Chapter 9
Agroforestry Systems in Southeastern Spain

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Abstract Two types of agroforestry systems can be found within the Segura river basin: (a) silvopastoral systems (forest-pasture-ruminants) on cold and moist mountain zones (1,000–2,000 m); – occupying 20% of the basin, where the Segura river originates and the major proportion of protected forest is concentrated – but where human presence is insignificant (1%) – livestock activity is scarce (11.6% of the census), and (b) agrosilvopasture systems (sheep-cereal-rangeland), on dry and cold high tableland (500–1,000 m altitude); occupying 40% of the basin; sustaining half of the ruminants; where half of the land is cultivated under dryland agriculture and sustains a high biodiversity, its human population is scarce (16% of total basin); the economic situation is marginal and; soil erosion losses are high (40% of total). In the other 40% of the basin (lower coastal areas), true agroforestry systems do not exist because livestock is fed with forage by-products from agriculture and concentrates, maintaining high stocking densities, exceeding the capacity of the natural resources. Altogether, agroforestry systems occupy 60% of the basin territory and maintain 62% of the livestock population, but only 17% of the human population, who live under a marginal economic situation and depend on external assistance to maintain their economic activity and to protect the water, forest and biodiversity resources of the basin.

Keywords Segura river basin, agrosilvopasture, land use, desertification

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Introduction

The study area is the Segura river basin, a representative natural unit in the southeast of the Spanish Peninsula, with an area of 18,840 km^2 (3.7% of Spain), and affecting four self governing regions: Murcia, Castile-La Mancha (province of Albacete) Andalusia (provinces of Almería, Jaén, Granada) and Valencia (province of Alicante) (MMA 1997). This diversity makes overall management of the area difficult.

The Segura river basin is the most deficient basin in water resources in Spain with an annual demand of 1,760 hm^3, and only 860 hm^3 renewable. The difference is made up by 540 hm^3 transferred from the Tajo river basin, 210 hm^3 from non-renewable subterranean water and the rest from recycled water. Higher consumption of water for irrigated agriculture, (89% of the total water demand) followed by the urban population of the basin (3.9% of the total Spanish population consuming 10% of the water) and by industry (only 1%). The basin is currently in a fragile equilibrium. In some areas this means there is overexploitation and unsustainable activities, and in others it is the opposite, human desertification and loss of agro forestry activity. The present chapter will deal with the main types of agroforestry systems, environmental issues related to land management (biodiversity, desertification, and fire risk), socioeconomic changes, the future and potential improvements. In the past, agroforestry systems were an important land use and economic activity in the higher and moister areas of the basin. Currently, however, it is now a marginal activity which is less important due to the intensification of agricultural activities in the drier but climatically milder lower plateaus and coastal areas. This has attracted away a large part of the population from the higher and middle basin areas. The future of agroforestry systems in the Segura basin will probably be linked to the preservation of water and biodiversity resources, and to the re-establishment of organic, sustainable agroforestry systems. These issues will be discussed in this paper.

Physical Geography, Topography and Climate

Around a 60% of the Segura river basin is situated in the Region of Murcia (11,150 km^2), 25% in the Province of Albacete (4,713 km^2), 9% in the Andalusia provinces of Almeria, Jaén and Granada and 7% in the Province of Alicante (Fig. 9.1).

The orography of the territory is very complex, with abundant mountain ranges aligned in a SW-NE direction, between which alternate deep valleys, plateaus and plains that spread towards the coast. Forty percent of the basin surface is below 500 m asl, being 81% below 1,000 m asl. The mountain ranges that occupy the largest part of the NW basin often exceed 1,000 m altitude and reach maximum heights over 2,000 m. The plateaus, with altitudes between 500–1,000 m, occupy large parts of the central basin, having a smooth topography and pronounced slopes on the edges. Around 32%

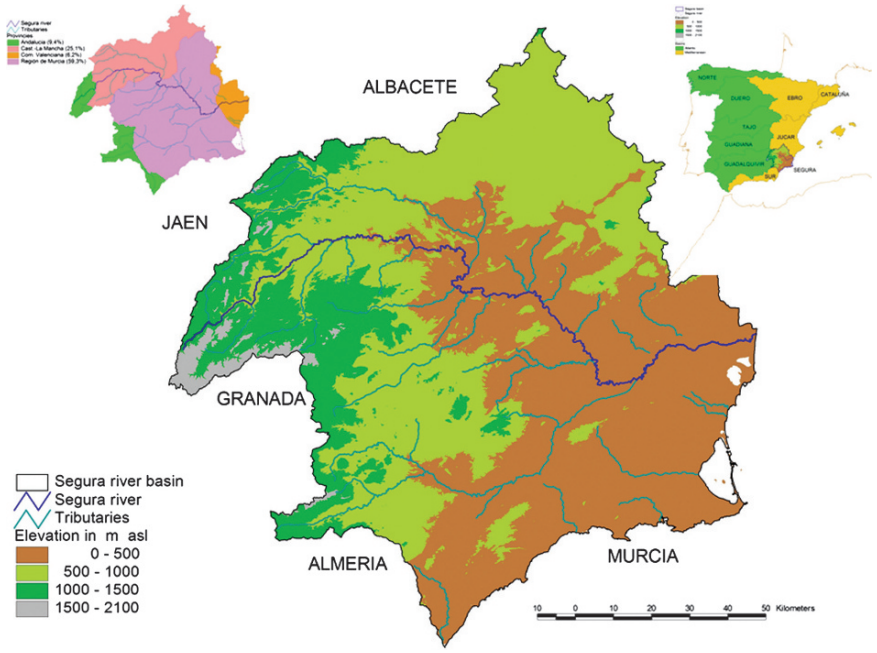

Fig. 9.1 The Segura river basin. Tributaries, ravines, altimetry and administrative provinces included in the basin. The small maps show the localization of the Segura basin in Spain and the Spanish region's territories included in the basin (MMA 1997; IGN 2000)

of the basin territory has a mean slope of less than 5% (coastal plateaus and tablelands), 42% of the basin has a mean slope between 5–20% (hedges and rangelands of the central basin), between 20–50% (the upland areas) close to 22% of the total basin and around 4% of the basin has a mean slope over 50% (high mountains).

The mean annual rainfall in the basin is around 400 mm, but the rainfall regime is very irregular. There are large spatial differences between the highest zones of the basin, where rainfall means exceed 1,000 mm $year^{-1}$ and the lower coastal areas, where mean rainfall is around 300 mm $year^{-1}$ and even lower (Fig. 9.2). The basin receives an annual mean water input of 7,000 hm^3 (equivalent to 370 mm m^{-2}); however, drought years are frequent, and agroforestry systems suffer shortages up to 50% of the time. The pastures of the Segura basin show a clear seasonality, determined by the distribution of the humid and dry periods, and by interruptions to vegetative growth during the winter freezing periods.

Torrential rains are frequent, especially at lower altitudes close to the sea, where rainfall intensities of 100 mm day^{-1} are usual, causing sudden and severe floods.

The lowest temperatures of the basin are found in the northwest mountain ranges, such as the Segura Range, where the mean annual isotherm is 10°C.

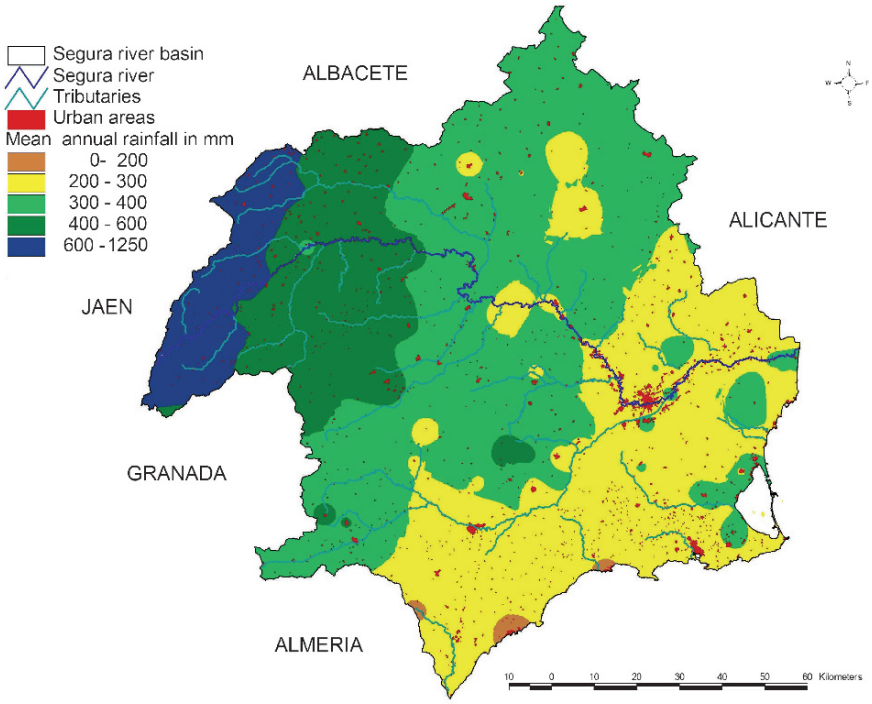

Fig. 9.2 Mean precipitation in the Segura basin (IMN 1961–1990)

Descending towards the coast the temperatures increase, reaching annual means of 18°C in the coastal areas (Table 9.1).

