Ecological Impact of Tropical Pastures and the Potential of Forage Plants for Sustainable Land Use Systems in the Tropics

An Annotated Bibliography

A. Christinck, K. Probst, R. Schultze-Kraft

Contents

1 Abstract

This annotated bibliography lists and summarizes the most relevant references on the ecological impact of pastures and forage plants in tropical land use systems. It attempts to provide knowledge from ecosystem and ecology-relevant disciplines to researchers and development workers.

The bibliography is structured into different sections, considering on the one hand research results at farm-ecosystem level, and on the other hand studies at the regional and global level. Numerous reports are presented on the cultivation of multipurpose herbaceous and woody forage plants and their effects on soil properties, nutrient cycling, erosion, microclimate, and phytosanitary aspects. On a regional and global level, focus is given to hydrological aspects, the regeneration of degraded land, biodiversity, and climate.

The review indicates that basic data on ecological effects of pasture establishment and livestock production are still scarce. This is the case in particular for long-term effects at the regional and global levels. Areas of future research are suggested. For a successful development of sustainable land use systems interdisciplinary and interinstitutional collaboration is indispensable.

2 Introduction

In view of the growing human population and progressive degradation and destruction of the natural resources, the search for sustainable land use systems is one of the most important challenges of our decade. Farming practices and livestock production are generally known to contribute on a large scale to environmental degradation if they focus on short-term productivity only.

The aim of this study is to summarize current, tropical-pasture related knowledge from different ecosystem and ecology-relevant research fields. A second aim is to encourage interdisciplinary research for developing sustainable farming systems that make use of the potential that tropical pasture plants are suggested to offer for a wide range of ecological and socio-economic conditions.

The bibliography is structured into different sections, considering research at farm-ecosystem level on the one hand (soil properties; nutrient cycling; erosion control; microclimate; diseases, pests and weeds), and studies at the regional and global ecosystem level on the other hand (hydrology; regeneration of degraded lands; biodiversity; atmosphere and global warming). Each section consists of a summarizing review giving insight into the subject, the main approaches of current research, and the lack of knowledge. References are numbered and are presented in Chapter 6 in numerical order, including keywords and abstracts. The list of keywords (Chapter 7) was especially prepared for this bibliography and does not necessarily represent the keywords given in common databases (e.g., CAB-Abstracts, TROPAG, Agricola). If a reference lacked an abstract or summary, an own abstract was added and is identified as such („Abstract by bibliography authors“).

The study is based on an effort to gather relevant literature that was readily accessible in 1995 but by no means do the authors claim the bibliography to be complete. The intention is rather to provide a starting point for subsequent, exhaustive literature searches within the nine individual research areas that are outlined in this study.

3 Forage plants and pastures within tropical farm ecosystems

3.1 Soil properties

Although a wide range of soil types are found in tropical regions, highly weathered and low-activity clay soils (Ultisols, Oxisols and Alfisols) in tropical forest and savanna regions are the most important groups used for farming, generally because of the favorable topographic and climatic conditions in the respective regions {1, 2}. Ultisols and Oxisols are strongly acid and leached soils with low cation exchange capacity (CEC), very low inherent fertility, multiple nutrient (N, P, K, Ca, Mg, Zn) deficiencies and nutrient imbalances (e.g., toxic levels of Al or Mn). Alfisols which are less acid and have high base saturation, are characterized by inherently low nutrient (N, P, K, S and Zn) status and low structural stability {1, 3}.

Maintaining soil fertility and productivity are the major management problems when these soils are used for crop and pasture production {1}. In traditional cropping systems, based on shifting cultivation or bush fallow rotation, soil fertility was regenerated during fallow periods through the activity of trees and other natural vegetation {4, 5, 6, 7, 8}. With the rapidly raising human population and increasing pressure on cropping land, fallow periods are becoming shorter so that fertility regeneration is less effective and productivity declines {1, 4, 5, 7, 8, 9, 10}.

In recent years, the cultivation of multipurpose herbaceous and woody forage plants became more and more relevant to maintain soil productivity in low-input productions systems under shortening fallows {1, 4, 5, 7, 8, 10, 11, 12, 13, 14, 15, 16, 17, 18}. Numerous studies have been conducted to assess changes in soil chemical, physical and biological properties associated with the growth of pasture plants in different integrated farming systems.

3.1.1 Soil chemical properties

Nitrogen deficiency is a major cause of declining soil fertility {13, 19, 20, 21}. As N is a very expensive nutrient to manufacture necessitating high energy inputs {13, 22} (section 4.4), the use of leguminous plants as a source of N is particularly interesting in low-input farming systems of the tropics {14, 23, 24, 25, 26}.

Leguminous plants used as mulches, green manures, cover crops, or as components of pastures or fallow vegetation, are generally known to improve soil organic matter (OM) and enhance total-N through symbiotic nitrogen fixation {4, 5, 6, 10, 11, 12, 13, 14, 16, 17, 21, 22, 24, 25, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40, 41, 42, 43}. On soils with low N contents, the amount of N_2 fixed depends largely on the dry-matter production of the plant, which in turn depends on the legume genotype and environmental conditions during growth

{1, 13}. Annual N yields of tropical forage legumes with average growth range from 30-400 kg/ha (1, 22, 33, 34).

However, when using legumes to improve soil total nitrogen content, it should be remembered that:

- Not all legumes can associate with rhizobia {7};
- legumes fix N_2 in inverse relation to the amount of nitrogen available in the soil. In soils with moderate to high levels of available N, soil improving legumes are of little value {24};
- the growth of legumes depends on the presence of a suitable rhizobium strain; inoculation may be necessary {7};
- growth and also N_2 fixation can be hindered by an unfavorable pH {32, 44} and/or lack of other nutrients (particularly P, Ca, Mo, Zn) or by Mn toxicity {7, 34};
- environmental conditions such as irradiation have to be favorable to ensure adequate production of carbohydrates in the plant's leaves and their downward translocation to the nodules {13}.

If N_2 fixation and nodulation of legumes was significantly reduced, a greater demand on soil N was frequently observed, possibly leading to competition for N between legumes and associated crops {13, 45}. Another source of N is N_2 fixation through associative symbiosis between grasses and bacteria (e.g., *Azotobacter paspali, Azospirillum brasiliense, Beijerinckia indica, Enterobacter cloaceae*). There are indications that the amounts of N_2 fixation achieved under grass can be as high as 45-100 kg/ha {9, 35, 46}.

A proportion of the plant litter N becomes 'stable' and might not be available for re-uptake by plants for several years as it accumulates in soil OM and in living remains {35}: Nitrogen in material with less than 1.0-1.5 % N is largely immobilized in tissues of the decomposing microfauna and becomes available to plants only slowly, whereas in material with higher N concentrations a proportion of N is in excess of requirements for microbial growth and is released to the soil ammonium pool {47}.

Decomposition pattern and mineralization of organic matter are essentially determined by the C/N ratio and the content of secondary compounds: N mineralization from C_4 grasses is relatively slow because of their high C/N ratio {31, 46}. A high lignin/N ratio promotes the incorporation of N into stable humic complexes {20}. Polyphenolics which can be common in legumes growing on poor soils {48}, are highly reactive compounds and can form stable polymers with many forms of N {23, 48}. Thus legumes and grasses with slow decomposition rates may not provide enough N for plant growth in the short term, but they contribute to the build-up of soil organic N and therefore can provide a low but continuous supply of N in the

long run. On the other hand, legumes with low polyphenolic content release N rapidly, providing sufficient N for plant growth, but nitrogen may be lost by leaching of nitrate (NO_3^-) {23, 31, 46}.

