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Agroforestry and sylvopastoralism: The role of trees and shrubs (Trubs) in range rehabilitation and development

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Abstract

Fodder shrubs, either naturally established or set up by man, constitute a feed reserve for livestock and wildlife in periods of inter-seasonal or inter-annual drought. There are nearly 10 million hectares of those in the world arid and semiarid lands today, about a third of them planted by man. They occur under all types of arid climates: Mediterranean, tropical, temperate. They belong to a relatively small number of genera and species from various families, including a number of legumes. Their productivity is far above that of rangelands under similar ecological conditions. In addition to constituting a feed reserve and thus being amenable to improving animal performance, they offer a number of ecological benefits, such as erosion control, landscape amenities, and struggle against desertization. But they are also subject to a number of constraints pertaining to land tenure and ownership, land and animal management, controlled access, cost of establishment and availability of plant material. Beyond their role as fodder reserves hence improvement of animal performance, they play a major role in erosion control, landscaping, and landscape management.

Key words: arid and semiarid zone, agroforestry, sylvopastoralism, erosion, drought.

Résumé

Agroforesterie et sylvopastoralisme : le rôle des arbres et arbustes dans la régénération et le développement des parcours

Les arbres et arbustes fourragers, soit établis naturellement, soit mis en place par l'homme, constituent une réserve fourragère mobilisable lors de sécheresses intersaisonnières ou interannuelles. Ils occupent environ 10 millions d'hectares dont un tiers sont plantés par l'homme et se rencontrent dans tous les types de climats arides : méditerranéens, tropicaux et tempérés. Ils comprennent un relativement petit nombre de genres et d'espèces végétales, dont un certain nombre de la famille des légumineuses. Leur productivité est très supérieure à celles des parcours soumis aux mêmes conditions écologiques. Outre leur rôle de réserves fourragères, donc d'améliorateurs des performances animales, ces arbres et arbustes jouent un certain nombre de rôles environnementaux dans la lutte contre l'érosion et la désertisation et dans la gestion des paysages. Mais ils sont aussi soumis à un certain nombre de contraintes relatives à la tenure et à la gestion des terres, au coût de mise en place et à la gestion des troupeaux ou de la faune.

Mots clés : zone aride et semi-aride, agroforesterie, sylvopastoralisme, érosion, sécheresse.

Agroforestry is the growing of forest trees and shrubs (Trubs) on farmland while sylvopastoralism is the nurturing of forage shrubs and trees in forest, wood, bush, shrub and/or rangeland. We are here concerned with man-made shrub and tree plantation for the feeding of ruminants, with other side-benefits. This is a technique developed over the centuries by peasant civilizations in most of the continents, e.g., the *dehesa* of Spain, the *montado* of Portugal, the *Faidherbia albida* systems of West and East Africa, the North and South American *mezquite/algarobo* systems, The *kejri/* millet system of Rajasthan, the argan/ barley system of southwest Morocco, etc. These cover some 10 million hectares in various arid lands of the world as shown in *table 1* [1], using various kinds of forage trees and shrubs for the feeding of various kinds of livestock (often small stock).

Such traditional systems are now threatened by the expansion of "modern" agricultural systems which often prove less adapted to the environment than the older ways. These new mechanically-intensive systems, as a rule, favour soil erosion and provoke a definite reduction of soil fertility/ productivity, but they are easier too handle by the farmer with modern motored equipment and require less manpower.

Since the 1930s some enlightened agronomists have become conscious of the situation and have advocated the establishment solid plantations of new exotic or native species as fodder reserves for times of drought. Among the species utilized were spineless *Acacia* spp. (wattles e.g., *A. saligna*), *Atriplex* spp. (saltbushes), *Colutea* spp. (bladder sennas), *Cytisus proliferus* subsp. *palmensis* (tagasaste, tree lucerne), *Faidherbia albida* (apple-ring acacia), *Gleiditsia tracanthos* (honey locust), *Gliciridia sepium* (gliciridia), *Haloxylon* spp. (saxaouls) *Leucaena leucocephala* (Leucaena), *Medicago arborea* (tree medic), *Morus* spp.(mulburry), *Opuntia* spp. (cacti), *Prosopis* spp.(mezquite, algarrobo), *Quercus* spp. (oaks), *Robinia pseudo-acacia* (black locust), and a number of others [1-17].

