

FORESTS AND GRASSLANDS AS CRADLES FOR AGRICULTURE

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Keywords: Origins of agriculture, agroforestry, nutrient cycling, seminatural communities, grasslands, savanna, biodiversity, agroecosystems

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Summary

The emergence of agriculture in forests, woodland, and savanna regions in different regions of the world is reviewed, including the transition to combinations of hunting, gathering, and early agriculture. This article reviews the long-term human subsistence use of forests and grasslands and its effects on the ecosystems in tropical and temperate regions. This includes the impact of fire as a tool for clearing of forest to grasslands and the development of seminatural biological communities. The process of transformation of natural communities into seminatural communities has had a significant influence on biological diversity at the local and regional scales leading to landscape, ecosystem, and community changes, in part from forested to nonforested, often grass-dominated ecosystems. In alpine habitats often the forest limit was lowered by anthropogenic activities. In addition to a change in species composition of communities, transformations into seminatural communities have changed the genetic composition of populations over the past 10 000 years. This process led to evolution of new varieties and species. The cycling of plant nutrients in forests and grasslands is explained, and the coupling of the nutrient cycles through the development of subsistence agroecosystems is analyzed. An overview of current agroforestry systems is given, and it is shown how

different forms of agroforestry/forest gardens have been/still are crucial for food production in various parts of the world. From scientific knowledge and practical experiences in biological production, both in developed and less developed countries, it is evident that food production based on integrated animal and plant production systems, including agroforestry systems, has the largest potential for sustainability. Such systems have a high production potential at low environmental costs, and allow the maintenance of local and regional biological diversity. The prospects for the development of sustainable agriculture and food production for the future rooted in traditional knowledge of use of forest and grassland ecosystems, are thus promising.

1. Humans as Parts of Forest and Grassland Ecosystems

1.1 Human Subsistence in Forests and Grasslands Based on Gathering and Hunting

The history of humans starts with the early hominids, our ancestors, *Homo habilis* and *Homo erectus* in Africa. The oldest records of human (hominid) technology, defined as use of tools and implements, have been registered in East Africa, in Ethiopia 2.5 million years ago, Kenya and Tanzania, circa 2 million years ago. The anatomically modern humans (*Homo sapiens sapiens*) have a dramatically shorter history; circa 70 000 years ago in Africa and 45 000 years ago in Europe. All the assumed cradle sites for the evolution of the hominids can be classified as grasslands—savanna environments, although on a local scale they contain a complex environmental mosaic with availability to different habitats. It is presently believed that the hominid populations migrated out from eastern Africa, and adjacent areas in southern Asia and Europe were colonized circa 500 000 years ago. The Americas and Australia are believed to be virtually uninhabited until circa 40 000 years ago, although new evidence is suggesting an earlier arrival in Australia.

Because humans used tools and weapons, their hunting success gradually increased and became better than that of the animal carnivores. Like other large omnivorous mammals, the *Homo* populations applied selective harvesting of the biological resources in their environment. This means that they selected not only certain plant and animal species but also certain development stages and age classes, e.g., buds and fruits from some plants species, larvae from certain insects, and so on. From the Late Pleistocene (circa 50 000 years ago) and onward human impact is evident, although the magnitude and scale are impossible to verify. For example, in New Guinea there are palynological indications of fire-induced forest destruction from 30 000 BP. This is interpreted to be related to human activity. Extinction of species, especially in the megafauna, has been documented to occur during the Pleistocene. However, the impact of the dramatic climatic change manifested through the repeated advances of continental ice sheets during late Pleistocene and early Holocene may have been more influential than the human impact, although this is subject to ongoing debate.