Drying and wetting generally leads to accelerated release of N, too. This may be of significance in areas with a pronounced dry season or when supplementary irrigation is given {46}.

Besides N, forage legumes and grasses in alley cropping, mulching systems {1, 4, 14, 15, 28, 39, 49, 50}, in ley farming {9, 46, 51, 52,} and cultivated fallows {5, 7, 12, 36} also mobilize large quantities of other nutrients. In the long run, soil fertility is built up through enhanced nutrient uptake from subsoil resources (e.g., Mg, Ca, K, P) and accumulation of OM. OM provides most of the CEC in highly weathered soils and, besides supplying N, it is an important slow-release source of sulphur and phosphorus {33, 46}. In tropical soils, phosphorus is a rather immobile element as it is absorbed by Fe and Al oxids on the surfaces of clays and precipitated by Fe and Al cations to form insoluble Fe or Al phosphates {53}. Vesicular-arbuscular mycorrhizae (VAM), which form symbiotic associations with roots of many forage plants, help to increase P uptake from soils poor in phosphorus {2}. Thus, phosphorus may be concentrated in plant biomass and will become more available after decomposition {2, 46}. The order of nutrient release from leguminous litter seems to follow the general trend potassium > phosphorus, nitrogen, magnesium > calcium. The initial immobilization of calcium is generally attributed to accumulation of calcium oxalate in the fungi that colonize decomposing leaf tissue {48}.

Under temperate-climate conditions, accelerated soil acidification has been observed where improved pastures of annual grasses in mixture with legumes (e.g., *Trifolium subterraneum*) have been grown continuously for 25 to 50 years {27, 54}. During acidification the base saturation (Ca^{++}, Mg^{++}, K^+, Na^+) is decreased and the proportion of CEC occupied by H_3O^+ and various forms of Al is increased {27}. Particularly in south-eastern Australia and some areas of New Zealand, the gradual decline in soil pH under leguminous pastures has caused considerable concern as manganese and aluminum have increased to phytotoxic levels. Applications of lime to neutralize acidity have become an important part of pasture management in these regions {27, 54, 55, 56, 57, 58, 59, 60}. Much of the accelerated soil acidification in pasture soils has been caused by increasing nitrogen inputs through N_2 fixation and fertilizer use {19}.

Major processes leading to acidification during N cycling (see section 3.2) in soils are {27, 54, 59, 56}:

- The excess uptake of nutrient cations over anions by N_2 fixing legumes with a consequent net efflux of protons (H^+) into the rhizosphere;

- the net nitrification of N derived from fixation ($NH_4^+ + 2O_2 \rightarrow NO_3^- + H_2O + 2H^+$);

- loss of N through leaching of nitrate;

- removal of plant and animal products.

Apart from climatic conditions and the buffering capacity of the soil, the degree to which acidity develops will depend upon the growth rate of the legume, the extent of N_2 fixation, the relative cation requirements as well as the form and amount of amino acids and organic acids synthesized within the plant {27, 54}.

There are indications that tropical legumes may have a lesser acidifying effect than temperate species: Part of the reason is that their NH_3 assimilation products appear to be ureides (allantoin, allantoic acid) which are unlikely to dissociate within the plant and to donate protons, whereas in most temperate legumes NH_3 is assimilated into the easily dissociating carboxylic acids, aspartate and glutamate. The H^+ ions produced by dissociation of organic acids within temperate legumes have to be exported into the rhizosphere in order to maintain the plant's internal pH balance {54}. Moreover, many tropical legumes have evolved in acidic soil environments and therefore have generally lower cation levels (Ca^{++} and K^+) in their tissues {27}. Thus, the excess of cations absorbed seems to be less for tropical than for temperate legumes, so that the former species do not apparently acidify their rhizosphere as much as do temperate species when actively fixing N_2.

In contrast to temperate leguminous plants, the growth of grasses absorbing nitrate (by exchange of OH^- or HCO_3^- generally tends to raise soil pH {9, 27, 46, 61}. In addition, the leaching loss of nitrate (NO_3^-), which is another major process with a net acidifying effect on the soil {27, 54}, can be reduced by growing perennial grass species with a continuously active, dense root system {27, 58, 59}. The leaching of NO_3^- in temperate leguminous pastures is often in the order of 8 to 10-fold greater than under pure grass pastures. In the course of this process exchangeable cations may be moved downwards as counterions with NO_3^- resulting in a decrease of base saturation {27}. Hence, the effect of a grass-legume pasture on soil acidity and fertility will depend to a large extent upon the ratio of grasses to legumes present {27}.

Most of the studies concerning legume-induced soil acidification have been conducted in temperate regions. However, recent work indicated that degradation of soil through acidification might also be a problem in tropical agriculture {56, 62}. Thus, further research will be necessary to clarify the long-term effects of legumes and grasses on pH of poorly buffered tropical soils.

3.1.2 Soil physical properties

The maintenance and improvement of the soil structure are important for sustainable agriculture. In addition to pedogenetic and climatic factors, farming practices such as tillage, crop rotation, grazing and manure application influence both the form and stability of soil structure {63}: As cultivation and tillage operations are usually accompanied by a decline in OM and by subsequent mineralization {9, 46}, arable cropping tends to destroy soil structure, to decrease total porosity and to increase soil bulk density. This may in turn cause a decline in rainfall infiltration rate {9}, thereby increasing the rate of soil erosion. Also trampling by grazing cattle can contribute significantly to soil compaction (see section 3.3).

Apart from applying repeatedly high doses of organic manures and mulching material {64}, a rest period under grasses or/and leguminous cover crops is the best means of increasing organic matter and improving physical conditions of arable top-soils {46, 65}. By adding organic matter, providing a good canopy cover and by loosening the soil surface through vigorous rooting, pasture plants and woody perennials help to improve soil structure (increase of aggregate size and stability, porosity, permeability; decrease of soil bulk density) and soil microclimatic parameters (increase of water holding capacity and soil aeration, decrease of soil temperature) (section 3.4) {9, 10, 28, 31, 33, 36, 46, 51, 63, 64, 65, 66, 67, 68}.

Some studies indicate that grasses appear to be more effective than legumes in improving the soil structure and in restoring the OM level, as the N-rich leguminous plant material often decomposes more rapidly {31, 46, 65}. Soil under grasses contains some of the highest concentrations of roots of any agricultural system: Natural grassland soil may contain over 12 t of roots/ha, compared with only 2-5 t/ha of above-ground material {46}. The roots of Buffel, Rhodes, Kikuyu grass and *Themeda* can grow as deep as 6 m. When these roots are decomposed, they produce channels through which water can move into deeper soil layers {46}.

In addition, grass roots can be particularly strong stabilizers of soil aggregates for reasons that have not been fully explored. Probably fungal hyphae and gum-producing bacteria in the rhizosphere of some grasses are involved in holding soil crumbs around grass roots {46}. Further research is needed to reconsider if grasses generally have higher potential for soil structure formation than legumes, and which parameters are decisive in this regard (e.g., rooting pattern, C/N ratio, lignin content, polyphenolics, microorganisms etc.).

