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Ecological consequences of the abandonment of traditional land use systems in central Spain

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SUMMARY - The traditional land use systems on a pediment surface near Madrid, Spain, are described in this paper. Shifting agricultural systems and sylvopastoral systems had important environmental advantages, including maintenance of biological diversity and resistance to wild fire. Field margins and meadows were important components of landscape diversity. Abandonment of the arable land may have positive effects if fire erosion can be controlled. Disturbance of the sylvopastoral systems may involve overgrazing, as in feed lots, or undergrazing. Undergrazing results in growth of coarse vegetation and increases the potential for fire, as well as causes a decline in biological diversity. Traditional land use systems may be a source of inspiration in the design of new land management systems.

Key words: traditional agrosystems, pastoral systems, diversity, grazing, fire, landscape, Spain.

RESUME - "Conséquences écologiques de l'abandon des systèmes traditionnels d'utilisation des terres dans l'Espagne Centrale". Nous allons décrire dans cet article l'utilisation traditionnelle des terres dans une région proche de Madrid (Espagne). De précieux avantages environnementaux ont découlé de l'évolution incessante des systèmes agricoles et pastoraux, entre autres la conservation de la diversité biologique et la résistance aux incendies naturels. Les bordures, haies et prairies ont contribué fortement à cette diversité du paysage. L'abandon de terres cultivables peut avoir des conséquences positives si l'on peut contrôler l'érosion causée par les incendies. Le remaniement des systèmes sylvopastoraux peut être dû à un surpâturage, comme dans les parcelles fourragères, ou bien à un sous-pâturage. Le sous-pâturage a comme conséquence l'apparition d'une végétation plus ligneuse et l'augmentation du risque d'incendie, ainsi qu'une réduction de la diversité biologique. Les systèmes traditionnels d'utilisation des terres constituent une source d'inspiration en vue de la conception d'un nouveau type d'aménagement des espaces agricoles.

Mots-clés: agrosystèmes traditionnels, systèmes pastoraux, diversité, pâturage, incendie, paysage, Espagne.

Study area

The pediment forming a broad strip around the Guadarrama Mountains has an altitudinal range from about 700 m. in its southern border near the town of Madrid, to about 1200 m at its northern end. It forms a gently sloping surface (10° to 20°) between the steep slopes of the Sierra and the borders of the sedimentary basin of Madrid (Comunidad de Madrid, 1986). The pediment is formed by granitoid and gneiss rocks (upper reaches) and by blocks, gravel and coarse arkose (lower part). The soils include rankers and dystric ochrepts on the granites and gneiss, and rankers and alfisols (brown non calcic soils) in the arkosic part.

The pediment surface is broken by water courses, flat depressions ("navas"), and some residual relief ("inselberg"). Because of altitudinal differences, there is a marked climatic gradient across the pediment, with precipitation ranging from 500 mm to 900 mm and an average annual temperature of 13° C-19° C. The climate is typically mediterranean, with a markedly dry period in summer.

Prior to the urban and industrial transformation of the Madrid area, very old land use systems had seriously altered the natural environment of the area (González Bernáldez and Gallardo, 1989).

1. The most altered granitic areas (depressions, biotite, granite, etc.) and the arkosic region were occupied by agrosylvopastoral systems, that had transformed the original forest into a holm oak and ash parkland ("dehesa"), partly subject to shifting cultivation.

2. The areas with less developed soils (certain gneiss and leucocratic granite) were used for browsing (goats)

and charcoal production. Characteristic vegetation was Mediterranean shrubland: holm oak, cistus, lavender and broom species (*Cistus ladanifer, C. laurifolius, Lavandula stoechas, Cytisus scoparius, Genista cinerea,* etc.).

Environmental aspects of traditional land use systems

Prior to considering the abandonment and destabilisation processes of the traditional land use systems, it would be interesting to describe their characteristics and their environmental advantages, as compared with either the more intensive forms of agriculture or, conversely, the landscapes that result from their dereliction.

1. Arable land

The primitive agricultural systems on the rather poor soils of the Madrid pediment were characterized by long fallow periods. These systems can also be considered as forms of "shifting cultivation". No, or very few, fertilizers (in the form of farm manure) were applied to these soils, fallow periods being inversely proportional to soil natural fertility and recovering capacity (the latter was related to silt and clay content). As a rule, about 40-60 trees per hectare were conserved ("dehesa system"). With very long fallow periods (10 to 15 years) this parkland landscape persisted, but tree regeneration was prevented with shorter fallow periods, and a treeless landscape ultimately resulted.