Land Use

Land use in the Segura basin, can be separated into forest and rangeland on one hand and croplands on the other. Rangelands include uncultivated grasslands, shrublands or forested lands with an herbaceous and/or shrubby understory. Agroforestry systems, that is to say the integration of trees and crops, can be found in both types mainly as silvopasture, agrosilvopasture and orchards.

Forest and Rangelands

Almost half (49.5%) of the basin consists of mountain zones and rangelands, occupied by forest species, shrubland and pastureland. The other half is cultivated and the rest (2.5%) is unproductive land (Fig. 9.3). The main forest cover is extensive

Table 9.1 Segura river basin environments: climatic characteristics, population distribution, livestock, and soil erosion, and main types of climax vegetation and agroforestry systems

Segura river basin environments	Cold and moist mountain zone	Dry and cold tablelands and rangelands	Dry and warm lower plateaus and coastal areas
% Basin	20	40	40
Altitude (m)	1,000–2,000	500–1,000	0–500
Pluviometry (mm)	600–1,000	400–600	200–400
Mean annual temper-ature (°C)	10–12	12–16	16–18
% Population	1.2	16.0	82.8
% Livestock census	11.6	50.6	37.8
%Soil erosion losses	13	40	47
Main types of climax vegetation	1. Deciduous and evegreen oak forest 2. Pine-juniper open forest	1. Evergreen oak woodland 2. Pine open forest	Evergreen sclerophyl-lous matorral
Main types of agro-forestry systems	1. Silvopasture 2. Forest farming 3. Riparian forest farming	1. Agrosilvo pasture 2. Fodder trees?	Fodder trees

pastures covered by trees (27% of the basin; 513,000 ha). Almost three quarters (73%) of the forest has more than 20% tree cover (373,000 ha), and the rest has a 5–20% tree cover (139,000 ha). Pastures with a shrub cover occupy 22.5% of the basin (513,000 ha). Natural, climax vegetation only covers 1% of the surface, giving an idea of what the final vegetation cover might be if man had not had such a huge influence on the original landscape.

In the vegetation of southeast Spain, woody species are dominant and herbaceous species are rare, except in the high mountain zones where pastures are more developed. Because of that, browsing of woody species is an important component of domestic and wild herbivorous diets. The original *Quercus* forest was transformed through long series of alternative burning and grazing episodes, into a continuous layer of leafy stems of high pastoral value. This woody fodder layer, dominated by species of the genus *Quercus, Pistacia*, *Phillyrea*, *Arbutus*, *Rhammus*, *Juniperus*, etc.(Quezel 1981), is known in different Mediterranean languages as ‘mancha’, ‘sarda’, ‘machia’, ‘maquis’ or ‘matorral’.

Croplands

Croplands occupy 48% of the basin (908,000 ha), and about one quarter of the cropland is under irrigation (13% of the whole basin) occupying the valleys of

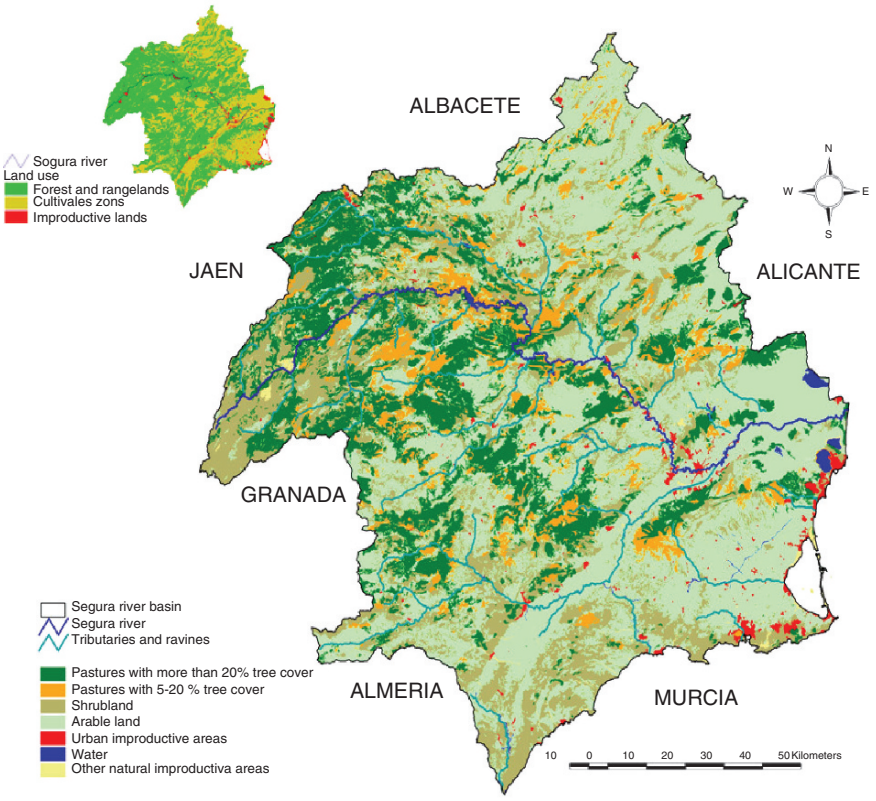

Fig. 9.3 Pasture resources in forest, rangelands and cultivated areas of the Segura basin (MMA 2000a)

the Segura river and its tributaries(Mundo, Quipar, Argos, Mula and Guadalentín) and the Cartagena coastal plain. The most widespread crops in the dryland areas are cereals but there are also some tree crops such as almond trees, vineyards and olives. In irrigated areas horticultural crops and citrus trees are more important.

Biodiversity Resources

The Segura basin has serious environment problems, such as the preservation of its biodiversity, desertification and a high risk of erosion.

It is one of the most biodiverse areas of the Iberian Peninsula despite its small size. The mixing of murcian-almeriense, andalusian, manchego, valencian and even

north African elements, has been the basis of this high biodiversity (more than 3,000 plant taxa) (Valle et al. 1989; Pajarón and Escudero 1993; Alcaraz et al. 2000).

The agroforestry systems host the greatest biodiversity because the presence of mosaics creates numerous ecological niches and ecotones. Even the weed communities linked to soil cropping and dryland crops are very diverse. The shrub and pasture communities are particularly rich in species (genus *Teucrium*, *Thymus*, *Sideritis*, *Helianthemum*, etc.) especially in the semi-arid lower areas and in mountainous areas, where there are high levels of endemism.

Climatic stress and grazing pressure have had an important effect on the composition of many vegetation communities. They have led to frequent anti-nutritional adaptations which can be physical (thorns, inedible fibres, etc.) or chemical (poisons, rubbers, resins, etc.) all of which largely reduce their palatability (Ríos et al. 1989, 1991; Robledo et al. 1989).

New information on the faunal diversity is being added continuously, and invertebrate species new to the area are discovered annually. Man has had a long history of involvement in the region and there have been sudden historical changes and events during the Middle Ages when the basin area was a frontier border. This has resulted in the complete loss of large predators like the bear, wolf, lynx, etc. and the reduction to near extinction of many birds of prey during the 17th to 19th centuries (García-Abril et al. 1989). At present, the end of the trophic chain is occupied by man as hunter. Currently, some large herbivores such as indigenous wild goats and introduced species such as "arruí" Atlas goats (*Ammotragus lervia* Pallas) and mouflón wild sheep (*Ovis aries* L.) from Corsica are increasing in number to an extent that they pose a threat to the ecosystem.

The Segura basin is an important refuge for birds of prey such as the golden eagle (*Aquila chrysaetos* L.), partridge's eagle (*Hieraaetus fasciatus* Gmelin), booted eagle (*Hieraaetus pennatus* Gmelin), snake's eagle (*Circaetus gallicus* Gmelin), northern goshawk (*Accipiter gentiles* L.), owl (*Bubo bubo* L.), etc. Many steppe birds such as black-bellied sandgrouse (*Pterocles orientalis* L.), stone curlew (*Burhinus oedicnemus* L.), warblers (*Sylvia* spp.), trumpeter finch (*Bucanetes githagineus* Lichtenstein), Dupont lark (*Chersophilus duponti* Vieillot), etc. use the basin for nesting or overwintering. There are interesting species of vertebrates like amphibians and reptiles such as the Iberian midwife toad (*Alytes dickhilleni* Arntzen and García-Paris) or the dappled tortoise (*Testudo graeca* L.).

Approximately 29% of the basin (547,000 ha) is protected by the Natura 2000 Network (MMA 2000b) (Areas of Communal Interest – LICs – and Zones of Special Protection for Birds – ZEPA) under EU supervision, or by other designations like Regional Park, Ramsar Convention sites, etc. Nearly half of the protected area is in the Region of Murcia and the rest is mostly located in the mountainous areas of Albacete, Jaén and Almería, which form the upper part of the basin (Table 9.2).