Table I. Main agroforestal and sylvopastoral production systems under present use in the various arid and semiarid lands of the world.

Regions/countries	Hectares
Australia (saltbushes)	100,000
South Africa (cactus, saltbushes, agave)	800,000
East and South East Africa (*Leucaena, Faidherbia*, *Acacia*, wattles)	100,000
North Africa (cactus, saltbushes, wattle)	500,000
West Africa (*Faidherbia, Acacia, Prosopis, Leucaena*)	100,000
South West Asia (saltbushes, mainly)	100,000
India (*Prosopis, Leucaena*)	200,000
North America, USA, and Mexico (saltbushes, agave, *Leucaena*, and cacti)	500,000
Pakistan (mainly saltbushes, some *Prosopis* spp.)	100,000
Nordeste Brazil (cacti)	500,000
Chile (mainly saltbushes and *Prosopis* spp.)	200,000
Former USSR States of Middle Asia (saxaouls, *Calligonum*, *Salsola*)	300,000
Subtotal	**3,500,000**
Mediterranean basin, North Africa and South West Asia excluded : Cacti, *dehesa*, *montado*, sclerophyll oaks, abandoned vineyards, olive and chesnut groves, mulberry, Russian olive, black locust, honey locust, tagasaste, escobon, wattles, *mezquites/algarrobos*, saltbush, tree medic, tree lucerne	6,400,000
Estimated grand total	**9,900,000**

Benefits from agroforestal and sylvopastoral systems

The benefits provided by these systems are multiple, they may be grouped under three headings:

– firstly, *environmental improvement*, hence increased land productivity and amenities;

– secondly, *animal production enhancement*, hence increased economic performance of the farmers/stock owners;

– thirdly, *water and erosion control* and *land development*, and prevention and control of desertization.

Environmental improvement

Environmental improvement comes from the impact of Trubs on the microclimate, land and soil. These are complex and interacting, they may be summed up as indicated below.

. Because of their size Trubs increase the landscape roughness, hence reduce wind velocity, hence lower potential evapotranspiration, water demand, and water stress.

. Because of their powerful rooting system Trubs may reach deep moist layers in soil and substrate, excepting, however, CAM[1] species like cacti and agave which, on the contrary, have a shallow root system enabling them to make use of light rains and dew. The latter require high air moisture (RH[2]>70%), at least at night.

. Because of their ground cover and above ground biomass, rain interception by foliage, branches and stems reduces rainfall intensity, and defer rain-water intake, hence decrease runoff and ensuing soil erosion.

. With the turnover of the deciduous dry matter produced annually (leaves, phyllods, bark, flowers, unpalatable fruits, etc.), an important part of this biomass is turned into litter and then amalgamated with soil particles, increasing the organic content of the upper soil horizons, stabilizing and strengthening soil structure, hence an increased resistance to erosion.

. Increased organic content, reducing soil compactness, increases permeability, hence oxygenation, water intake, storage, budget and balance therefore more percolation and, again, reduced runoff.

. Trubs are amenable to planting in land inappropriate for cropping: too stony, too steep, too clayey, sand dunes, saline land, water-logged soils.

. On the contrary, Trubs may profitably be associated with cropping in particular of cereals. The association and mixed farming is beneficial to both entities as the cereal benefits from the soil improvement brought about by the Trubs and the latter from the care given to the cereals: cultivation, weeding, fertilizing, and dung/ urine left by browsing animals. It has been shown that this mixed farming does not reduce the cereal crop, quite the opposite.

. The increased organic matter in the soil boosts microbial activity and the turnover

[1] CAM: Crassulescent Acid Metabolism.
[2] RH: Relative Humidity.

of geobiogene elements (B, Ca, Co, Cu, K, Mg, Mo, N, Na, S, Zn), hence ameliorates plant nutrition and productivity.

. Mesofauna is also favoured by increased soil organic matter and microbial activity: insects, larvae, worms (Lombricidae), fungi, actinomycetes, etc. increasing soil oxygenation and permeability.

. Megafauna then develops with scavengers, rodents, birds, which all contribute to further soil oxygenation and permeability.

. Because of the shade they produce from their canopy, Trubs buffer extreme temperatures hence lower potential evapotranspiration, less water demand and consumption, lower freezing hazard. Herbage thus remains green 3-5 weeks longer in the shade side (North in the Northern hemisphere, South in the Southern hemisphere) at the end of the rainy season. When animals are concerned above it has been shown [18] that sheep allowed to rest under tree-shade may consume 40% less water and grow 30% faster than in the open under otherwise similar conditions. On the other hand, the wind-break effect of Trubs may considerably reduce young animal losses when icy winds blow, particularly in the spring and fall, as in Patagonia.