Shifting cultivation with very long fallow periods still occurs in some dehesa areas in the Madrid pediment and in many regions of the SW of the Iberian Peninsula, its purpose being shrub control or the management of game animals, specially the red partridge. Such form of agriculture can provide many examples of succession for assessing community evolution following set-aside practices. Nomadic or itinerant cultivation resulted in a high diversity of habitats (high β diversity), because of the coexistence of different successional stages and the presence of specialized flora and fauna.

2. Sylvopastoral systems

Ruiz and González Bernáldez (1983), Barrios, *et al.*, (1985) and Ruiz, *et al.*, (1985) have studied the characteristics of the grazed landscapes in the Madrid pediment, relating landscape characteristics to management systems and environmental perception.

Typical sylvopastoral systems consisted of two layers: a tree layer of holm oak (*Quercus ilex* subsp. *rotundifolia*) with improved, large and very poor in tannin fruits and a legume rich herb layer. The original forest has been transformed into a pseudosavanna, and the density of holm oak is about 40 to 100 trees per hectare depending on tree age. There is evidence of holm tree improvement from ancient times, as they were usually planted from selected acorn sources (a practice still observed by the author in Salamanca, SW Spain, in the 1950s). The sharp boundaries of two neighbouring estates may neatly separate *Quercus ilex* subsp. *rotundifolia* from other *Quercus* species (*Q. pyrenaica* or *Q. faginea*) by a straight line. This separation can be observed for *Q. pyrenaica* along a stone wall in Las Golondrinas area, Cercedilla, in the upper reaches of the Madrid pediment. This evidence is in accordance with the anthropic substitution of *Quercus* spp. by *Quercus ilex* in western Mediterranean, supported by palynological fact (Reille, *et al.*, 1980).

Every grazed piece of land includes two geomorphological and hydrological components:

- The well drained ridges ("altos", "cerrillos") characterized by rocky outcrops, producing early grass in winter.
- The depressions ("bajos", "baenes") flooded by groundwater in winter. Although too wet and cold for winter grazing, they produce grass during the dry summer, thus helping to buffer the marked seasonality of the mediterranean climate.

A similar geomorphological-climatic complementarity is found in areas without noticeable flow of groundwater, such as the Sierra Morena shale, but here the southern and northern slopes ("solana" and "umbría") are the alternating sectors.

Studies on the perception of environmental quality revealed that traditional livestock raisers are very sensitive to deviations from an ideal or canonical landscape model. For instance, dry grass patches refused by cattle ("rehúsos") are avoided, as are heavily grazed surfaces ("lamido"). Uniformity of grazing within the whole area is important, and is achieved by different methods (careful planning of gates, shelter trees, watering, salt and feeding point location).

Perception and system studies show that the landscape model of traditional livestock raisers corresponded to an adaptive adjustment aimed at buffering external influences.

- The two vegetation layers allow the consumption of acorns and branches ("ramón") during cold periods (De Miguel, 1989).
- Geomorphological complementarity between drained ridges and humid lowlands represents a climatic buffering system. This complementarity is taken into account when the land is bought or divided.
- Tree cover at given densities had a marked microclimatic effect, buffering radiation and lowering

wind speed at ground level, thus improving both grass production and livestock shelter (González Bernáldez, *et al.*, 1969); (De Miguel, 1989).

- The extensive root system of the holm oak brings cations to the soil surface, thus improving grass nutrition on poor soils (González Bernáldez, *et al.*, 1969). The advantages of the oak mycorhizas and of microbial nitrogen fixation in the soil are additional benefits.
- The frequently grazed, evenly textured short grass layer ("majadal") is rich in annual legumes. There are at least 29 clover species in the granitic pediment of Madrid (Ruiz, 1980). These species are adapted to various microrelief and grazing intensity patterns, but most are suppressed when grazing is discontinued. Clover and annual Medicago species are responsible for nitrogen inputs to the system, and very likely for maintaining a pool of organic phosphorus.

This traditional land use system required no, or very few, external inputs (fertilizers, energy), and was aimed at promoting stability by buffering fluctuations, although its productivity was low compared with intensive forms of agriculture.