Table 9.2 Protected territory in the Segura basin in relation to the area of the Segura basin

Provinces	Surface (ha)	% Protected	% Protected in relation to ASB
Murcia	264,437	14.0	48.3
Albacete	159,412	8.4	29.1
Jaén, Almería, Granada	109,707	5.8	20.0
Alicante	14,128	0.7	2.6
Totals	547,684	28.9	100.0
Area of the basin (ASB)	1,893,151		

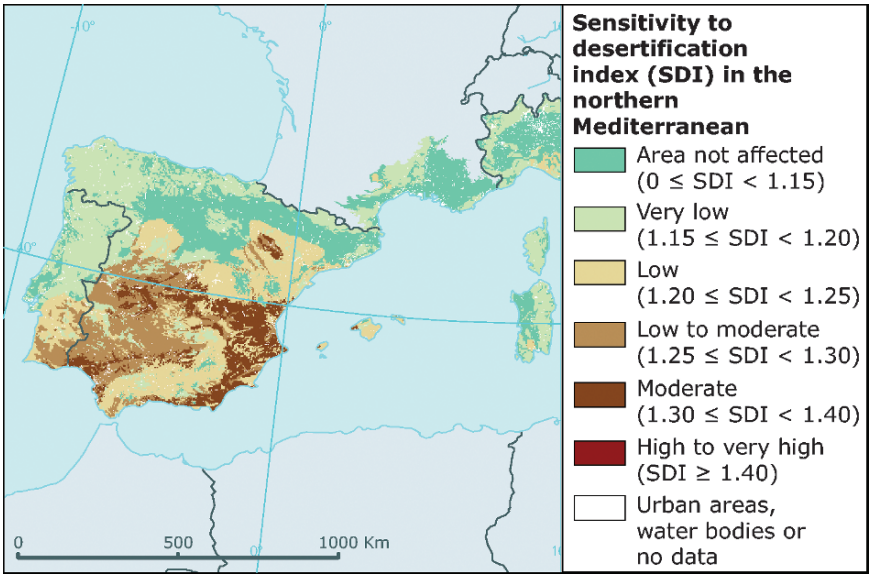

Fig. 9.4 Desertification risks in Spain and in the Segura basin (map copyright EEA, Copenhagen 2005)

Desertification Problems

The Segura basin is in the Northern Mediterranean area with the highest sensitivity to desertification index (SDI) (Fig. 9.4), an index derived from three datasets: vegetation, soil and climate sensitive indexes (EEA 2005).

Two thirds of the territory loses between 5 to 200 t ha^{-1} $year^{-1}$ of soil, but 77% of the basin soil losses, estimated at 46 million tons $year^{-1}$, occur in a third of the territory.

The soil losses in the basin's reservoirs (mean of 3 t ha^{-1} $year^{-1}$) produce about 4 million tons of sediment which reduces the water storage capacity by, on average, 3.6 hm^3 $year^{-1}$. This reduction is equivalent to a 0.5% annual loss in capacity.

In the Region of Murcia, 47% of soil losses occur in coastal areas (between 0–500 m altitude), where torrential rains are more frequent and the vegetation cover is sparse. In the high table lands (500–1,000 m), where dry farming crops such as cereals, almond trees and vineyards predominate, another 40% of soil losses occur. More than 160,000 ha (14% of the surface of Murcia) have an arid terrain with clay-rich soil that has been extensively eroded by water (badlands) and where water erosion processes are very aggressive (López-Bermúdez 1990; MMA 2002).

Fire Risk

Between 1993–2004, around 28,000 ha of forest were burned in a total of 1,600 fires. However, a majority of the burned area (25,700 ha, two thirds covered by trees) was destroyed by one fire in 1994. This fire was accidentally started by a high tension electrical cable falling, followed by strong winds which quickly spread the fire from its initial site.

The abandonment of traditional forestry uses such as charcoal burning, selective felling and forest grazing is producing a denser forest structure more prone to fire and there is a recommendation by fire experts that the woods, pastures and paths need to be cleaned and cleared. During summer months, fire is common in many Spanish territories and it is known that fires are frequently started deliberately; but, this is not the case in south-east Spain.

Population; Social Situation; Rural Development

Most (83%) of the population of the Segura basin (1,587,706 inhabitants in 2000) live in villages, small towns and cities with more than 10,000 inhabitants (urban areas) mostly found in valleys and coastal areas. The other 17% live in small villages located in the mountain areas and hinterland (INE 2000) rural areas (Table 9.3). The population is distributed into 128 municipalities, half of these localised in the lower area of the basin (0–500 m). The territory of the Segura basin is very poorly

Table 9.3 Municipalities and population in the Segura basin by altitude range (INE 2000; IGN, 2000)

Mean altitude range of municipalities (m)	Municipalities		Population		
	Number	%	Number (n°)	%	n° ha^{-1}
<500 m	65	51	1,314,735	82.8	2.1
500–1000 m	39	30	255,742	16.0	0.6
1000–2000 m	24	19	17,229	1.2	0.1
Total number	128	100	1,587,706	100.0	

developed, very agrarian, Mediterranean and marginalised and is classified as an objective area 1 of the EU, where community structural funds can be implemented.

Economic Analysis; Productive Parameters

Around 68% of the forest lands in the Murcia Region are privately owned and the remaining 32% are in public ownership (Region and municipalities), mostly under the control of the City councils (63%). On average, 62% of the income generated from the forest area can be attributed to environmental aspects, 29% from recreational aspects and only 9% from productive aspects (CHS 1997). Less than 18% of the forest area has significant timber production because most of the trees in the basin (Aleppo pine) have no commercial value.

Sheep breeding, in general, is not profitable, even with the support of subsidies from the EU. For example, a sheep producer in the middle zone of NW Murcia (average of 265 sheep per flock) would need 50 euros per head more on top of the current subsidy of 31 euros per sheep to break even, while in the lower area of the basin (Cartagena plain), for example, where flocks are larger (400 sheep per flock), they only need a subsidy of 34 euros per sheep to break even (García et al. 2005).

Goat breeding is more profitable, particularly on goat farms that have invested to produce high quality cheese – the "Queso de Murcia al vino". This is a creamy cheese that is washed with the strong local red wine, providing a stark contrast between the white cheese and the crimson rind.

Goats have a unique ability to convert the poor quality grazing in such tough, arid landscapes into rich milk and meat. They have a highly developed sense of sight, smell, and taste and a very discerning palate. They will often eschew easily accessible fodder on the ground in favour of tender young shoots on trees which they must stand on their hind legs to reach.

We think the future of sheep farming relies on increasing the size of farms and flocks, and in the promotion of differentiated quality products. The agrarian policy of the EU grant environmental subsidies to maintain the landscape, enhances the biodiversity, reduces the risks of fires, etc. and for food production to conform to rigorous quality and welfare standards. Examples are organic livestock farming and subsidies linked to productive systems. Together these could justify an increase in subsidies for extensive livestock if they are bound to the preservation of rural life and environment in this marginal basin territory.

Biodiversity, Desertification, Sustainability

The high zone of the basin occupies 20% of the territory and contains a high biodiversity, but its population (1% of the total) and livestock activity (12% of the total) is very low. This scenario could favour a the future of this zone as a silvopastoral area, managed by

a low number of people, who have the responsibility to shepherd livestock and manage seasonal grazing, plus achieving the general objectives of preserving the landscape, biodiversity and water resources.

The middle zone of the basin, (40% of the territory), has an intermediate level of biodiversity, a low population (16% of the total), but a high number of livestock (51% of the basin livestock units). Land use is economically marginal agrosilvopastoral systems with an associated risk of permanently overgrazing pasture resources and enhancing desertification processes. Finally, the lower zone of the basin has a relatively high biodiversity, but also the highest human density (83% total), and supports livestock. These result in a heavy pressure on land, vegetation and water resources, making this the zone with the largest desertification risk and one where the sustainability of productive systems is very fragile (Table 9.1).

Agroforestry Systems in the Segura River Basin

Agroforestry practices include not only the integration of the agricultural and tree components on the same land, but also the temporal integration of agricultural and forest land, as is found in the Segura basin.

There are three main types of agroforestry systems in the Segura basin: silvopasture, agrosilvopasture and uses of the forest areas not involving livestock. The system practised varies with the environment of the basin, being mostly extensive in the mountain zones, semi-intensive in tablelands and rangelands and intensive in the lower plateaus and coastal areas. Hence the agroforestry systems present in the Segura basin will be a function of the three environments already described in the introduction (Table 9.1).

High Mountain Zone

In the mountain zone of the Segura basin there are two types of forest: deciduous and evergreen oak forests and pine-juniper open forests. Within these forests, where the environment is moist and cold such as in the Segura and Alcaraz mountain ranges, there are pastures dominated by perennial grasses and spiny cushion plants, forming part of extensive silvopastoral systems. These pastures are used between June and September through the well known system called transhumance.

The main source of fodder for livestock is natural vegetation. Most of the biomass eaten is from browsing trees and shrubs and in open forest spaces, grasses and other forage plants make also a forage contribution. Extensive grazing with local breeds of sheep, goats and cows is practiced during the warm months (spring-summer) and there is seasonal migration in the coldest months (winter) when no supplementary feeding is used. The grazing area, approximately 80,000 ha, 85% rangelands and 15% cultivated land (mainly cereals), is surrounded by olive groves

in a hilly countryside**.** Part of the cereal production and pruned olive branches are used for animal feed.

Livestock graze across a gradient of mountain-valley pastures according to seasonal variations of cold-warm and wet-dry regimes: river valleys during spring and autumn, and high altitude pastures ("agostaderos" at >1,500 m) during summer. In winter, livestock migrate to warm valleys or warmer neighbouring areas (e.g. Sierra Morena in Andalusia), and finally in spring, livestock return to the mountain ranges of the Segura basin. The whole process is supported by old grazing infrastructure facilities such as drinking troughs made with tree logs ('tornajos') or stones and cement ('abrevaderos'), livestock transit tracks ('cañadas') and shelters.