Improvements of soil structure increase the amount of water available for crops. They improve aeration and drainage and encourage root growth {46}. These benefits may have only small short-term effects on yield, but they provide ecologically more sound conditions for crop growth and help to reduce erosion {46, 64}.

However, the soil physical improvements achieved by mulching or during a rest period under grass and legumes are rapidly lost during subsequent arable cultivations. In order to plan sustainable crop rotations the rate of deterioration of soil structure during the arable period is as important as its rate of restoration; it requires further critical examination {46, 65}.

3.1.3 Soil biological properties

As plant residues provide the main food for many soil organisms {46}, pasture plants are likely to have a significant effect on soil biological activities. An increased primary productivity of improved pastures and a higher nutritional value of the sown plants {69} may enhance the activity and number of both soil micro- and macroorganisms.

Decomposers, feeding on dead organic matter, comprise the greatest bulk of grassland soil fauna. The predominance of this trophic group reflects the high rate of return of dead organic matter to the soil in most grasslands {70}. Microbial activity of agriculturally important organisms such as N_2 fixing bacteria and VAM is generally greatest in the plant rhizosphere and seems to be stimulated by the abundance of organic substances supplied as root exudates and decomposing roots {46}.

Among the macrofauna, earthworms are often the most abundant as well as the most obvious zoological component of soils and therefore have been the subject of a considerable amount of research, especially in the palearctic region {71}. Several physical and chemical environmental factors have been suggested as determinants of the distribution and abundance of this group of animals. These include available moisture, temperature, soil texture, soil depth, quantity and persistence of organic matter, secondary compounds, C/N ratio, calcium content and pH {67, 70, 72, }. As discussed above (see sections 3.1.1 and 3.1.2), most of these parameters are substantially influenced by vegetation. A number of studies confirm that the growth of leguminous cover crops and grasses {1, 28, 33, 67} as well as the use of dung {71, 73} increase earthworm activity.

However, little research has been done to investigate the interactions and relationships between particular pasture species and the soil fauna. The greater number of publications has been concerned rather with the role of soil organisms in soil improvement and nutrient cycling, which in turn improve plant growth and crop yield (see section 3.2). Though there is no doubt that soil biological processes are of utmost importance to soil fertility and sustainable plant production, the complex interactions between plants, soil fauna and environmental parameters (including management practices) are still rather unexplored and hence deserve more attention in future research.

3.2 Nutrient cycling

In low-fertility soils, nutrient cycling is an important basis for sustainability {2, 23, 74}. It is the main reason why acid, infertile Oxisols and Ultisols are able to support exuberant tropical rainforest vegetation in udic environments {2, 53}. The majority of the nutrients in these ecosystems is stored in the living biomass and detritus (fallen leaves, residues from forest and animals), whereas nutrient amounts in the soil deposit are rather low {3, 53, 75, 76}.

The conversion of such a natural ecosystem, which is in equilibrium with regard to nutrients, into an agro-ecosystem with a totally new set of inputs and outputs, will inevitably lead to a change in nutrient fluxes {62}. When forests on poor soils are cleared and burned, nutrient cycling mechanisms are destroyed or interrupted and the non-volatile elements in vegetation are released to the soil {53, 75}. As a result the soil undergoes dramatic increases in K, Ca, Mg, NO_3^- {77}, available P, and pH, as well as a reduction in Al saturation {3, 38, 74, 76}. This high initial fertility after burning decreases rapidly because of nutrient losses through leaching and erosion if the forest is replaced by highly extractive systems and if the soil surface has only a sparse or temporary cover as in the case of arable cropping {53, 78}.

However, the replacement of forests by agroforestry systems or well-managed pastures with a dense and constant soil coverage may provide a recycling process similar to that of native vegetation {53, 74) although the amount of nutrients recycled in pasture ecosystems is considerably less than in an intact forest {74}. Like a forest, pasture systems store nutrients in both the living and dead biomass, and in the soil. Rain carries atmospheric dust and N, and promotes the incorporation of nutrients into the soil {53, 74}. Pastures containing legumes benefit from fixation of atmospheric N, and it seems that legume contents of 20-45 % of herbage dry matter could provide enough nitrogen to maintain a productive and sustainable pasture {35}.

In a pasture, nutrients are taken up by plants from litter and soil, and are subsequently transferred to grazing animals. Man removes part of the nutrients in the form of animal products, and the rest should return to the soil in the form of faeces and urine {53, 74}. Cattle detritus as a nutrient cycling pathway differs from litterfall in that (i) nutrients are more chemically mobile and (ii) patchily distributed. Dung and urine produced by cattle make nutrients readily available for plants enhancing productivity {46, 76, 79}, but excretion might also be associated with greater losses {35}. Thus, compared to an ungrazed ecosystem, grazed grasslands have a more rapid turnover of vegetation and nutrients {76, 80}.

Plant and animal remains decompose and are incorporated as organic material into the soil, thereby enhancing the quantity of nutrients available {74}. To study the fate of N in plant residues during their decomposition, ^{15}N-labelled plant material is used {47}.

Among the animal remains, the value of invertebrate residues (corpses and excreta) which are available for decomposition and mineralization should not be underestimated concerning their contribution to the soil nutrient status, especially to the phosphorus economy in pastures {81}. Apart from the formation of nutrient rich residues, the net functional contribution of invertebrates to nutrient cycling depends largely on their ability to stimulate microbial activity. Several studies of invertebrates and their interactions with microorganisms demonstrate the regulatory roles of invertebrates in nutrient cycling:

Earthworms, which in humid tropical grasslands can reach population densities of several hundred individuals/m^2 with a biomass up to 60 g/m^2, play a major role in creating and maintaining soil fertility through litter ingestion, burrowing and soil mixing {70, 71, 81, 82}. By their burrowing activities earthworms incorporate plant remains from the litter into the soil. They increase the total pore space as well as the proportion of larger pores within the soil and thereby influence its drainage, aeration and infiltration characteristics {71, 81, 82}. Both the burrowing and feeding activities of these animals produce large amounts of faecal material. Earthworm casts are the solid remains resulting from these activities that are deposited at the soil surface. These casts have been shown to contain more water-stable aggregates and to be microbially more active than the surrounding soil. Due to this enhanced microbial activity within the cast material, earthworms help to increase the availability of nutrients {71, 81}.

Where worms are not present in pastures, dense mats of dead and decaying root material may accumulate at the soil surface, 'locking up' large quantities of valuable nutrients {71}. The introduction of earthworms to such unpopulated soils, for example in New Zealand, or into polder grassland in the Netherlands, has led to significantly higher grass production with initial yield increases of greater than 70 per cent {20, 71, 72}.

In drier tropical soils, termites usually are the dominant macroinvertebrates. Termites and other arthropods, notably ants, mites, centipedes, isopods and collembola, help to fragment plant residues and hence increase the surface area available for microbial colonization and mineralization {70, 81}. If food is scarce, there can be a competition between macroinvertebrates and soil microorganisms for the exploitation of the more easily digestible and energy rich substrates. On the other hand, the macrofauna can also benefit from microbes when they feed on degradation products such as cellulose or hemicellulose which the former cannot digest themselves {82}.