From a modern point of view, the landscape maintained by these land use systems is endowed with important environmental advantages:

- A high biological diversity. As in other areas grazed over long timescales, plant diversity is very high (Naveh and Whittaker, 1979). Diversities amounting to 5 bits using Shannon's formula have been found by Pineda *et al.*, (1981).
- Animal diversity in holm oak parkland is also high (Herrera and Soriguer, 1978; Parra, 1988). Wintering bird species from northwestern Europe are important components of the avifauna: *Sylvia atricapilla, Phylloscopus collybita, Erithacus rubecula, Turdus philomelos,* etc. As most of these species are insectivorous and very popular components of the landscape in their northern breeding grounds, traditional sylvopastoral landscapes in Spain are important in maintaining ecological balance in other European countries.
- The contrast between the tree and herb layers allows the occurrence both of characteristic species of open areas (*Anthus pratensis, Motacilla flava* and wood species such as *Fringilla coelebs, Certhia brachydactyla, Sitta europaea* and some *Paridae*). The cavities of the long lived trees facilitate the presence of tree hole specialists such as *Athene noctua, Strix aluco, Coracias garrulus, Uppupa epops,* or tree hole-dependent mammals, *Eliomys quercinus, Genetta genetta, Mustela nivalis,* etc.
- The floristic diversity is reflected by the richness of insect species. Gómez Bustillo and Rubio (1974) have reported on the butterflies of the Casa del Campo and El Pardo area managed as "dehesa" since ancient times. Seventy five species of *Rhopalocera* are known from the Casa de Campo (2600 hectares).
- The presence of game species (hare, rabbit, red partridge, wood pigeon) is an important economical aspect, specially when shifting cultivation is practised.
- The resistence to wild fires of the adequately managed "dehesa" system is very high. Fire resistance is not a function of tree species, but of stand structure and management characteristics. As in other mediterranean species, the burned holm oak tends to regrow from the base giving rise to dense patches ("arderas" or "barderas") which prevent erosion.
- The traditional system demanded no or very few external fertilizer inputs, thus minimising the risk of pollution typical of intensive forms of agriculture.
- The large amount of long lived phytomass represented by holm oak is an important factor in reducing the greenhouse effect (as in the case of old olive tree stands).
- Some studies on landscape quality perception stress a preference for parkland structures (Abell, 1984; Woodcock, 1984; González Bernáldez and Gallardo, 1989). Picnicker behaviour studies in the Madrid area show a strong preference for dehesa parkland specially in winter, preference for riverine forest increasing in summer (González Bernáldez, 1981).

Land use system abandonment and destabilisation

1. Arable land abandonment

Succession following the itinerant ploughing which is traditionally carried out in some parts of the Madrid pediment has been described and analyzed by Pineda *et al.*, (1981); De Pablo *et al.*, (1982); Casado *et al.*, (1988) and Peco (1989).

Abandonment after ploughing results in a succession process that requires over 20 years to reach equilibrium as a mature ecosystem under the prevailing grazing pressure. Alfa diversity increases with succession, and niche amplitude tends to diminish, the new plant species becoming specialists of increasingly narrower habitats (Table 1 and 2).

Table 1. Changes in entropy resulting from ploughing abandonment of slopes in the Viuelas area, Monte de El Pardo (Madrid). After Pineda et al. 1981.

	Years after ploughing			
	1	2	4	> 20
Number of species	25	33	34	44
H(E), diversity	2.76	3.52	4.42	4.94
$Ap = \frac{H(P/E)}{\log_2 \text{nb.plots}}$	0.81	0.77	0.77	0.74
$Ap' = \frac{H(S/P)}{\log_2 \text{nb.sectors}}$	0.86	0.76	0.76	0.69

H (E), represents the entropy of the species and is equivalent to Shanon's diversity index.
Ap and Ap' are measures of niche amplitude derived from the total entropy theorem. H (P/E), entropy of the sampling plots conditioned by the species, is a measure of the incertitude about the sampling plot from which a given specimen is taken. As this value depends on the number of sampling plots, it has been standarized by dividing by the $\log_2$ of the number of plots, similarly to Pielou's index for niche amplitude W = H (P/E) / H (P).
Similarly, H (S/P) represents the niche amplitude when slope geomorphological sectors (erosion, transport, and accumulation zones slope toe) instead of sampling plots are used.

Table 2. Number of species with weak entropy values (specialists) during succession. After Pineda et al. 1981.

	Years after ploughing			
	1	2	3	4
Number of species	25	33	34	49
Number of species of weak entropy, Ai ≤ 0.3	6	8	10	20
Ratio	0.24	0.24	0.29	0.41

Ai, specific niche amplitudes, = H (P/E_i) / $\log_2$ nb.plots are the specific components of niche amplitude referred to sampling plots H (P/E) /$\log_2$ nb.plots.
See explanation in table 1.