. Trubs produce other benefits than animal nutrition and comfort, such as fuelwood or charcoal, pollen and nectar favouring beehives and honey production or bark and tanning substances for craft industries and various amenities (shade, blossom, bird nesting, wildlife refuge, shelter, and feed, etc.).

Enhancement of animal production

The quantity of feed produced from foliage, twigs and palatable fruits (acorns, legume pods, etc.) is high, particularly when planting is combined with the techniques of water-harvesting and of runoff farming [10, 19-23]. This is assured through contour-line planting with or without contour banks and with or without graded sloping land surface. The productivity expressed in terms of Rain Use Efficiency (RUE) may be manyfold above the average world arid and semiarid rangeland figure of 4.0 ± 0.5 kg DM/ha/yr/mm [24]. In agroforestry systems, RUE may exceed the 20-25 kg DM/ha/yr/mm, using various species of Trubs (*Atriplex* spp, *Acacia saligna, Opuntia ficus-indica, Prosopis* spp., etc. [1-14].

The feed produced is in general of an excellent complementary quality: relatively poor in energy but rich in proteins, vitamins, and minerals, thus complementing poor rangeland and/or cereal stubble and fallow roughage. Some species actually constitute a kind of concentrate feed and are sold as such on village markets in Africa, e.g., apple-ring pods in West Africa [3, 25].

When Trubs are grown on cereal farmland, the benefit for livestock is enhanced by the fact that Trub production is ideally suited to complement stubble as the latter provides energy in the diet while Trubs add nitrogen, minerals, and vitamins, making the diet a perfectly balanced one for an optimal animal production.

Runoff and erosion control

Browse hedges of Trubs may contribute to marking property and paddock limits on the ground and to the partitioning of slopes, thus reducing erosion hazard.

Utilization of deep aquifers

Due to the powerful root systems of many of them, Trubs may reach and exploit deep aquifers which cannot be reached by herbaceous species. The geographic distribution of *Faidherbia albida* in Senegal, coincides with the piezometric level of -80m below ground surface of the upper aquifer (we witnessed -75m in Senegal). *Prosopis cineraria* is known to pump water from a depth of over 20m in the Thar Desert of Rajasthan [17] and up to -60m in the Wahida Sands of Oman [26]. *Atriplex halimus* and *A. nummularia* have been shown to draw water from water tables 10m deep in Algeria and Tunisia [2]. One-cm diameter living roots of *Ziziphus lotus* have been extracted from a depth of 60m near Marrakech in southern Morocco [27]. Trees living on water tables 20-40m deep are common place in the driest parts of the Sahara. Such was the case of the famous "Ténéré Tree" in North East Niger (*Acacia tortilis*), uprooted in the 1970s by a backing military truck! As a matter of fact, many of the Trub species utilized in agroforestry and sylvopastoralism are phreatophytes, and virtually all the arid lands' *Prosopis* spp.; the same ecological behaviour applies to the Asian Saxaouls (*Haloxylon* spp.) [13, 14] and to many other species of desert trees and shrubs.

There is also an enrichment of soil in nitrogen symbiotic fixation [Bacteria (Rhizobia) and Actinomycetes (Frankia)]. As many of the species utilized belong to the legume family or to other Nitrogen fixing families, soil enrichment in nitrogen from root decay reaches 100-450 kg N/ha/yr under arid, semiarid and subhumid climates [28, 29].

Their phreatophytic ecology makes them relatively independent of rains but able to make use of out-of-season rains, contrary to herbaceaous species which do not respond to such rains. This situation still increases their RUE.

Constraints

Trub development is also subject to a number of constraints that limit the extension of their utilization.

Land tenure

Because they represent a heavy investment for the small farmer, Trubs require a secure land tenure, and a full control of access to the land. Free livestock loitering cannot be accepted, hence sometimes an additional fencing cost [30].