The consumption of microbes has an important role in nutrient cycling through lysis of the ingested organisms and excretion of formerly immobilized nutrients {70, 81}. Microbivory, however, can also have negative effects on the nutrient balance. For example, it has been found that some collembola reduced the phosphorus uptake and growth of plants by feeding on the external hyphae of a mycorrhiza endophyte {81}.

The soil nutrient status will decline if the outputs in plant and animal products {83} and the losses in erosion, runoff, leaching and atmospheric gasses exceed the inputs to the soil in the form of fertilizer, weathering of rock, atmospheric accession and fixation {62}. The majority of studies that have been conducted to investigate and to quantify nutrient fluxes in agro-ecosystems, focus on processes within the carbon cycle and particularly the nitrogen cycle. In addition to the agronomic importance of these cycles there are also environmental implications, which explain the great interest in this area, such as nitrate leaching {27, 62}, N_2O production during denitrification under oxygen-limited conditions {73, 84, 85}, and acid production through incomplete nutrient cycling {54, 59, 62}.

Acids are produced in many of the nutrient cycles, but the main acid production in pasture ecosystems occurs in the carbon and nitrogen cycles {60}. In the carbon cycle, acids are produced in association with increases of OM, with the removal of plant material and animal products, and with transfer of dung and urine to stock camp areas of paddocks. Pasture improvement through fertilizer applications or introduction of legumes may contribute to increased OM accumulation and higher animal production associated with increased stocking rates and consequent higher product removal {59}. In the nitrogen cycle, inputs of symbiotically fixed N, ammonium fertilizers and losses of nitrate by leaching are involved in accelerated acidification of agricultural soils {54, 59}. In north-eastern Victoria (Australia), carbon and nitrogen cycle acidification accounted for 65 and 35 %, respectively, of the net acid addition on a fertilized pasture {59}.

The production of gaseous N compounds is potentially one of the most important routes of N losses from pastures {85} as well as from tropical forest soils, where measured fluxes of N_2O have been substantially greater than from temperate or boreal forests {84}. In well-draining soils, denitrification generally occurs under anaerobic conditions in microsites of high contents of labile C and mineral N. Research conducted under temperate climatic conditions revealed that earthworm casts and burrow walls which generally have higher ammonium concentrations, labile C, and water holding capacity than bulk soil samples, constitute sites of high denitrification potential and also influence nitrate leaching patterns {73, 85}.

Soil management practices in low-fertility soils should encourage nutrient cycling as much as possible {2, 53}. Effective soil fertility conservation may require that cycling components and mechanisms are introduced into agricultural systems {75}. Management options exist to improve nutrient cycling and the productive stability of agro-ecosystems, for instance:

- Nutrients should be returned to the production cycle by minimizing dung transfer, reducing hay cutting, leaving harvest residues in the field, using different forms of fallow etc. {7, 59};
- the inclusion of trees and shrubs acting as nutrient pumps helps to transfer (via falling leaves) nutrients to the soil surface that had percolated to the subsoil or that were released

in the rock weathering zone {2, 7, 49}. Secondary species may cycle nutrients at higher rates than climax species {75};

- biological N fixation by symbiotic or non-symbiotic microorganisms should be promoted (e.g., by mixed cropping, inoculation, adding micronutrients etc.). The use of VAM could result in higher yields on P-fixing soils {7, 74}.

In spite of optimum management practices, it is often necessary to replace nutrient losses through periodic fertilizer applications {7, 62, 74}. Additional data are required on the spatial and temporal variation in recycling processes in order to develop management strategies which allow a better synchronization between the supply of nutrients from all sources, and plant requirements {35}. To fully appreciate the extent of degradation of soil fertility under current farming practices and the potential role of pastures, we need better nutrient balance studies considering the different environments and climatic conditions. There is an urgent need to quantify nutrient fluxes, including annual emissions of gaseous compounds, nutrient influx through deposition of atmospheric dust, rates of organic matter decomposition etc.

3.3 Erosion control

Losses of topsoil through erosion depend mainly on soil properties, topography, climate and land use {86, 87, 88}. In dry areas, wind is a major cause of erosion {89, 90}, whereas in humid tropical and monsoonal regions intense rainstorms are leading to severe erosion problems {32, 46, 86, 91}. Water runs off the surface when the rate of rainfall exceeds the rate of infiltration. This may imply loss of much-needed water and of valuable topsoil threatening the long-term productivity of arable land {46, 92, 93}.

Deforestation, shifting cultivation, the use of steep slopes for cropping, reduced fallow periods, cutting of woody perennials to obtain fuelwood and forage, as well as overgrazing have resulted in increased erosion problems throughout the tropics {15, 87, 88, 89, 94, 95, 96, 97}. Undoubtedly, pastoral activities have contributed on a large scale to degradation of the soil resource. Severe changes in composition of plant communities may occur under heavy grazing {87, 98}. With increasing grazing intensity, a shift from shrubs and perennial grasses to annual grasses and forbs is frequently observed, and removal of perennial plants is usually associated with increased erosion {87, 97}.

Moreover, trampling by stock has been shown to reduce infiltration rates by promoting soil compaction and surface sealing {56, 78, 87, 99, 100, 101, 102, 103}. Seed removal during runoff, high temperatures, low water content in the sealing surface, and mechanical impedance subsequently prevent seedling emergence, thereby increasing erosion and desertification {56, 87, 96}. The sparse vegetative cover left by livestock finally might be removed by termites,

microorganisms and rapid phytomass decomposition due to high temperatures, creating an environment highly susceptible to erosion {33, 87}.

Cropped hillsides with slopes between 18-50 % are generally most severely eroded {15}. A study conducted in a mountainous area of Peru revealed that after changing land use from forest to crops or pasture, the suspended-sediment concentrations in the streams of the respective watershed increased significantly. This study confirmed the importance of maintaining a forest cover for soil protection on slopes steeper than 40 % {86}.

In this context, tree crops are generally suggested to be ecologically suited to the tropical environment causing little or no damage to soil {1}. However, the erosive energy of rain may increase under a high tree canopy through coalescence of raindrops into larger drops to such a degree that high erosivities have also been recorded under forest plantations {90}.

All soil conservation practices in tropical agriculture emphasize the need for good ground cover and the addition of OM which is known to have a favorable effect on soil physical properties (section 3.1.2) {15, 33, 46, 88, 104, 105, 106} as well as soil biological activities, e.g., the presence of earthworms (section 3.1.3) {33, 90, 104, 105}. Improvements of the soil structure will permit more water to penetrate and will store or drain any excess {46}. Thus, by decreasing the amount of run-off water, the transport of fine particles and the loss of nutrients will also be reduced {15, 46, 86}.

During recent years there has been an increasing interest in the introduction of herbaceous and woody forage plants in crop production systems as sources of mulch, green manure, ground cover, supplementary browse, contour hedges and windbreaks in order to control erosion {1, 9, 15, 32, 33, 37, 90, 95, 96, 104, 105, 236}.

The use of shade-tolerant, creeping leguminous covers (e.g., *Pueraria phaseoloides, Desmodium ovalifolium, Centrosema pubescens, Calopogonium mucunoides*) has become a standard practice in several plantation crops such as rubber, coconut and oil palm {33, 46, 237}. The legumes are expected to quickly provide a dense vegetative cover of the soil and thus to decrease the erosive energy of raindrops. By shading the soil they reduce soil temperature and the decomposition rate of organic matter, which helps to improve soil texture, water infiltration and water holding capacity {33}. Weeding activities, through which soil surface is disturbed and exposed to erosion, are not necessary if a cover crop smothers weeds successfully {1, 33, 104}.