This decrease in niche amplitude is visible when the data refer either to sampling plot units or slope geomorphological factors, corresponding to an increasingly finer spatial resolution as succession proceeds (Pineda *et al.*, 1981; Casado *et al.*, 1988).

Succession after ploughing is influenced by weather, the humid periods corresponding to rapid advances toward maturity, and the dry years to slower progress or even to regressive succession episodes. Peco *et al.*, (1983) and Peco (1989) studied the influence of climatic factors on succession in abandoned fields. A model of succession including weather influences is given by Peco (1989) as:

$$D = a_0 + a_1\, S(i) + a_2\, y + a_3\, S(i)\, y + a_4\, n + a_5\, r$$

where:

D is the value of the coordinate on an ordination axis (correspondence analysis) expressing vegetation dynamics.

S(i) is the site. This value is qualitative and has 5 values corresponding to 5 sites.

y is the number of years since last ploughing in a particular sampling year.

n is the precipitation in November of the autumn prior to the vegetation sampling.

r is the total rainfall during the growing season.

The building up of a grassland seed bank in land subjected to ploughing over a long period can be a long process. Abandoned agricultural land in areas with no livestock access can be devoid of seeds of perennial species such as *Agrostis castellana, Melica ciliata* subsp. *magnolii, Stipa lagascae* subsp. *celakowskii, Koeleria caudata* or *K. longipes* for many years (Departamento de Ecología, UAM, 1978). Livestock is usually a necessary agent for seed transference from grassland to abandoned arable land; other processes, wind, myrmecory, etc., are relatively inefficient for sward formation. As erosion can be a problem in abandoned, non revegetated, agricultural land, distance to uncultivated field margins or interstitial grasslands and the livestock presence are important conservation factors.

Abandoning a percentage of arable land, as contemplated in EEC set-aside regulations, will probably result in an increased wildlife abundance and species richness, and may have positive environmental effects, if the negative side-effects, such as wildfires and erosion, are controlled by promoting succession. A method based on traditional practices could be the overnight livestock grazing in neighbouring pastures ("redileo").

2. Role of interstitial, uncultivated landscapes

Non-cultivated land mosaics, such as old field margins and the characteristic interstitial meadows of the arkosic pediment, are very important for landscape and species diversity within the more intensively cultivated pediment area (Bernáldez *et al.*, 1989a). In the arkosic area, the network of uncultivated meadows contribute to the habitat and biological diversity of a landscape predominantly under cereal crops. These areas are important in providing insect food for the young of some birds of open habitats, such as red partridge (*Alectoris rufa*), sand grouse (*Pterocles orientalis*), little and great bustard (*Otis tetrax* and *O. tarda*), etc., and shelter and feeding grounds of hare and harrier (*Circus pygargus*). Furthermore, they are the wintering habitats of lapwing (*Vanellus vanellus*), golden plover (*Pluvialis apricaria*), etc. (Bernáldez *et al.*,., 1989a).

On the other hand, these meadows will be important grazing areas in summer, and can have also a role as propagule sources for abandoned land succession. *Agrostis castellana, Poa bulbosa, Phleum bertholoni, Festuca ampla* and most of the annual clovers are important for promoting revegetation in erosion sensitive old fields.

Unfortunately, these insterstitial meadows correspond to groundwater discharges that tend to decrease as groundwater is used increasingly for irrigation and other purposes within the area (Bernáldez *et al.*, 1989a,b; Rey Benayas *et al.*, 1989). In large areas of the arkose pediment, the groundwater level is being lowered at a rate of 2 m/year, which encourages ploughing of the drying out meadows. From 1945 to 1977, about 60% of this interstitial uncultivated land was lost in the northern slopes of the Guadarrama, and the rate has probably increased since then.

3. Abandonment and destabilisation of sylvopastoral systems

In addition to their conversion under intensive farming, traditional sylvopastoral systems are subjected to two different types of change related either to the increase or the decrease in grazing pressure.