The human use and control of fire is dated back circa 1.4 million years. Where evidences of fire are found it is usually in connection with settlements. It is assumed that fire was used for directing the game in the hunting process; for the manipulation of vegetation, e.g., creation and maintenance of favorable patches for game, such as grass-

lands or semi-open forests; for cooking purposes; for protection, and for ritual and religious reasons. Indications of early forest disturbances by human-induced fires from 17 800 BP is based on pollen data from highland rain forests in Sumatra. Paleoecological data from lowland rainforests in Panama show indications of human activity as reflected by forest clearings and remains of charcoal from 11 000 BP. The human activity here persisted until 4000 BP but this area is now covered by rainforests. Studies such as those and the ecological-anthropological studies from the rainforest of the central Amazon, which also presents evidence of early and long-lasting human impact in present rainforest areas, give rise to exceptionally interesting interpretations on the role of human impact as one source of current high biological diversity in rainforests. The diverse human use of the biological resources in the forest environment created a mosaic of disturbances along temporal and spatial scales. Theories of patch dynamics and the ecological “intermediate disturbance hypothesis” are involved as explanations of the high biodiversity of those ecosystems.

Natural fires are part of the normal disturbance regime in tropical and temperate ecosystems. The human use of fires caused intentional or unintentional modification of the ecosystems and increased the natural disturbance regime. This influenced the distribution of successional patches in woodlands, which in turn affected the dispersal and colonization processes of both plants and animals, leading to new and changed community composition and subsequently also to changes in landscape pattern.

1.2 Transition of Natural Communities into Seminatural Communities

The domestication of large grazing animals, ungulates, had a major impact on the landscape (see *Animal Husbandry, Nomadic Breeding, and Domestication of Animals*). Fossil records of domesticated species appear relatively late in human history. The earliest evidence for domesticated animals is bones of sheep and goats from the Near East dated to circa 10 000 BP and circa 9000 BP, respectively. Evidence for domesticated cattle appears in Turkey dated at 8400 BP (see *Historical Origins of Agriculture*). Although acknowledging the human impact on ecosystems by their change of natural fire regimes—see above—the keeping of these domesticated grazers and browsers implied a more systematic impact on natural systems, and their domestication may be used as the starting point for the development of seminatural communities.

The continuous grazing and browsing of the livestock, in combination with burning to maintain the grasslands, led to a change from forested and half-open woodland ecosystems to open grass-dominated communities. Also, where there was not a complete shift from forested ecosystems to grasslands, the grazing and browsing impact on the woodland led to biotic and edaphic changes creating seminatural communities. Certainly the domestic herds were not the first big grazers affecting the woodland ecosystems. The existence of the large wild herbivores such as mastodons, mammoths, horses, antelopes, bison, and so on during the Pleistocene, circa 1 million to 10 000 years ago, was of great significance for creating and maintaining grassland sites within the woodlands. Grazing pressure increased the possibilities for grassland species to exist within the forested ecosystem long before the introduction of the domesticated ungulates. However, some argue for the standpoint that Neolithic humans met a fully

forested landscape, and that it was the human impact that created the seminatural habitats such as grasslands and heathlands.

The ecological effect of wild large herbivores and of livestock grazing is related to a variety of factors:

- i) herbivore species and breeds: cattle, camel, llama, horse, goat, sheep, pig, reindeer, and so on
- ii) grazing by single species or mixture of herbivore species
- iii) grazing pressure (number of animals per area)
- iv) time of the year and duration of the grazing periods (all year round; seasonal; rotating system)

Mere grazing per se is also composed of sub-factors such as the consumption of biomass, the possible effect of animal saliva on plant metabolism and growth, trampling (soil compaction, creation of vegetation free-patches, the effects on albedo and soil temperature, and so on), the deposition of dung, and so on. The multiple combinations of all those factors in combination with environmental factors determine the ecosystem effect and the structure and composition of the communities created and maintained. Seminatural communities can be defined as plant and animal communities composed of species that are indigenous to the region, but where the development and the maintenance of the communities requires direct or indirect human activities. Such human impact includes forest clearing, burning, grazing by domestic animals, and/or mowing. The long-term persistence of these activities is essential; often the seminatural communities were already in existence during prehistoric time, and their duration is thus measured in thousands of years.