The concept of leguminous ground cover in tree plantations led to the idea of "living mulches" (intercropping) in food crop production {1, 32, 37, 51, 92, 104}: The "live-mulch system" is a crop production technique in which food crops are planted directly in a low-growing cover crop (*Centrosema pubescens, Psophocarpus palustris, Vigna trilobata* etc.) with minimum soil disturbance {1}.

Short-term fallows with pasture plants and subsequent (chemical) killing of the vegetative cover provide another method to grow arable crops, possibly with no-tillage cultivation. The killed sod mulch has proved to be effective in controlling soil erosion {1, 67}.

Not only herbaceous, but also woody forage species can be instrumental in erosion control within (integrated) farming systems: On rangeland, microsite soil enrichment through litter accumulation in the immediate environment of woody species {66, 90, 105} may be important, as biomass in the shrub understorey aids infiltration and decreases run-off, especially beneath thorny shrubs where livestock grazing is restricted {87}.

A large amount of studies have been carried out on alley cropping, an agroforestry system in which arable crops are grown between hedgerows of woody shrub or tree fallow (e.g., *Leucaena leucocephala, Gliricidia sepium, Flemingia macrophylla (*syn. *F. congesta), Sesbania* spp., *Albizia* spp., *Calliandra* spp., and *Populus* spp. and *Salix* spp. in highland regions). The hedgerows are pruned periodically during the cropping season to provide green manure for the companion food crop {1, 15, 96, 105}. In situations where soil conservation (erosion) is considered a major issue, high foliage productivity coupled with a slow decomposition rate of foliage are advantageous characteristics of hedgerow species {105}, due to great effects in reducing erosion by maintaining a ground surface cover of litter and mulch {90}.

In addition to maintaining soil cover and improving soil physical structure, the formation of dense vegetation barriers is a desirable option in soil and water conservation: In alley cropping systems on steep slopes, hedgerows planted along the contours provide a biophysical infrastructure within which cropping can be carried out without danger of massive soil erosion {15, 90, 96, 105}. The distance between hedgerows should be adjusted to the slope degree: the steeper the slope, the narrower the interspaces with arable crops {15}. It is generally observed that in about three years of continuous cultivation the strips between hedgerows level off, becoming a series of natural terraces {15, 95}. Such terraces can be stabilized by rocks and stones at the base of the hedgerow, or by planting additional grass strips {15}.

Where wind is a major cause of soil erosion, windbreaks can make sustainable production possible. Windbreaks (shelterbelts) usually consist of (several) multistorey strips of trees, shrubs and/or grasses planted perpendicular to the prevailing wind. They can reduce the velocity of wind and thus its ability to carry or deposit soil and sand, which might lead to sandblasting or burying of crops {89, 90, 107}. Windbreaks have to be designed and maintained semi-permeable for good function. Otherwise (very dense structure or gaps), they might promote erosion by creating strong turbulences or channeling the wind, actually increasing its velocity. A properly designed windbreak can protect a field at least 10 times as long as the height of the tallest trees {90}. Even windbreaks with predominantly low growing herbaceous vegetation (*Cenchrus biflorus, Cassia mimosoides, Stylosanthes* spp., *Andropogon*

gayanus) can create a rather homogenous obstacle and effectively reduce wind speed and the amount of air-carried soil particles {89, 108}.

3.4 Microclimate

Plant communities have a substantial influence on climatic conditions close to the soil surface {109}. In the tropics, reduced temperature and increased moisture availability in the upper soil strata are particularly important in relation to early plant development (germinating seeds, sprouting in vegetative propagation), growth of superficially rooting species and nitrogen fixation in root nodules {64}.

Microclimatic conditions are to a considerable extent related to the transmission of solar radiation by the plant canopy. The different illumination of soil by solar rays under vegetation causes differences in temperature and humidity of the air and soil, depending on canopy structure and density {109}. Cover crops shade the soil from direct sunlight and thereby aid to reduce soil evaporation, to lower soil temperature and to keep down the rate of decomposition of organic matter {33, 110}. Topsoil temperatures (2.5 cm depth) dropped, for instance, from 42°C in bare soil to 25°C under a grass cover of 25 cm height {46}. Also the daily range of temperature variation under plants is generally lower than in open areas {109}.

Conversely, herbage removal, e.g., through grazing, may encourage evaporational loss and create a lighter, warmer and drier microenvironment. This is probably one reason why effects of drought and overgrazing tend to be confounded {98}. Fast-growing and deep-rooting grasses and cover crops with high rates of transpiration may cause a strong demand on soil water and can dry out the soil to a considerable extent. This can lead to adverse effects, especially in arid environments {46, 90}. Thus, establishing plants for improvement of microclimatic conditions in particularly difficult, arid environments requires careful selection of suitable species.

The accumulation of organic matter contributes greatly to soil moisture conservation. However, mulch materials have different capacities in terms of soil temperature reduction, moisture conservation and duration of these beneficial effects {50, 64}:

- Voluminous layers (e.g., mulch of *Flemingia macrophylla*) trap considerable quantities of air which form a barrier to heat transport and evaporation of soil moisture;
- dark-colored surfaces (such as *Leucaena leucocephala* mulch) absorb more radiation compared to lighter-colored surfaces. As a consequence, temperatures under dark mulch layers are relatively higher;
- the chemical composition (C/N ratio, lignin, polyphenolics) is an important factor that determines the effective life-time of a mulch material and hence the longevity of microclimatic improvement {64}.

Further research is needed to determine and to quantify the effect of pasture plants and mulches on microclimatic parameters and to assess the importance of these parameters regarding plant growth, soil biological activities, and incidence of pests and diseases.

Shading by trees and shrubs is not only for the benefit of cattle, but may also stimulate pasture productivity {20, 109, 111, 112}. For example, *Paspalum notatum* under *Eucalyptus grandis* trees has been shown to be more productive than grass without shade, and *Panicum maximum* yielded more under a canopy of *Albizia lebbeck* than it did in the open {20}. The mechanisms for this response are not yet clear, although there are suggestions that water availability may be an important factor {20}.

Tree and shrub plantings have a noticeable effect on the redistribution of precipitation and thereby influence the distribution of moisture within the soil profile: Generally, the windward side of soil under trees is more heavily moistured than that of the leeward side, and the depth of wettening the soil is particularly high under the trunk due to runoff {109}. Furthermore, multistorey strips of trees and shrubs as well as herbaceous vegetation, provide effective windbreaks. By lowering the wind speed, evapotranspiration is reduced in the protected area. However, despite reduced potential evaporation, subsoil water reserves may decline if the windbreaks are narrow-spaced and vegetation consumes large quantities of water {89, 90}.

For successful exploitation of potential microclimatic improvements through trees, shrubs and pastures, further information is required on the physiology, water economy and canopy structure of eligible species as well as on suitable planting patterns to minimize competition for water, nutrients and light.