Local livestock breeds are used for meat production: Segureña sheep, White Celtibérica and Black Serrana goats, and cows similar to the Retinta and Avileña breeds of the western and central Spanish mountain areas. The "red" meat produced has high quality but it is bought and marketed by people from other areas. There are about 160,000 sheep and goats distributed in 15 villages and 3 provinces. Flocks of 100–200 sheep are common, but 500 ewes per shepherd are needed to make a living. The shepherds are the owners of the flocks

Around 80% of the forest pastures are communal and 20% private but the latter are also rented for grazing. Trees, mainly *Pinus nigra* subsp. *clusiana* and *Pinus pinaster* Aiton, are managed for timber production.

There is a seasonal and spatial pasture growth heterogeneity related to altitude(1,200–2,500 m,) and orientation (sunny southern slopes versus northern more shadowy slopes). Summer pastures are communally grazed in management units of 1,000–2,000 sheep and 300 cows, managed by local shepherds following a three months rotation. This involves flocks grazing freely during part of the time and when livestock has to be moved to a new grazing area, shepherds get together and, using horses and dogs to control livestock, move them to the new pastures.

The high Mediterranean mountains (e.g. Segura and Alcaraz Mountains with a maximum of 2,500 m in La Sagra peak) have been grazed for millennia. Formerly, the forests in these areas were dominated by oak trees forming woods of *Quercus ilex* L. subsp. *ballota* (Desf.) Samp. ('encinares'), *Quercus faginea* Lam. subsp. *faginea* ('quejigares'), and *Quercus pyrenaica* Wild. ('melojares'), as well as copses of *Corylus, Ulmus, Acer, Taxus* and *Ilex* in shaded and humid areas, and of *Sorbus aria* (L.) Crantzand *Amelanchier ovalis* Medicus ('mostajos') on the peaks and highest areas. However, nowadays forest covers a very limited surface area, being replaced by open copses of spiny shrubs ('espinares'), not higher than 3 m, dominated by *Crataegus monogyna* Jacq, y *C. laciniata* Ucria, and covered by several species of *Lonicera* and *Rosa*, etc. These copses are common in the Segura and Alcaraz mountains, and in other mountains of Alicante and Valencia such as 'Font Roja', and the Aitana and Mariola ranges. Beneath these copses pastures are composed of *Festuca* species (some endemic) which represent a summer pasture and forage reserve for many of Spain's domestic and wild ruminants in the east and southeast of the country.

Evergreen oak woods are more extensive under dry climate, where they represent the climax vegetation. In many areas, individual oaks are bushy and undersize, but produce sprouts and leaves of good forage value which are well browsed by

livestock (acorn production is occasional). On stony ground, oak woods have open spaces occupied by a diversity of bushes and pastures.

In the calcareous oromediterranean areas (>1,700 m) vegetation cover is (i) pine juniper forest which forms an open formation with (ii) spiny cushion bushes and (iii) a pasture understorey. Species found are (i) *Pinus nigra* Arnoldsubsp. *clusiana* (Clemente *in* Arias et al.) Rivas-Martínez*, Juniperus sabina* L., *Juniperus communis* L. subsp. *hemisphaerica* (K. Presl) Nyman); (ii) genus *Genista, Erinacea, Ononis*, *Ptilotrichon, Vella*, *Prunus*); (iii) hard-leaf grasses (genus *Festuca, Poa, Koeleria, Dactylis*) and annual species such as legumes (genus *Medicago, Astragalus, Lotus*), and members of the *Compositae* and *Caryophyllaceae* families. All of these combined have a good pastoral value and are almost the only feed available at the end of the summer season in the highest areas of the southeast.

The high moorland continental areas are occupied by small juniper woods ('sabinares') of *Juniperus thurifera* L. (white 'sabina'), forming open copses where short-cropped pastures develop, under the influence of livestock grazing.

Livestock have been fed tree branches and leaves as a feed supplement in riparian zones (rivers and streams) where deciduous vegetation grows and in shady mountain areas. The hackberry (*Celtis australis* L.) and the elm (*Ulmus minor* Miller) are the species most eaten by many species of ruminants. Hence they were hand pruned to take advantage of their sprouts. The branches of wild olive trees (*Olea europaea* var. *sylvestris* Brot) which are present in rocky canyons and stony areas have also been used by livestock.

In the high mountains of Segura and Alcaraz, where there are frequent snowfalls, a mosaic of padded matorral, false brome 'lastonares' (*Brachypodium phoenicoides* (L.) Roem. & Schult), and hard leaf pastures, along with some meadows and deciduous spiny copses ('espinares') in small depressions or next to water points (springs and 'tornajos') is found. Pastures are grazed at a high stocking rate by mixed flocks of Segureña' sheep and Celtiberian white goats during the summer. In this situation, red deer and wild goats compete for the same pastoral territory.

The spatial distribution of flocks is unequal, more stock graze on pastures near inhabited areas and this livestock pressure causes soil erosion and loss of endemic and vulnerable species. The survival of potentially toxic wide leaved herbs (forbs), (e.g. *Arum alpinum* Schott & Kotschy*, Geum urbanum* L., *G. heterocarpum* Boiss, etc.) from the grazing pressure of herbivores under the cover of spiny species of the genus *Berberis, Crataegus, Rosa*, etc., while unpalatable species proliferate in the clearings (e.g. *Eryngium*) is an index of overgrazing.

Montane pastures are 2–3 times more productive than those from mid mountain areas. However, their current management is inadequate, because flocks are large (often with over 1,000 small ruminants) and are not moved off the area.

Non-livestock Uses of the High Mountain Forest Zone

Exploitation by the timber industry in the higher area of the Segura basin was very intense from early times until the 18th century, when there was a demand by the

naval industry for high quality timber (*Quercus pyrenaica, Q. faginea, Pinus nigra* subsp. *clusiana*) for warship construction. Other tree species with high calorific value (e.g. *Quercus ilex* subsp. *ballota*) were used for charcoal, for heating, or as fuel for the iron, glass and resin factories located in the area at that time.

Nowadays wood for trees growing in the basin is scarce and of low quality, except that of the 'laricio' pine (*Pinus nigra* subsp. *clusiana*), which is used as a timber for furniture in the small area of forest at the head of the basin.

The extraction of resins from *Pinus pinaster* (Alcaraz Mountains) and 'miera', from the *Juniperus* spp. to caulk boats and ships, was an important economic activity until the mid 20th century.

Bee keeping for honey production is widespread throughout the entire mountainous and agricultural areas of the basin, producing high quality single and multiflower honey.

Wild mushrooms, principally the genus *Lactarius*, represent an economic resource in the high areas of the basin. There is a significant harvest every 5–7 years, and this is an important area for tourism in autumn. However, there is no regulation of this activity, and in the long term it can cause an environmental problem. Something similar occurs with the harvest of wild snails across the territory.

During recent decades, one of the most important new economic activities has been the proliferation of limestone quarries in high and middle zones of the basin. This extraction of minerals sometimes conflicts with environmental regulation, for example, the gravel extraction from fluvial beds may cause destruction of the riparian vegetation.

Tablelands and Rangelands

In the semiarid cold plains (500–1,000 m altitude) of the Segura basin, the dominant agroforestry system is a semi-extensive *agrosilvopasture*, where crops and rangelands are grazed by extensive herds of livestock, except during periods when pasture is scarce and animals are fed in barns. The whole zone is economically marginal, and dryland agriculture and extensive livestock are under risk of extinction.

Depending on the contribution of woody and herbaceous species, the following rangeland pasture types can be identified:

Pastures with a Tree Cover

Pastures with a dense tree cover (>20%) represent about one half of the forest area. The main tree is Aleppo pine (*Pinus halepensis* Miller) which has expanded from the coast up to 1,100–1,200 m height due to human activity, either directly by reforesting or indirectly by management. When the pine density is low, it has a minimum influence on the botanical composition of the rest of the vegetation. In contrast to the holm oak, the Aleppo pine makes no contribution to livestock feed resources. The forage value of these pine woods is variable, depending on the diversity of the stratum of bushes and pastures growing below them. Most frequently, the

understory stratum is dominated by shrubs of the *Labiatae*, *Cistaceae* and *Fabaceae* families, and by herbaceous pastures of *Brachypodium retusum* (Pers.) P. Beauv. Bulbous and rhizomatous species of the *Orquidaceae* and *Liliaceae* families also grow between them.

Shrubland Pastures

Shrubby pastures are those that support the highest livestock pressure in this area. The most abundant are the least evolved and include communities of high diversity and contain numerous endemic species. Usually, these pastures like light and have a good capacity to colonise disturbed soils, frequently representing the understory of a majority of pine woods, and its main pasture resource. These pastures are mainly formed by Labiatae (*Rosmarinus officinalis* L. and several species of the genus *Thymus*, *Sideritis*, *Teucrium* and *Satureja*), Cistaceae (genus *Cistus*, *Helianthemum*, *Fumana*), legumes (genus *Anthyllis*, *Coronilla*, *Onobrychis*, *Astragalus* and *Hedysarum*) and other genus (*Staehelina*, *Lithodora*, *Ruta* and *Haplophyllum*). In general, the feeding value of the species is medium, but due to the high botanical diversity of these pastures, herbivores can meet most of their requirements by consuming and selecting between a wide range of species, except during the summer months, when the browsing biomass of shrubland pastures is reduced by drought.