Overgrazing normally occurs following the predominant use of concentrated animal food and the simultaneous destruction of natural pastures. These pastures are no longer the main source of food, and become merely grounds for "walking and basking" of cattle nourished with imported products. In this way, the traditional rules and feedbacks which prevent overstocking and overgrazing may be violated resulting into the replacement of valuable grasses and legumes by impalatable nitrophilous vegetation. The following species are indicators of overgrazing (Departamento de Ecología, UAM, 1988): *Capsella bursa-pastoris, Hordeum murinum, Erodium moschatum, Onopordon illyricum, Diplotaxis catholica, Trifolium retusum, Sisymbrium runcinatum, Sisymbrium officinalis, Anacyclus clavatus, Lepidium heterophyllum.*

Localized nitrophilous vegetation patches of this kind appear when the even distribution of grazing pressure characteristic of the traditional system is disrupted, thus allowing uncontrolled livestock wandering (Departamento de Ecología UAM, 1988; De Miguel, 1989).

Conversion into coarse or rough pasture results from a release of grazing pressure. It is striking that the abandonment of traditional land use systems has led to derelict, ungrazed, surfaces that coexist with overgrazed areas. Release of grazing pressure is indicated by the encroachment of coarse grasses, such as *Stipa lagascae* o *S. gigantea* and the abundance of dry remnants of *Agrostis castellana*. The thick mats of dry *Agrostis* and other species suppress the development of annual legumes, such as *Trifolium subterraneum, Biserrula pelecinus, Medicago polymorpha*. The coarse grass facies is very sensitive to fire, and is usually followed by shrub encroachment ("matorralización"). Which shrub species invade depends on soil and climatic conditions. *Cistus ladanifer, Lavandula stoechas* invade abandoned pasture in the coarse textured soils of the lower pediment, while *Lygos sphaerocarpa* encroaches into finer-grained deeper soils.

Advanced "matorralización" and coarse grasses induce a decrease in biological diversity as in other mediterranean areas (Naveh, 1974) and are sensitive to fire. Fires are more severe when there are pine plantations; the increased amount of energy released during fire damages the soil and inhibits the otherwise vigorous regrowth of Mediterranean shrubland.

Discussion: traditional land use systems as a source of inspiration for landscape design and environmental protection

Traditional land use systems in central Spain were maintained by the application of empirical knowledge and skills that can be irreversibly lost (Ruiz and González Bernáldez, 1983; Ruiz, *et al.*, 1985).

Many of these systems are characterized by their low energy costs and external inputs, and have a number of environmental advantages. They are also less expensive to the tax payer than the more intensive, highly subsidized forms of agriculture. Although less productive in absolute quantitative terms, they are often highly rated by the excellent quality of their products (for instance, holm oak pore products, "iberian" or "serrano" pig, high quality sheep meat, fine game animals, etc.).

The abandonment of traditional land use systems results in a loss of pastoral value, soil erosion, fire risk, a decrease in biodiversity and threatened vulnerable species. Their abandonment or their conversion to more intensive land use forms usually produce negative effects, because these systems represent very old biological adjustments and equilibria that include complex foodwebs, migration patterns, symbionts, etc. representing delicate balances.

Traditional land use systems may be a source of inspiration for new forms of landscape design and management practices. Research into these vanishing ecosystems is important in order to combine their favourable environmental characteristics with technical and social progress. For instance, some of the sylvopastoral system practices can be useful in promoting succession in abandoned arable land.

Preserving those remnants of traditional land use systems which are threatened by competition with heavily subsidized forms of agriculture and the associated scientific research should be important objectives in conjunction with the new EEC extensification practices.