3.5 Diseases, pests and weeds

Diseases, pests and weeds can be controlled chemically, biologically, culturally and genetically {113}. Because of the potential adverse impact of pesticides on fragile ecosystems, integrated control strategies based on agronomic management, host plant resistance and biological control agents should be given preference {114}. The use of pasture plants in integrated farming systems offers a range of possibilities to control phytosanitary problems by cultural and biological means:

Several studies indicated that certain leguminous cover crops and grasses (e.g., *Cynodon* spp.) have potential for management of nematode populations in susceptible crops {9, 115, 116, 117, 118, 119}. When *Pueraria phaseoloides, Arachis pintoi,* and *Centrosema pubescens* were co-cultivated with tomato in greenhouse pot tests, a significant reduction in galling caused by *Meloidogyne arabicida* was observed in tomato {117}. Planting *Aeschynomene americana* and *Indigofera hirsuta* in rotation with soybean reduced juvenile populations of *Meloidogyne arenaria* and *Heterodera glycines* at the end of the season; however, this

suppressive effect was short-lived {116, 118}. Also green-manuring with some cultivars of *Cajanus cajan* and *Crotalaria spectabilis* seems to be a suitable way to reduce populations of the root-knot nematode *Meloidogyne incognita* {119}.

As in the case of nematodes, the severity of soil-borne fungal diseases often depends on cropping history. Ley pastures may help to break disease cycles {43}. Experiments conducted in Queensland (Australia) revealed that common root rot in wheat, caused by *Bipolaris sorokiniana* (= *Cochliobolus sativus*), was less severe when wheat was planted after *Medicago sativa, M. scutellata* and *Cenchrus ciliaris,* than when it was grown continuously {120}.

Some tropical legumes even may serve for control of insect pests: Freshly cut leaves of jackbean (*Canavalia ensiformis*) can be used as a biological control agent for leaf-cutting ants (*Atta* sp.) as they contain the fungicide demethylhomopterocarpin affecting the ants' fungus gardens {121}. Another strategy to reduce pest populations in certain crops is the use of trap plants. *Indigofera* spp. might be suitable trap plants for *Piezodorus guildinii* (Heteroptera: Pentatomidae), a neotropical stink bug, thereby reducing the impact of this pest on soybean crops {122}. Some cultivars of the commercially important genus *Stylosanthes* have been shown to trap host-seeking larvae of the cattle tick *Boophilus microplus* and could provide a means of controlling cattle ticks in improved pastures {123}.

Creeping leguminous cover crops which grow rapidly and vigorously (*Centrosema pubescens, Pueraria phaseoloides, Mucuna pruriens* and *Desmodium ovalifolium*) help to eliminate weeds and to reduce weed seed banks {1, 18, 124}. Today, such cover plants are widely used for weed suppression in tree plantations {33, 46}. Even very aggressive weeds such as *Imperata cylindrica* may be controlled by using *Pueraria phaseoloides, Stylosanthes guianensis* and *Calopogonium mucunoides* {1}.

Mulching showed promising results in retarding weed development, too. However, the value of mulching seems to be limited to the control of weed species that were multiplied by seed, whereas regrowth from roots or stumps from former vegetation is unlikely to be suppressed by a mulch layer {125}. Biochemical interactions such as allelopathy seem to be involved in the ability of pasture plants to suppress weed growth {126}.

The use of pasture plants seems to be very promising for management of phytosanitary problems in integrated farming systems and therefore deserves more attention in future research. On the other hand it cannot be ignored that in recent years an increasing number of pathogens and pests has been identified on tropical forage plants {113, 127}. If such parasites possess a wide host range, they might affect associated crops {128}.

Phytosanitary problems are more common in agroecosystems than in natural, diverse ecosystems. Therefore pasture improvement and cultivation of large areas with genetically similar forage plants have increased the potential for losses to pests and diseases {113, 114,

129}. There are several publications describing the most commonly found nematodes {130}, insect pests {113, 131, 132, 133, 134, 135, 136, 137, 138} and diseases {75, 113, 128, 129, 139, 140} associated with tropical pastures. Awareness of the range and distribution of parasites recorded on pasture plants as well as of potential seed-borne diseases is regarded as essential for preventing global transmission of these organisms {141}. Unfortunately, introduction of contaminated seed is yet rather common {128}. Bacteria and potyviruses constitute a particular danger due to the difficulties of eliminating them from seed {129}.

Pests and diseases of pastures can reduce forage quantity and quality. They can even cause undesirable changes in plant persistence and botanical composition of grazing land with long-term effects on productivity {74, 142, 143}. However, caution should be taken in estimating yield loss and disease severity: For example, herbivorous insects are not generally deleterious to grassland production. Studies revealed that some chewing and sucking insects, such as hemipterous insects {144} or grasshoppers {145}, may inject growth-promoting substances into the plants during feeding, thus stimulating regrowth potential and seed production.

Often, pasture disease evaluation is done in small monoculture plots neglecting that grazing and competition between associated plant species can influence disease development. Heterogeneous perennial pastures grazed by cattle would be a more realistic place for this kind of evaluation {127, 142}. More information is required concerning ecology and host plant range of pasture pests and diseases and their practical importance at the farm level. There is still a need to determine whether certain parasites cause significant reductions and economic losses in animal or crop production {146}, and whether control strategies are really needed {142}.

Current research for control strategies mainly focuses on selecting and breeding for host plant resistance {113, 114, 115, 147, 148}. As tropical pasture plants have been selected for only a short time, vast sources of genetic variation still exist in their centers of diversity where plants have been associated with endemic parasites over a long period. This natural variation should be used first for germplasm screening and multilocational selection instead of initiating costly breeding programs {113}.

An increased use of resistant varieties may lead to selection of highly virulent pathogenic races and the breakdown of (single-gene based) resistance {113, 114}. To ensure durability, resistance should be combined with biological and cultural methods (e.g., burning, grazing, cutting, tillage, rotation etc.) in integrated pest management (IPM) programs. Biological control of pests and diseases of forage plants is still largely unexplored {113}, except for economically important species such as the *Leucaena* psyllid, *Heteropsylla cubana* {138}. Further research will be needed to identify beneficial organisms and natural enemies of pasture pests and to develop complex IPM strategies.

4 Tropical pastures within regional and global ecosystems

4.1 Hydrology

Inputs of water through rainfall and irrigation, its storage in the soil, and the outputs (runoff, evapotranspiration, deep drainage and groundwater recharge) are elements of the hydrological cycle that have to be in balance for an ecosystem to be stable and sustainable {56}. By changing a virgin landscape for the purpose of crop production and pastoral utilization, agriculture contributes not only to alteration in the flux of water, but also to changes in water quality:

Large-scale deforestation is supposed to result in regional climatic and hydrological changes {149, 150, 151, 152}. For example, about half of the precipitation in the entire Amazon basin seems to result from water recycled by transpiration. Extensive deforestation would be expected to greatly reduce the transpired water available for rainfall {151}. In Venezuela it has been observed that deforestation of the southern slopes of the coastal Cordillera and north-easternmost Andean spur has led to loss of water retention capacity and to more rapid runoff. Streams draining this region, which formerly were year-round flowing across the Llanos, now dry up during the dry season {151}.