The 'retamares', shrubland communities dominated by broom species such as *Retama sphaerocarpa* (L.) Boiss. and genus *Cytisus*, *Genista* or by thorny shrubs (genus *Genista*, *Ulex*) belong to a later climax stage. They are spatial transition vegetation and although of low palatability, they encourage the establishment of good pastures.

The 'coscojar' is the most evolved shrubland community of these areas. It is a dense impenetrable matorral which is the climax vegetation in semi-arid areas. In dry climates it is a precursor to the oak woods community. The dominant species is *Quercus coccifera* L. ('coscoja'), with *Rhamnus lycioides* L., *Rhamnus alaternus* L., *Juniperus oxycedrus* L. subsp. *oxycedrus, Phillyrea angustifolia* L., *Coronilla juncea* L., *Ephedra fragilis* Desf. subsp. *fragilis*, etc., and in lower warmer areas by *Pistacia lentiscus* L., *Rhamnus oleoides* L. subsp. *angustifolia* (Lange) Rivas Goday et Rivas Martínez. The forage value of this shrubland community is high, both that of the dominant species and the accompanying herbaceous species and bushes that grow among the shrubs. Together these contribute to their diversity and nutritional value which raises possibilities of feed complementation.

Productivity of Shrubland Pastures

Shrubland pastures provide fodder for livestock during the autumn-winter, when the fallow weeds have been eaten, or in spring, when the fallow land has been ploughed. They usually produce 1–2 t DM ha^{-1} of browseable dry material (DM), but it is mainly a volume feed, because most fodder shrub species are of low quality.

One of the most extensive formations in the 'romerales' is a low shrub community dominated by rosemary. Management affects its morphological structure and biomass yield (260–670 g plant^{-1}, 32–47% browse; 40–80% of canopy cover). On one hand, a moderate grazing increases the production of green matter, while on the other hand, keeping the shrubs from grazing favours their lignifications and reduces their productivity (Robledo et al. 2001). Formations dominated by *Anthyllis cytisoides* L. are widespread in the southern half and provide large quantity of browseable biomass (1.3–3.0 t DM ha^{-1}), an important feed resource for goats and sheep in dry areas. However, its herbage has a low protein level, contains tannins that reduce its digestibility, and leaves are lost during the summer (Robledo et al. 1991a).

Herbaceous Pastures

There is only a small area where herbaceous pastures are dominant vegetation. However they are a constituent part of other woody and shrubby aggregates. The most frequent pastures are those with *Brachypodium retusum*, which cover large areas below natural and reforested pine woods, mixed with low matorral like 'tomillares' (dominated by thyme) and middle matorral of *Q. coccifera*. As altitude and rainfall increases, they are displaced by pastures of *Festuca* and *Arrhenatherum*, of higher pastoral value.

The 'esparto' grass communities (*Stipa tenacissima* L.) cover large areas of the thermo and meso-Mediterranean belt, usually found at the overlap with the lower shrubland. Esparto fibre was one of the most important raw materials produced in southeast Spain until mid 20th century. Nowadays its use as a fibre has been mostly abandoned, and the stipa grass communities are slowly evolving into pine and shrubland communities. 'Esparto' has a low forage value. It tends to be only grazed during flowering and periods of feed scarcity, nevertheless it plays an important role in stabilising the soil and protecting it against water erosion. At high altitudes and on stony soils, it is displaced by *Helictotrichon filifolium* (Lag.) Henrard grass pastures, which are grazed by wild and domestic goats.

Meadows are only found around waterfalls, springs and humid ravines, and on high lands with clay soils remaining humid during a large part of the year. There are few of these meadows, but because of their quality and high yields they represent an "oasis" among the general aridity of the region. The most common meadows are those dominated by *Cynodon dactylon* L., *Festuca arundinacea* Schreber subsp. *fenas* (Lag.) Arcangeli, *Brachypodium phoenicoides* (L.) Roemer et Schultes, *Lolium perenne* L., *Agrostis stolonifera* L. on the particular soil and climatic conditions, but legume species *Medicago sativa* L., *Lotus corniculatus* L., *Ononis repens* L., *Trifolium* diversity *fragiferum* L., *T. repens* L. are also abundant.. These pastures should be carefully managed because excessive grazing pressure could degrade them, but an absence of grazing would make them evolve towards reed communities with lower diversity and palatability (Ríos et al. 1990).

Productivity of Herbaceous Pastures and Meadows

The most important pastures are formed by perennial tussock grasses of low palatability and poor nutritional value, such as the 'esparto' (*Stipa tenacissima*), 'albardín' (*Lygeum spartum* L.), 'lastón' (*Brachypodium retusum*) and *Helictotrichon filifolium*. In the *Brachypodium* pastures, most of the biomass is dead matter; hence they are often burnt to induce vigorous sprouting, which improves pasture quality. In the NW of Murcia accumulated yields of 2.6–8.6 t DM ha^{-1}, were measured. In a second cut a year later, yields were 0.7–1.7 t DM ha^{-1}.

Dactylis glomerata Roth pastures have good quality, but are only found in good soils, such as those underneath oak woods in NW Murcia, where yields between 0.7–2.0 t DM ha^{-1} have been measured.

In the tussock grass communities dominated by *Stipa tenacissima* (95% 'esparto') yields of 4.4 t DM ha^{-1}have been measured but only 1.5 t DM^{-1} of this is available, low quality fodder forage. There are other less frequent *Stipa* pastures such as those dominated by *Stipa celakovskyi* Martinovsky, in which yields of 1.2–3.7 t DM ha^{-1} have been measured.

The existing meadows (species of the genus *Festuca*, *Agrostis, Lolium, Hordeum, Trifolium, Medicago*, etc.) located in humid areas are very productive (8–12 t DM ha^{-1}) and of high quality.

Forage Resources from Dryland Crops

Forage crop resources from drylands consist of by-products from cereal crops (straw, stubble and fallows), herbaceous layer under almonds, vineyards and olive groves, and by-products from the trees such as fallen leaves, fruits and pruned branches.

In semiarid areas such as those found in the middle zone of the Segura basin, arable systems are low-yielding and winter cereals use fallowing, frequently in association with sheep rearing to maintain soil fertility. The proportion of fallow (30–80%) and the importance of livestock increases as rainfall decreases. The number of fallow years increases also in poor soils (2–3 years).

Higher labour costs and declining prices have contributed to the reduced viability of farming in these areas where forestation, marginalisation or complete abandonment can occur. Hence a loss of agricultural habitats associated with the drier, traditionally less intensive farming systems has been noted.

The combined use of sheep-cereal-rangeland is the dominant agrosilvopasture system; cereal stubbles are grazed in summer, cereal fallows in autumn and rangelands in winter. However, during periods of feed scarcity, rangelands are overgrazed, with the consequent degradation of vegetation and soil. Winter cereals are the best-yielding alternative to the potential biomass produced by dryland pastures and rangelands. For example, in semi-arid NW Murcia, where about 50% of the land is under cereal cultivation, the mean productivity of the twice yearly barley-fallow systems (2.7 t DM ha^{-1} $year^{-1}$) is very high compared to

that of native rangelands (1.8 t DM ha^{-1} $year^{-1}$ in scrublands and steppes) and dry land pastures (1.2 t DM ha^{-1} $year^{-1}$) (Robledo 1991; Correal et al. 2006). A semi-extensive system which is becoming generally adopted is that of maintaining dry ewes on grazing residues from cereal crops and shrublands, but fattening lambs and supplementing animals with barley and other concentrate feeds during periods of high nutritional requirements.

Cereal Crops

Barley is the most widely cultivated species, only at higher altitudes it is replaced by wheat (white and hard) and rye. The dominant cultivation system is a crop-fallow biannual rotation. Sheep breeding is associated with cereal cultivation, animals grazing the cereal stubble during summer, and fallow pasture until spring (March–May), after which the fallow land is cultivated. In June–July, after the harvesters collect the grain and bale the straw, livestock moves into the stubble to eat the fallen grain, the standing straw and the opportunist weeds, remaining there during the whole summer (July to September).

Those barley grains, which fell to the ground during harvesting, start to germinate along with seeds of the native flora with the first autumn rains. The most important fallow species are *Lolium rigidum* Gaudin, *Bromus diandrus* Roth. and genus *Eruca, Moricandia, Biscutella, Papaver, Vicia*, *Trigonella* and *Medicago*. From March–April the germination of summer species (genus *Salsola, Chenopodium, Polygonum* and *Amaranthus* types) (Robledo et al. 1991b) begins. In general, most fallow weeds are well grazed, and are an important feed resource for livestock, which tend to overgraze rangeland pastures when feed is in short supply.

Productivity of Cereal Stubbles and Fallow Pastures

Once the cereal has been harvested, animals graze the stubble, where 0.9–1.7 t DM ha^{-1} have been measured in normal years, and 3.3 t DM ha^{-1} in rainy years. Animals also consume the cereal grain on the ground, which on average is 0.2 t DM ha^{-1}. After the summer, livestock eat the fallow weeds, which in the NW of Murcia produce 0.5–0.6 t DM ha^{-1} when cut fortnightly, and around 1.2 t DM ha^{-1} when only one harvest is made. In some cases yields of 0.9 t DM ha^{-1} have been measured with eight fortnightly cuttings and around 2.1 t DM ha^{-1}, when only one single final harvest is made. The more productive species are the grasses *Hordeum vulgare* L., *Lolium rigidum* and *Bromus diandrus*, barley (*H. vulgare*) which make the largest contribution – about half of the biomass produced during the fallow year (Robledo 1991).