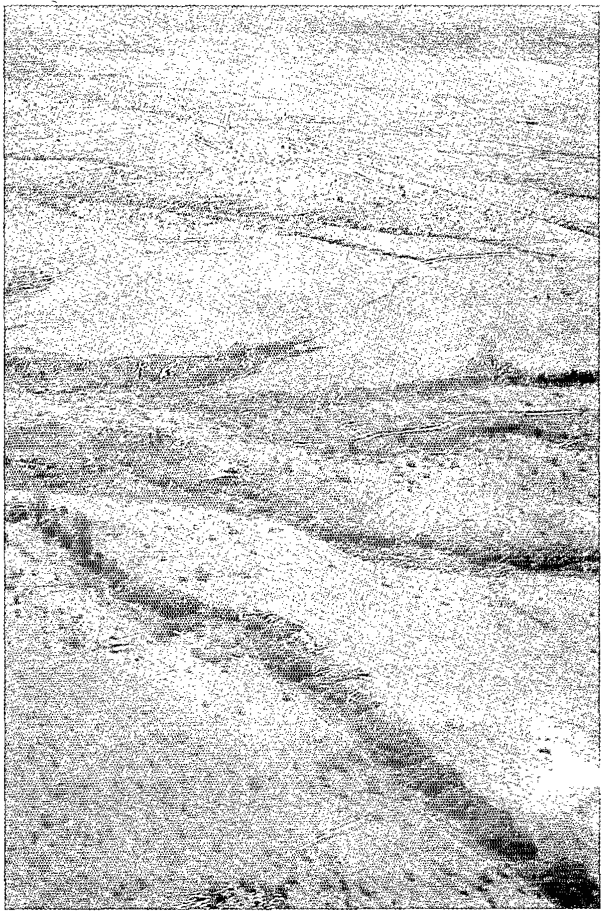

Fig. 1. Abandoned arable land in the arkosic part of the Madrid pediment. Invasion by *Lygos sphaenocarpa* shrubs and very slow revegetation mostly by therophytes. Erosion signs are noticeable. El Garzo (Madrid).

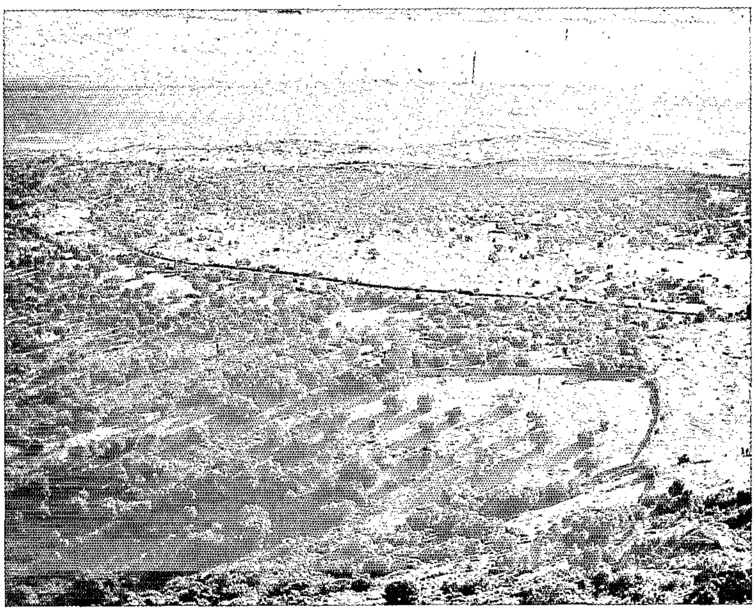

Fig. 2. Ancient way for transhumant livestock, enclosed by stone walls ("cañada") across more or less abandoned "dehesa" landscape in the granitic pediment.

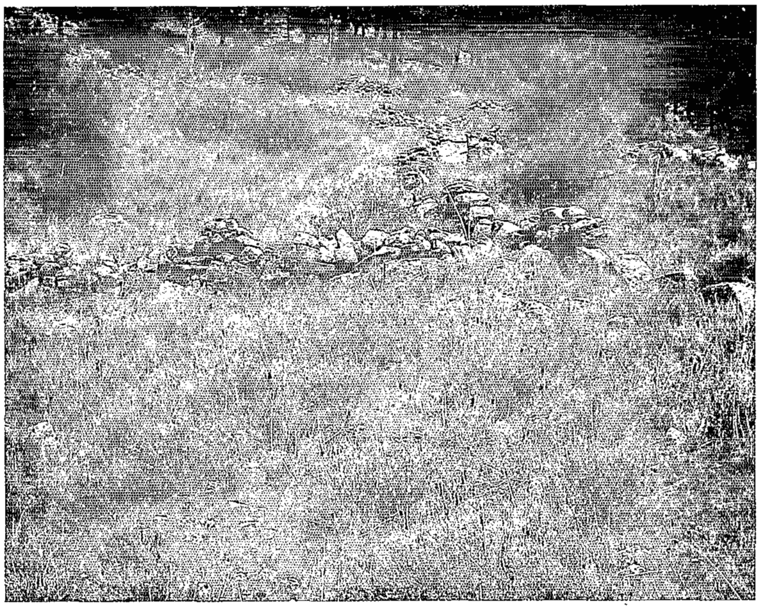

Fig. 3. Abandoned pasture land in an intermediate stage of succession. After a facies of *Stipa lagascae subsp. celakowskii,* encroachment by *Lavandula stoechas* subsp. *pedunculata, Thymus mastichina,* etc. and *Pinus pinaster* from neighbouring plantation. This is a fire sensitive stage. Cerro del Castillo, Colladomediano (Madrid).

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