Mixed farming

The above-mentioned situation may however be overcome in some instances by mixed farming of cereals and Trubs. Access to growing cereals is generally not socially accepted and therefore Trubs are protected from stock intrusion during the 120-180 days of the growing season. This technique has been used in South Africa, Libya, and Spain since the early 1980s (*figures 1A* to *1D*). This mixed farming of Trubs exhibits other advantages: cereal farmland soil is generally deeper, better watered, and of higher quality than the average rangeland soil and therefore Trubs grow faster and have a higher productivity. These Trubs benefit from the care allowed to cereals, e.g., cultivation, weeding, and fertilization.

Trubs and runoff farming

Trubs are amenable to various techniques of runoff farming in arid lands, the techniques being the same as those used for forest tree plantation and for fruit trees planting. These techniques may increase productivity manifold; they are mandatory for some species and all the more so as these are little climatically adapted to the planting zones (e.g., mulberries, *Gleditsia, Gliciridia, Leucaena, Prosopis, Robinia* in arid lands). The cost of production is higher due to amortization of the hydraulic works, but the increase in production may be rewarding.

Cost of establisment

The cost establishment is high, representing several thousand dollars per hectare, depending on the country and the economic circumstances that need an amortization period of at least 10 years [30]. Some countries – e.g., Tunisia – have developed an incentive legislation of allowances and soft loans amenable to alleviating this problem [10]. This constraint may be alleviated in the near future as research is active to find alternative solutions to the customary costly, but secure, utilization of nursery grown seedlings [1, 10].

(A)

Mean annual rainfall (MAR): 200 mm; "m": ?3°C.
The shrubs received a complementary drip irrigation of ca. 200 mm/an.

(B)

Elevation <50m; mean annual rainfall (MAR): 125mm+60 days of fog estimated to add another 100mm of water; "m": ≈ 8°C. A. nummularia *shrubs are spaced 10-15m between rows and 1-2m on the rows, and barley is grown in between the rows.*

(C)

Cabo de Gata is the driest place in Europe with a mean annual rainfall (MAR) of 150mm; "m": ≈ 7.0°C

(D)

The mean daily consumption was 1.6 kg dry matter (DM) per head of sheep and the number of browsing days provided was 2,200 days/ha; this is a consumed production of 3,200 kg DM/ha/yr, i.e., a Rain Use Efficiency (RUE) of 16.0 kg DM/ha/yr/mm.

Figure 1. Examples of mixed farming.

A) A commercial caper plantation near Totana, south of Murcia, southeastern Spain ; B) Mixed *Atriplex nummularia* and barley production system, near Lambert's Bay, some 125 km north of Cape Town ; C) Same system with a young stand of A. nummularia in a barley crop, established in southern Spain at Cabo de Gata, 36 km east-south-east of Almeria ; D) A flock of Segureña sheep browsing on *A. nummularia* near Totana southeastern Spain (photos by Henri Noël Le Houérou).

Availability of plant material

In many instances plant material is not locally available and must therefore be imported from other regions within the country or from abroad. In other instances, when native species are concerned, there is just no seed production. Producers then have to organize their own seed production, which is a disincentive.

Selection and breeding of elite germplasm

Types of material better adapted to local conditions and/or of higher production potential ought to be developed as incentive to use by farmers and stock-owners. In most cases, this kind of research is in the infancy. But there are a few exceptions, e.g., in the USA a number of commercial cultivars of four-wing-saltbush (*Atriplex canescens*) have been developed to meet various ecological conditions of soil and climate. The same scheme applies to *Leucaena leucocephala* in the tropics and to some extent to some other saltbushes (*A. nummularia* in South Africa, *A. amnicola* in West Australia, *A. halimus* in the Mediterranean basin).

Conclusion

The utilization of agroforestry and sylvo-pastoralism techniques may be a potent tool for land rehabilitation in range country. But it is subjected to constraints of land tenure and financial availability as well as to technical constraints such as the availability of adequate plant material and/or agricultural technology, and/or credit facilities. Some of these constraints may be alleviated by legislative and management organization, as exemplified in few countries. But then the political will of States may again be another constraint. However, the emergence of "green" political parties may be viewed are positive from this perspective, as compared with the classical political parties. This is why these techniques have so far been relatively little developed, since only 10 million hectares, out of a total 10 million km^2 of arid and semiarid rangelands (1%), have benefited from theses techniques. Research and education efforts are being devoted to the removal of some of these major constraints, particularly the cost of establishment, the availability of special credit facilities, improved plant material and the conditions of land tenure. The subject is further addressed in several other contributions to the present issue of *Sécheresse* [18, 31-34].

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