Woody Crops

Among the dryland tree crops the almonds stand out as they can be used by livestock, which eat dry leaves, pruning leftovers and soil weeds. Other important crops are

olive trees, whose pruning leftovers have been a traditional livestock feed in winter. Vineyards are grazed during autumn and winter, when they are dormant, consuming the dry leaves and the spontaneous weeds. Livestock also eat the pruned branches of olive trees (*Olea europea*) and vineyards (*Vitis vinifera* L.), and the leaves of mulberry (*Morus alba* L.), fig (*Ficus carica* L.), apricot (*Prunus armeniaca* L.), and peach trees (*Prunus persica* (L.) Batsch). In warmer areas, the fruits of the carob tree (*Ceratonia siliqua* L.) used to have a good economic value, (bought or leased). Nowadays, woody crop by-products have a very limited value, except for pruned olive branches which still have some commercial value for feeding animals.

In the case of irrigated tree crops, previously it was common to harvest the weeds and prunings from tree orchards to feed livestock, a practice that has disappeared due to the widespread use of insecticides. On the other hand, the food canning industry provides a large quantity of by-products consumed by livestock, such as pulps, discarded fruits, peelings and other leftovers from the food processing industries.

Non-livestock Uses of the Table Lands and Rangeland Forest Areas

The lower quality but abundant Aleppo pine has a certain economic value, yielding around 300,000 euros per year at loading point (30–40 euros m^{-3}) during the period 1995–1998.

The harvest of wild or cultivated aromatic and medicinal plants (rosemary, thyme, lavender, salvia, etc.) has been an important activity in the basin, where 600–700 t $year^{-1}$ are produced which, at 140 euros t^{-1}, yield an economic output of 86,000–97,000 euros $year^{-1}$ (period 1995–1998). Such extraction is not always sustainable and could create conservation problems, unless some of the species in most demand by the pharmaceutical and cosmetics industry are cultivated.

Esparto fibre (*Stipa tenacissima*), is still used in some lower areas of the basin, where the annual harvest is around 200 t $year^{-1}$ with a loading point value of 26,000 euros (1995–1997). This is considerably lower than before. Wild snails are also harvested in this part of the basin.

Lower Plateaus and Coastal Areas

In this basin environment, intensive agropasture systems are dominant because irrigation helps produce large quantities of fodder by-products to feed livestock, which are also fed concentrates. These intensive livestock systems do not have a tree component.

In this environment, small areas of dryland crops and rangelands are also found but their productivity is lower than in the middle zone of the Segura basin. As a result their forage contribution to agropasture systems is slighty smaller.

In the past, mulberries (planted along the irrigation channels) and carob trees (planted in the deep soils of the Cartagena plain) were an important source of income (silk and carob seeds and pods) and forage for livestock, but are currently in decline.

Livestock Numbers; Stocking Densities

Sheep are the ruminants that mostly graze montane pastures, rangelands, stubbles, fallows and forage by-products from agricultural areas. Goats and cows also make use of pasture resources in high mountain areas but most of them are localised in intensive dairy units where they are pen fed with fodder and concentrates. The same happens with other species like pigs, rabbits and chickens which are fed in pens and do not have any call on pastoral resources.

Approximately, 50% of sheep and 60% of goats are found in the middle zone of the basin (500–1,000 m altitude), and mostly associated with agrosilvopastoral systems (Table 9.4). More than 50% of cattle and about 25% of the sheep and goats are found in the lower zone of the basin (below 500 m), forming part of intensive livestock systems (dairy cattle and goats, and sheep for meat). Finally, the high area of the basin (1,000–2,000 m) maintains a small proportion of sheep (16% of the total census) and goats (12% of the census) and only 2% of the cattle. If we analyze the altitudinal distribution of all the ruminants using their total equivalent in livestock units (1 sheep or 1 goat, equivalent to 0.1 LU), the results are similar: 51% of the total LU are located in the middle area of the basin (500–1,000 m), where agrosilvopastoral systems are predominant, and 12% of the LU are in the highest zone (1,000–2,000 m) where silvopastoral systems prevail; 38% of the LU are located in the lower coastal area (0–500 m) where intensive livestock systems are dominant.

The mean stocking density in the districts of the basin is lower than 1 sheep per hectare per year. The mean sheep density (sheep per hectare) in the different municipalities of the basin is shown in Fig. 9.5. These are classified by their stocking densities, their numerical distribution and their position in the basin. Four categories can be recognized: (a) with less than 0.25 sheep per hectare, 42 dispersed municipalities through the whole basin only representing 7% of the sheep population; (b) with 0.25–0.5 sheep per hectare – (35% of the total) 50 municipalities like Lorca, located in the middle area of the basin, with an abundance of agricultural

Table 9.4 Distribution of sheep, goats and cows, by altitude of municipalities where livestock is registered

Altitude range (m)	Sheep	%	Goats	%	Cattle	%	LU	%
<500	300,216	33.1	56,867	28.5	21,263	53.2	56,971	37.8
500–1,000	465,080	51.2	118,073	59.3	17,947	44.9	76,262	50.6
1,000–2,000	142,685	15.7	24,322	12.2	742	1.9	17,442	11.6
Total	907,980	100.0	199,261	100.0	39,953	100.0	150,675	100.0

Legend: LU Large livestock units (cows or its equivalent; 1 sheep or goat = 0.1 cow)

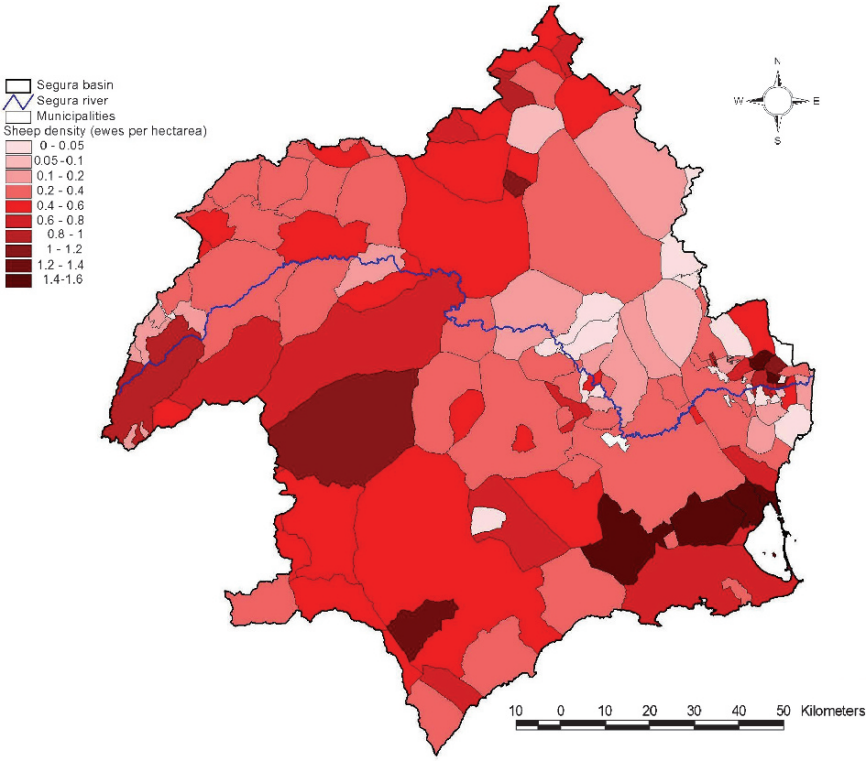

Fig. 9.5 Livestock densities (sheep per hectare) in the municipalities of the Segura basin (MAPA 1999)

by-products from rain-fed crops, such as cereals; (c) with 0.5–1 sheep per hectare (34% of sheep numbers) – 25 municipalities located in mountain areas such as Moratalla, or in highlands like Caravaca, with a mixture of rain fed crops, forest and rangelands and (d) with 1–2 sheep per hectare (24% of total sheep) – 10 municipalities located in the coastal plain of Cartagena, where large quantities of fodder by-products from intensive agriculture and agricultural industries are available. This is common in the municipalities of Torre Pacheco and Fuente Álamo (Erena et al. 2004).

Despite what has been said, seasonal variations of pasture resources generally mean that active stocking densities exceed the sustainable optimum as determined by the resources available in summer and winter months. The opposite happens during spring and autumn, when the available resources are usually higher than the requirements of the livestock population.

In 1999, there were 900,000 sheep in the Segura basin, representing 3.6% of the Spanish sheep population. This is similar to the area in the Segura basin (3.7% of Spain), where meat production (lamb and mutton) is the main agricultural output.

Current Land Use Changes and Future of the Agroforestry Systems

Changes in Soil Use (1990–2000)

To analyze the change in soil use, the "CORINE data base of land cover" from 1990 (revised) and 2000 have been used (IGN 2005). From these it can be concluded that:

1. 10.6% of the area evaluated (201,800 ha) has seen changes in the CORINE land cover classes and in 97% of the cases this means a loss of natural vegetation.
2. The biggest recorded changes were from agroforestry systems and extensive agriculture (Fig. 9.6). Altogether they lost 157,520 ha (25% of their area in 1990); Most (91%, 146,796 ha) of this loss was to intensive agriculture, which increased its cereal cover by 40% compared to 1990.