European examples of seminatural vegetation include most lowland heathlands and grasslands, and many woodlands and shrublands that have been affected by burning, grazing, and coppicing. By comparison, *natural* grasslands and heathlands in Europe are shaped mainly by climatic and edaphic factors; these include alpine grasslands and heathlands and communities affected by periodic flooding along freshwater and marine shores. Many European seminatural grasslands have their origins in early prehistoric times, circa 6000 years ago or even earlier. The Atlantic heathlands characteristic of coastal areas in Western Europe were developed from forested ecosystems during the Early Iron Age, circa 2000 years ago. Seminatural ecosystems in temperate and alpine regions have had fundamental significance as the basis for the development of agriculture and the function of preindustrial agroecosystems. They provided fodder resources (summer grazing and winter fodder—hay) from prehistoric time until the end of the pre-industrial era, which encompasses, in temperate Europe, about 6000 years. Such heathlands and grasslands are today threatened ecosystems that harbor a number of endangered plant and animal species and act as refuges of biodiversity. The threats are mainly changes in land use such as cessation of grazing or mowing, or the onset of plowing or fertilizing.

In seminatural grasslands on limestone bedrock and calcareous soils, plant biodiversity reaches high levels. Among the highest species richness ever recorded of field layer species (expressed as number of vascular plant species per unit area) is reported from

seminatural meadows on limestone bedrock in South Estonia, 63 species per m⁻¹. The seminatural grasslands are definitely hot-spots of European biodiversity. In the absence of management these seminatural grasslands and heathlands revert by natural succession to woodlands and forests, and the species richness of vascular plants declines dramatically. The mowing and/or grazing regimes maintaining these communities might be seen as the critical ecological disturbances reducing the populations of dominating species and creating micro sites for colonization and completion of life cycles of short-lived species and thus positively contributing to high species diversity.

Evidence of rapid evolution in the sense of evolutionary adjustment to specific environments is documented from experimental studies of annual plant species. Consequently, it is not surprising that the long-term existence of seminatural communities (6000 years or more) has increased the grassland biodiversity by the development of subspecies (and maybe even new species) with adaptations to the specific ecological conditions prevailing in a grazed or mowed grass-sward. The alpine heathland species *Pseudorchis straminea* and its sister species *Pseudorchis albida* which is recorded only in seminatural grassland sites in Scandinavia are examples of this process.

It is also plausible that some of the present grassland endemics confined to seminatural grasslands might have their origin in the Pleistocene grasslands—or for areas subjected to European colonization with attached species extinction (e.g., the US)—in the pre-European grasslands. A study of *Primula alcalina*, an endemic grassland plant species in the central US, shows that this species might benefit from domestic stock grazing which in this area is a recent phenomena. This may be interpreted as an adaptation to ungulate grazing and where the present domestic herds are substitutes for the extinct native animal grazers. Incorporating a historical perspective, e.g., earlier land use and herbivore populations, is critical to interpret and to predict the dynamics of rare species and to assess relevant conservation measures.

It is believed that many tropical and subtropical grasslands are maintained by fire. A significant component in this dynamic is human-induced fires that result in increased fire frequency. Because of the long history of the human use of fire, the human impact probably has contributed to the present ecosystem structure and function. The evolution of prairies in North America can be interpreted in part as seminatural ecosystems maintained by the grazing of wild animals and by fires set by Native Americans. The absence of human-induced fires and the disappearance of big grazers led to significant shifts in the structure and functions of those ecosystems, as has been demonstrated in the prairie ecosystems of the US. Another example is the present savanna ecosystem of Cuba, which has been shown to be a product of the long-term human impact of cutting, burning, and livestock grazing. The process of transformation of natural communities into seminatural communities had a significant influence on biological diversity on local and regional scales leading to landscape, ecosystem, and community changes, in part from forested to nonforested, often grass-dominated ecosystems. In alpine habitats, often the forest limit was lowered by the anthropogenic activities. In addition to a change in species composition of communities, transformations into seminatural communities have changed the genetic composition of populations over the last 10 000 years. This process led to evolution of new varieties and species.

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