Land and stream salinization has occurred in several semi-arid and arid regions of the world {153} as a result of clearing the native vegetation for agricultural development. Clearing of forests and woodlands for crops and pastures usually results in less water use and evapotranspiration by the replacement vegetation. Thus, more water must either run off increasing the likelihood of erosion or move through the soil profile past the root zone {62}. This deep-drainage water enters the regional groundwater system and causes the watertable to rise. Salts (principally NaCl) in the soil profile are dissolved and accumulate at lower points in the landscape following evaporation or ultimately get into the streams {56, 62, 154, 155}. In Western Australia, only 48 % of the divertible surface water resources remain fresh (less than 500 mg total soluble salts per liter), and some 440 000 ha of once productive farmland have become salinisized {56, 154}.

Moreover, it is well known that excessive livestock pressure is upsetting the normal hydrological functioning of a landscape by decreasing infiltration and thereby increasing runoff, as already mentioned in section 3.3. Especially in mountain ecosystems, the negative effects of hillslope denudation and high stocking rates become evident in flash floods and increased sediment load in the draining rivers {150}. The increased suspended-sediment concentration debases water quality; the deposited sediments might block irrigation channels, generate severe flooding from raised riverbeds, fill reservoirs {156}, and might even lower the operational efficiency and lifespan of hydroelectric plants {157}.

In addition, deforestation implies a reduction of shade. This can increase the temperature of runoff water, which directly affects the dissolved oxygen content that is essential for the aquatic fauna in draining rivers {86}. Lower pH values in surface waters might be related to the organic deposits from cattle and the decomposition of organic sediments {86}.

Overfertilization of pasture land is another important factor which can have dramatic environmental and ecological impact such as accelerated eutrophication of surface waters: For example in 1986, one of the largest algal blooms ever documented appeared in Lake Okeechobee, a large, natural fresh-water lake in Florida, United States. When the algae began dying after completing their growth cycle, the resulting low dissolved O_2 levels and high NH_3 concentrations killed virtually all invertebrate life in the lake. Phosphorus was considered to be the major factor causing eutrophication of Lake Okeechobee. An important source of P in this special case was runoff of soluble P fertilizer applied to bahiagrass pastures (*Paspalum notatum*) {158}. Leaching of nitrate as a result of incomplete cycling of symbiotically fixed N under legume pastures or high inputs of ammonium fertilizers, contributes to the contamination of ground and drinking water, too {54, 56, 58}.

Most of the aforementioned hydrological changes that cause environmental problems are due to mismanagement of natural resources. Several studies have been carried out to resolve such problems and to find land use and grazing systems that, as far as hydrological aspects are concerned, are more sustainable:

With regard to salinization there would be less problems if the replacement vegetation used water in the same manner as the original vegetation {56}. Brigalow (*Acacia harpophylla*) forest is the original vegetation on approximately 8 million ha in north-eastern Australia. Much of the area has been developed for crop and pasture production. This development, together with the inherent salinity of the subsoil of much of the brigalow lands, has raised fears about the potential for widespread dryland salting in these areas. To tackle this problem a study was conducted assessing the effect of clearing brigalow forest on ground water recharge {159}. It was observed that no significant recharge occurred during the period in which crops and pastures were fully established. As brigalow is a shallow-rooted tree species and able to regulate transpiration in dry periods, the maximum depth to which water was extracted from the soil and the resultant soil water deficits under brigalow forest were similar to those under crop and pasture. These results suggest that under average climatic conditions of the region dryland salinity will not occur when these soils are developed for pasture production or opportunity cropping {159}. On the other hand, when removing deep-rooted trees and woody plants (e.g., eucalypt, pine) an ecological niche is created which should be filled up by deep-rooted species {160}.

To control salinization various reforestation strategies have been tested such as strip planting, valley planting, extensive reforestation and agroforestry. Agroforestry has a great potential to

lower saline groundwater tables, though high-density reforestation over a large proportion of the cleared area seems to be the best strategy when rapid and large groundwater level reductions are required {153, 154, 155, 161, 162}.

Concerning nutrient losses due to runoff and leaching, which might cause eutrophication of surface waters, there is an urgent need to reconsider current fertilizer application levels. A field study conducted on a bahiagrass pasture in Florida revealed that it is possible to reduce the P application rate by 50 % (from 48 kg to 24 kg P/ha) without significantly altering growth or quality of bahiagrass {158}. Grasses that form an intimate mixture with legumes in pastures, have the advantage of readily taking up N and thus minimizing loss of nitrate through leaching {163}.

Erosion control measures are indispensable to reduce the sediment load of rivers and thus to improve water quality. The potential contribution of pasture and forage plants to this issue is discussed in section 3.3.

The way in which a production system interacts with the hydrological cycle, and the implications of these interactions regarding the longer-term stability and sustainability are often disregarded. To understand the hydrological consequences of land use changes and deforestation it is necessary to appreciate the fate of deep drainage, salt and nutrient distributions, and the complex patterns of surface and groundwater movement. At the moment there is a lack of standard methodology for assessing the local, regional and global hydrological consequences of extensive forest clearing and land use changes. There is an obvious need for reliable models that describe hydrological processes if sustainable land use systems are to be developed {56}.

4.2 Regeneration of degraded land

As a result of overgrazing, deforestation, inappropriate cultivation techniques, mining activities, and other anthropogenic disturbances, large areas are today in an advanced stage of degradation. Land degradation affects three-quarters of the world's grazing land, half of the rainfed cropland, and a quarter of the irrigated land {164}. Some characteristic problems that are encountered in the course of degradation and desertification of ecosystems are loss or disturbance of vegetation cover, increase in soil erosion, loss of available nutrients and organic matter, soil acidity with high levels of toxic manganese or aluminum, salinization and scarcity of microbial activity {165}.

In view of population growth and the increasing demand for agriculturally productive land, strategies to restore the productivity of abandoned sites are of major importance and might help to reduce the pressure on still-productive ecosystems {156, 166}. Regeneration may range from restoration of a degraded ecosystem to the original ecosystem, from reclamation of

a desertified ecosystem to an ecosystem similar to that of the original situation by using preexisting species, or to rehabilitation of a desertified ecosystem by planting exotic species {135, 167, 168}.

The prospect of establishing forage plant species which at the same time improve soil chemical, physical and biological properties of a degraded area, often encourages the beginning of revegetation efforts in the tropics {109, 156, 169, 170, 171}. Input-intensive techniques to reclaim degraded pastures, such as mechanization and application of fertilizers and lime, have been employed in many Amazon countries, especially in the Brazilian Amazon. The vigorous forage grass *Brachiaria humidicola* which is well adapted to poor acid soils, has been used to replace degraded *Panicum maximum* and *Hyparrhenia rufa* pastures {74, 166, 172}. From a technical perspective, high-input technology can be effective in recuperating (pasture) ecosystems. However, the intensification of land use implies the disadvantage that it is expensive due to reliance on machinery and fertilizers {74, 172}.

An alternative to the above approach is a low-input soil management technology which is based mainly on the use of plants adapted to soil constraints rather than elimination of all soil constraints to meet the plants' requirements {2, 74}. Plants suitable for revegetation should be adapted to nutrient deficiency, should be easy and rapid to establish, should persist and be resistant to prevailing pests and diseases {143}.

On impoverished sites with a poorly developed nitrogen cycle, legumes efficient in N_2 fixation can be sown as early colonizers and as a 'nurse crop' facilitating the establishment of other species {168}. Today, much effort is made to select plant species and genotypes adapted to a wide range of unfavorable ecological conditions {2, 143, 169, 170, 171, 173}.