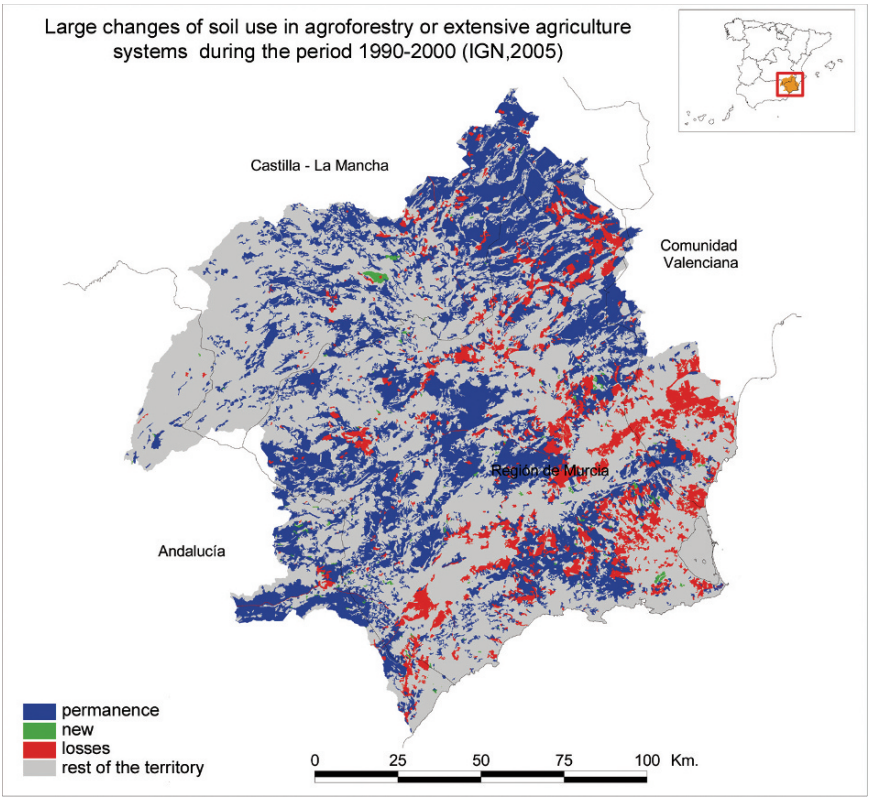

Fig. 9.6 Large changes of soil use in agroforestry or extensive agricultural systems during the period 1990–2000 (IGN 2005)

3. The lower plateaus and coastal areas of the Segura basin were those that suffered the greatest intensity of change. Land reclamation and man-made modification within 1 km of the coast is three times more than the basin average, and twice more than the average for the first 4 km. Similar values are obtained in the areas close to roads and highways.

In the Murcia Region (59% of the Segura basin), the forested area has increased from 41% in 1966 to 60% in 1999, probably due to the combined action of factors like reforestation, a reduction of pressure on forest and rangeland products (wood, fire woods and grazing), and to human abandonment in rural mountain areas. In contrast, the extent of rangelands (shrub communities, herbaceous pastures, etc.) has decreased by 53,000 ha during the same period, corresponding well with the 52,000 ha increase in the cultivated area.

Potential Future Improvements

People living in marginal areas like the Segura basin are faced with economic and ecological sustainability challenges (e.g. to make a living while preserving basic resources). However, only a small area of land is suitable for economically efficient agriculture, the rest is better suited for range and forest, and can only be used by grazing animals utilising areas which cannot be cultivated (Harlan 1975).

The following comments reflect on some potential improvements that could be introduced in the silvopastoral and agrosilvopastoral systemspresent in the Segura basin.

Annual Forage Utilisation Patterns to Match Resources with Sustainable Stocking Rates

The planning of annual feed calendars for livestock, to utilise all the potential fodder resources could reduce grazing pressure on degraded rangelands and improve the efficiency of animal production.

Forested areas of the Segura basin mountain area provide seasonal grazing during summer. This resource could be used to feed flocks of livestock from drier areas, like the middle zone of the Segura basin that have to sustain large stocking rate densities. This option is feasible as there is still a network of livestock transit tracks which would facilitate livestock movement between the middle and mountain zones. Additionally, these movements of livestock would help create biological corridors connecting different habitats.

Seasonal fluctuation in animal nutritional requirements and forage and pasture resources in Mediterranean environments like those prevailing in the Segura river basin must be matched in an optimal way. There are periods of fodder shortage but there are ways of improving the system, such as creating

fodder banks or hedges with forage shrubs, which can also support biodiversity, or introducing infrastructures like fences, water points and animal shelters in parts of the farmland. These would confine animals grazing permanently during long periods, and thus reduce shepherding requirements and labour (Correal et al. 1988; Correal 1993).

Extensive livestock farming subsidies and Rural Development support should be linked to the territory and its productive systems (extensive, semi-extensive, organic farming, etc.), to see if livestock grazing degrades, maintains or improves the vegetation and other natural resources.

Promotion of Biodiversity

Agricultural policy in Europe is changing from supporting production to encouraging environmental benefits in the context of sustainable rural development.

In the mountain zones of the Segura basin, ecotourism from urban populations could partly justify economic investment to protect biodiversity. Seasonal summer grazing, maintaining low stocking densities, may help preserve the environment and natural habitats of forest zones, many of which are of particular interest to the EU (Red Natura 2000). Good grazing management can reduce shrubby biomass and with it the risk of fires while maintaining the biodiversity present in the forest layer. However, if mountain zones are not protected by law, overgrazing can damage valuable natural resources, as is happening in part of the mountain area.

In the middle zone of the Segura basin, the winter cereal-stubble-fallow system maintains a cereal-steppe landscape where an important part of the Mediterranean flora and fauna, especially steppe birds, depend on the habitat and feed resources generated by stubble and fallows (Suárez et al. 2004). Of all steppe birds, the great bustard (*Otis tarda* L.) and the little bustard (*Tetrax tetrax* L.) are the two most threatened species, and 50% of the world bustard population is found in the Iberian Peninsula. To protect steppe bustards, the following measures are suggested: maintain fallows and their rich flora; preserve or create borders and living hedges; stop herbicide and pesticide use, fertilize with organic manure; use native seeds; and maintain traditional cropping cycles (Alonso et al. 2003).

Organic Farming

Current EU policy on rural development promotes livestock systems oriented towards the production of quality food. Under such a policy, organic farming could be a means of sustaining silvopastoral and agrosilvopastoral systems in mountain and steppe rangelands of the Mediterranean Segura basin zones. In place of fertilizers and pesticides, organic farming relies on local biological resources. Synthetic fertilizers are replaced by animal manure or legume cover crops, natural

weed control is practised, animals are reared outdoors with adequate space and natural medicinal practices are used. So organic farming could offer consumers food free of chemicals, and tasting better produced in an environmentally friendly manner. There is more manual labour with organic farming, but livestock are healthier and prices of animal products are usually higher. However, the high quality red meat produced in the silvopastoral zones of the Segura basin does not attract a premium and there is a need to organize the distribution and marketing of local products, such as meat, honey, aromatic plants, wood, resin and mushrooms to make it possible for the few people living in the zone to remain economically viable (Correal et al. 2006).

Use of Forage Cereals and Cereals as Forage in Sheep-Cereal-Rangeland Systems

When cereal yields are low, as in semiarid marginal areas, whole cereal crops like barley can be used as forage for livestock, either for winter and spring grazing, or cut and dried at the end of the cycle (milky grain stage) for later use in periods of forage scarcity, such as winter. Such a strategy might help the recovery and use of old cereal varieties and landraces, abandoned in the past because they had high straw yields.

Additionally, as the General Agreement on Trades and Tarrifs (GATT) agreements predict for the future, cereal production within EU countries will evolve towards a competitive open market and, in such a scenario, it seems logical that part of winter cereals, particularly barley, should be used for *in situ* consumption in extensive livestock systems.

Use of Woody Forage Species in Agrosilvopastoral Zones

Establishing crop hedges and field margins in environmentally sensitive areas could provide food and habitat for wild fauna and reduce soil erosion (Atkinson et al. 2002). Similarly, introducing woody forage species in natural fences and as protein feed supplements in cereal cropping areas, could improve the year round food availability profile and preserve biodiversity and protect soils.

Fodder shrub plantations can be used for several purposes: (a) to create fodder banks for annual and inter-annual feed scarcity periods, (b) as protein or mineral supplements to improve sheep intake of nutritionally deficient feeds (e.g. cereal straws, *Stipa* grasses, etc.), (c) to control soil erosion in cultivated areas with steep slopes, and (d) to provide refuge and food for wild fauna (Correal 1993).

Perennial woody legumes, like tree medics (*Medicago arborea* L., *Medicago citrina* (Font-Quer) Greuter) could be grown as fodder banks for winter-spring grazing. The introduction of cereal-*Atriplex* alley cropping (saltbushes planted in rows following widely spaced contour lines) could provide an *in situ* protein supplement to straw/stubble and protect the soil against erosion during heavy autumn rains (Correal et al. 1994).

Conclusions

The silvopastoral and agrosilvopastoral systems present in the upper and middle zones of the Segura river basin are important to maintain landscapes, biodiversity and rural life because they affect 60% of the territory. However, their economic output is marginal and the population living on them is relatively small (17%). Hence, their future is unclear, but it seems that the preservation and maintenance of the biodiversity and landscapes associated with them and the potential yield of quality products are reasons that might justify their economic support by EU agrarian policy.

