coniferous trees with active and passive pyrophytic qualities, as well as the most components of the fire-prone plant communities of the Canary Islands possess effective pyrophytic adaptions.

The standing biomass and availability of fuel is usually higher in Central Californian coniferous forests, where there is a more distinct winter humidity and long lasting winter snow than in the Canarian forests. The policy of fire exclusion between 1905 and about 1965 has created dense forest stands with understory thickets and a dangerous fuel situation in the Sierra Nevada, subject to destructive crown fires after ignition. Lightning-set fires are frequent. In the remote mountain landscapes the risk of uncontrolled and extensive high intensity wildfires is very high. Consequently, crown fires are widespread. In the Californian chaparral shrublands fires tend to burn hot and develop a water repellent layer in the soil (see e. g. DEBANO 1970, BAUER 1978), thus increasing runoff and erosion on steep slopes. A higher fire intensity and frequency in Californian mountains results in more far-reaching environmental consequences of the forest and shrubland fires than on the Canary Islands. The role of fire as a natural ecological factor is widely accepted in Californian forestry, national park and range management. Controlled burning (prescribed burning) increasingly finds use as a tool in landscape management and as a measure to reduce the high risk of catastrophic fires.

5 Concluding remarks

Fire always has been a natural geoecological factor on the volcanic Canary Islands, as well as in the "fire country" of California. In climates of pronounced seasonal aridity and reduced microbiologic activity the fire even brings positive effects under natural conditions by the accelerated remineralization of organic matter in the nutrient cycle and by the stimulation of plant growth. In fire geoecology general conclusions are delicate, however, because no fire is like the other, and the environmental consequences and economic damages can be expected to differ in each particular case and require special and detailed field studies. In a comparative view, the geoecological and economic consequences following fires are less detrimental and long lasting on the western Canary Islands than in Central or Southern California. This statement, however, should not be regarded as an encouragement for careless handling with fire or even for pyromania. Fire can be a natural ecological control factor and a useful tool in landscape management, but it needs not be said, that the frequent abuse of fire is detrimental to the forest or shrubland ecosystems. Frequent fires in short time intervals may bring about accumulated damaging effects. This is especially true for ecosystems in highly diverse island environments with limited space as against wide open continental areas. The major ecological problem, however, is not one of fire alone, but of growing human impact and stress on the natural environment.

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