In theory, the three zones of the Segura basin (high, middle and low) are complementary in terms of their fodder resources, because they are produced in different seasons and places, and hence annual forage calendars could be established to maintain sustainable extensive livestock systems, moving animals through the network of transit tracks connecting the different zones of the Segura basin, as was done in the past. However, this scenario is far from reality because the current trend is towards maintaining larger stocking densities in intensive farming systems close to coastal areas where a majority of the human population is concentrated, and in the semi-intensive systems in the middle zones of the basin. In contrast, the highest zones of the basin are experiencing abandonment of human population and livestock activity. In summary, there is a worrying trend towards depopulation in the upper zone of the basin and an increase of desertification risks in the lower and middle zones of the basin. All these combined will make sustainable management of the territory, the preservation of its biodiversity, the control of its erosion problems, and the long term development of the Segura basin very problematic.

References

Alcaraz F, Delgado MJ, Inocencio C, López-Bernal J, Clemente M, Barreña JA, Carreño E (2000) Aproximación a la diversidad de la flora vascular de la Región de Murcia, In: Calvo JF, Esteve MA, López-Bermudez F (eds.) Biodiversidad. Contribución a su conocimiento y conservación en la región de Murcia. Servicio de Publicaciones de la Universidad de Murcia, Murcia, Spain, pp 27–37

Alonso JC, Palacín C, Martín CA (2003) Status and recent trends of the great bustard (*Otis tarda*) population in the Iberian Peninsula. Biol Conserv 110:185–195

Atkinson PW, Fuller RJ, Vickery JA (2002) Large-scale patterns of summer and winter bird distribution in relation to farmland type in England and Wales. Ecography 25(4):466–480

CHS (1997) Proyecto de Plan Hidrológico de la Cuenca del Segura. Confederación Hidrográfica del Segura (CHS), Murcia, Spain

Correal E (1993) Grazing use of fodder shrub plantations. In: Papanastasis V (ed) Fodder trees and shrubs in the Mediterranean production system: objectives and expected results of the EC research contract. Commision of the European Communities, DG XIII. Agriculture: AGRIMED research programme. Report EUR 14459, Luxembourg

Correal E, Sánchez P, Alcaraz F (1988) Woody species (trees and shrubs) of multiple value for the arid and semiarid zones of northern Mediterranean EEC countries. In: Morandini R (ed) Les

especes ligneuses à usages multiples des zones arides méditerrannéennes. Commission de Communautés Européennes, DGXIII. Agriculture: Programme de recherche Agrimed. Rapport EUR 11770, Luxembourg

Correal E, Ríos S, Sotomayor JA, Robledo A (1994) Explotaciones ovino-cereal: sistemas alternativos basados en la utilización de arbustos forrajeros y leguminosas perennes. Main paper presented at the XVIII Jornadas SEOC on Producción ovina y caprina., Ed. Universidad de Castilla-La Mancha, Col. Estudios, 21. Albacete, 23–25 Sept 1993

Correal E, Robledo A, Ríos S, Rivera D (2006) Mediterranean dryland sheep-cereal systems. In: Lloveras J, González-Rodriguez A, Vázquez-Yáñez O et al. (eds.) Sustainable grassland productivity. 21st General meeting of the European Grassland Federation. Badajoz, 3–6 April 2006, vol.11. Grassland Science in Europe, p 847

EEA (2005) Sensitivity to desertification in the northern Mediterranean. DISMED project (Desertification Information System for the Mediterranean). Map on sensitivity to desertification index (SDI) in the northern Mediterranean. "Copyright EEA, Copenhagen (2005)". http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id = 1815. Upload 28 May 2007

Erena M, Robledo A, García P, Correal E, Vicente M, Alcaraz F (2004) Cartography of pasture resources of Murcia region (Spain): calculation of stocking rates. In: Lüscher, Jeangross B, Kessler et al. (eds.) Land use systems in grassland dominated regions. 20th General meeting of the European Grassland Federation. Luzern, Switzerland, 21–24 June 2004, vol. 9. Grassland Science in Europe, p 1230

García-Abril A, Yoldi L, Canga J (1989) Transformación y reconstrucción del bosque hasta el siglo XX. In: Ortega Hernández-Agero C (ed) El libro Rojo de los Bosques españoles. ADENA-WWF España, Madrid

García J, Rouco A, Carreño F, Correal E (2005) Análisis económico de las explotaciones de ganado ovino y caprino en la región de Murcia. An Vet Murcia (21):109–120

Harlan JR (1975) Crops and man. American Society of Agronomy, Crop Science of America, Madison, WI

IGN (2000) Modelo digital de elevaciones MTD200. Instituto Geográfico Nacional, Madrid

IGN (2005) CORINE Land Cover 1990 and 2000: Base datos ocupación del suelo actualizada y revisada. Instituto Geográfico Nacional, Madrid

IMN (1961–1990) Datos pluviométricos periodo 1961–1990. Instituto Metereológico Nacional, Madrid

INE (2000) Datos población cuenca del Segura. Instituto Nacional de Estadística, Madrid

López-Bermúdez F (1990) Soil erosion by water on the desertification of a semi-arid Mediterranean fluvial basin: The Segura basin, Spain. Agr Ecosyst Environ 33(2):129–145

MAPA (1999) Estadística agraria. Censos de ganado por municipios. Ministerio de Agricultura, Pesca y Alimentación, Madrid

MMA (1997) Confederación Hidrográfica del Segura-DGOH. Proyecto de Plan Hidrológico de la Cuenca del Segura. Ministerio de Medio Ambiente, Madrid

MMA (2000a) D. G. Conservación de la Naturaleza. 2° Inventario Forestal Nacional. Ministerio de Medio Ambiente, Madrid

MMA (2000b) Red Natura 2000 en España. Ministerio de Medio Ambiente, Madrid

MMA (2002) Inventario Nacional de Erosión de Suelos 2002–2012. Región de Murcia. Ministerio de Medio Ambiente, Madrid

Pajarón S, Escudero A (1993) Guía Botánica de las Sierras de Cazorla, Segura y Alcaraz. Pirámide, Madrid

Quezel P (1981) Floristic composition and phytosociological structure of sclerophyllous matorral around the Mediterranean. In: di Castri F, Goodall DW, Specht RL (eds.) Ecosystems of the world, vol 11. Mediterranean-type shrublands. Elsevier Scientific, Amsterdam/Oxford/New York, pp 107–121

Ríos S, Correal E, Robledo A (1989) Palatability of the main fodder and pasture species present in S.E. Spain: I) Woody species (trees and shrubs). In: Proceedings XVI International Grassland Congress, Nice, France, 4–11 Oct 1989, vol II, pp 1531–1532

Ríos S, Robledo A, Correal E (1990) Prados y pastizales vivaces del N.O. de Murcia. In: Actas XXX Reunión Científica de la SEEP. San Sebastián, Spain, 4–8 June 1990, pp 294–305

Ríos S, Correal E, Robledo A (1991) First screening of the more interesting pasture legumes present in matorral areas of south-east Spain. In: Proceedings IVth International Rangeland Congress, Montpellier, Francia, 22–26 April 1991. Association Française de Pastoralisme, vol 1, pp 417–421

Robledo A (1991) Las explotaciones de cereal-ovino en el N.O. de Murcia: balance de recursos forrajeros y perspectivas de futuro. In: Actas XXXI Reunión Científica de la SEEP, Murcia, Spain, 20–24 May 1991, pp139–159

Robledo A, Correal E, Ríos S (1989) Palatability of the main fodder and pasture species present in S.E. Spain: II) Herbaceous species. In: Proceedings XVI International Grassland Congress, Nice, France, 4–11 Oct 1989, vol II, pp 1533–1534

Robeldo A, Correal E, Rios S (1991a) An important fodder resource for livestock in southeast Spain: Anthyllis cytisoides L. In: Proceedings IVth International Rangeland Congress, Montpellier, Francia, 22–26 April 1991. Association Française de Pastoralisme, vol 1, pp 422–425

Robeldo A, Ríos S, Correal E (1991b) Las malas hierbas en los barbechos cerealistas del N.O. de Murcia: su importancia como recurso alimenticio para la ganadería ovina. I) Composición botánica; y II) Producción de biomasa. In: Actas Reunión Sociedad Española de Malherbología, Córdoba, 11–12 Dec 1991, pp 70–77

Robledo A, Ríos S, Correal E (2001) Influencia del grado de aprovechamiento sobre la estimación de biomasa en cinco poblaciones de *Rosmarinus officinalis* L. In: Crespo MB, Ríos S (eds.) Biodiversidad en pastos. Actas XLI Reunión Científica de la S.E.E.P. CIBIO-Alicante, Spain, 23–27 April 2001, pp 579–586

Suárez VA, Zilletti B, Capdevila L (2004) La agricultura ecológica como instrumento de conservación de especies amenazadas: El caso de la Avutarda (*Otis tarda*). http://www.uib.es/catedra_iberoamericana/publicaciones/seae/mesa1/avutarda.html. Last actualization 22 March 2005

Valle F, Gómez-Mercado F, Mota JF, Díaz de la Guardia C (1989) Parque Natural de Cazorla, Segura y Las Villas. Guía Botánico-ecológica. Rueda, Madrid