Plant establishment in acid or desertified ecosystems is often limited due to inadequate P nutrition, especially in the case of legumes which require relatively high levels of P for N_2 fixation. Also the absence of symbiotic microbes such as vesicular-arbuscular mycorrhizal (VAM) fungi, which are of particular importance for the absorption of nutrients of low mobility in soil solution (P, Zn, Cu), can severely limit seedling establishment, plant growth, and plant survival {165, 174}. In the case of degraded and eroded soils that have low concentrations of VAM propagules, VAM inoculation is likely to increase plant performance, establishment and drought tolerance {175, 176}. Also biological N_2 fixation may be improved by selecting highly effective rhizobium strains. Thus, appropriate microsymbiont management could be a tool to promote revegetation, but the practical and cost-efficient utilization of this technology will still require more research {2, 143, 176}.

Including woody plants in regeneration programs is of special importance to control salinity (section 4.1), reduce wind speed (section 3.3), and improve microclimatic conditions (section 3.4) {109, 111, 168}. Moreover, island-forming trees may provide attractive habitats for seed

carrying birds and thereby enhance the quantity and diversity of animal-dispersed plant species recruited in the surrounding area {166, 177, 178}.

Seed application methods for extensive revegetation approaches (e.g., aerial seeding) may be less successful unless good seed-soil contact is ensured {179}. The use of livestock as agents of seed dispersal may be an interesting alternative. Livestock could be strategically fed with seeds of desirable species to disseminate them into areas targeted for improvement. The moist, nutrient-rich dung may facilitate seed germination and plant establishment. Further studies will be necessary to test this approach and to find further inexpensive methods of seed application for revegetation {177, 179}.

The success of revegetation efforts depends, apart from abiotic factors, substantially on biotic interactions that affect plant establishment. Interactions within and between plant species as well as plant-animal interactions need to be considered {168, 177}.

The utilization of species mixtures and the development of diverse plant communities is potentially important for stability of vegetation cover and productivity. Regeneration of degraded land should not depend upon only one single species. However, research is needed to investigate if species sown in mixtures are compatible and if successful coexistence is possible {168}.

With regard to animals affecting plant establishment and persistence on regenerated land, more attention should be directed to pollinating insects {180}, seed dispersal, below-ground herbivory and grainivory. Seed predation is potentially a major factor contributing to the failure of regeneration. Especially rodents and ants have been shown to be primary seed predators. They can decrease seed reserves in annual grasslands and desert annual communities by 30-80 % {136, 177}.

Grasses, legumes and woody forage plants, e.g., in silvopastoral systems, have a great potential to play a major role in the revegetation of degraded land, in salinity control, erosion control, sand dune stabilization, shelterbelt establishment and rehabilitation of mined areas {178, 181}. However, besides the selection of species adapted to edaphic and climatic constraints, an understanding of the interactions between plants, animals, and microbes is crucial for the success of regeneration efforts.

4.3 Biodiversity

Biological diversity (= biodiversity) is the variety of life and its processes, including the variety of living organisms, the genetic differences among them, the communities, ecosystems and landscapes in which they occur, plus interactions of these components. In view of global environmental changes and accelerated extinction of species, biodiversity is more and more capturing public and scientific attention {182, 183, 184, 185, 186}. There are several reasons

for preserving the world's variety of life, such as the moral obligation to protect organisms, aesthetic reasons, the need to prevent genetic erosion for ensuring the evolutionary potential of our crops and pastures, and last but not least the maintenance of ecosystem functions. Loss of biodiversity may negatively influence the stability of ecosystems {187} as well as the quality and quantity of ecosystem services, such as maintenance of soil fertility, nutrient cycling, natural control of pest organisms, amelioration of climates, etc. {188, 189}.

It is estimated that a quarter of the world's biodiversity may be under serious threat of extinction over the next 20-30 years (15,000 to 50,000 species/year) {190}, and there is no doubt that rates of extinction greatly exceed rates of evolution of new species {188}. Especially those species, which require non-developed areas and stable conditions, are endangered whereas short-lived species with rapid growth rates are favored by cultivation and thus have increased in abundance {182}. Some of the main factors that affect species composition and diversity are large-scale changes in land use patterns and the introduction of new agricultural technologies (e.g., fertilizers, pesticides, irrigation, replacement of locally adapted varieties, etc.).

The role of grazing and pasture management in this context is rather complex:

Deforestation in tropical countries has dramatically accelerated during the last decade, increasing from 11 million hectares per year to nearly 20 million {191}. The loss of species as a result of deforestation and degradation of tropical forest land is widely discussed {183, 188, 191, 192}. In the Amazon basin, at least 10 million hectares of forest have been converted to highly unstable pastures, of which about 50 % were in advanced stages of degradation in 1990 {74}. Therefore, one of the main objectives of today's pastoral research is to increase the longevity of still-productive pastures and to reclaim degraded land in order to reduce the rate of forest clearing {74, 143, 172, 193}. Genetic erosion is being curtailed by germplasm collection and preservation. This collection is the basis for the identification and development of adapted forage species, suited to different environments and agricultural practices {114, 143, 161}.

Ecosystem dynamics that determine the composition of vegetation on rangelands are rather complex and are triggered by natural mechanisms (e.g., weather, fire, competition, allelopathy, shading) and by management actions (stocking rate, burning, introduction of exotic plants, fertilization, irrigation, etc.) {194, 195}. Increasing resource availability, e.g., through fertilizer application or irrigation, typically increases yield, but at the same time may reduce species diversity. This relationship between production and diversity is inverse because competitive plants are often better able to capitalize on increased resource availability and can therefore increase their biomass or density at the expense of slower-growing, stress-adapted species {91, 168, 187, 196}.

High stocking rates in the tropics frequently lead to overgrazing with subsequent degradation and decline in biodiversity. In environments with pronouncedly seasonal rainfall, perennial grasslands can be converted to annual grasslands by grazing {91, 195}. Livestock is also likely to select more palatable species to such an extent that eventually unpalatable plants predominate {98, 112, 194, 195, 197, 198}.

Concerning the effects of herbivores on plant growth and reproduction there are two major opposing views: On the one hand, herbivory is suggested to be detrimental to plants {199, 200, 201}, representing a selective pressure for the evolution of plant defenses. On the other hand, plants have been shown to benefit from being grazed, as their seeds may be distributed in the dung, and grazing may stimulate the production of flowers, herbage and roots, ultimately causing greater fitness {98, 177, 196, 199, 201, 202}. The extent of compensatory growth is influenced by external factors, e.g., competition with neighbor plants, nutrient availability and timing of herbivory {203}.

Selection pressure resulting from grazing in combination with a semiarid climate is an important force that through evolutionary periods has influenced the present structure of natural grasslands and their relative ability to withstand grazing: In semiarid environments, basal meristems, short stature, high shoot density, rapid regrowth following defoliation, and spreading by rhizomes and stolons constitute adaptations that enhance survival and may promote tolerance or avoidance of grazing. Many grazing-tolerant grasses have totally co-evolved with large herbivores. On the other hand, in subhumid areas tall grasses without the capacity of spreading by rhizomes and stolons predominate. Tall growth forms are adaptations that enhance the grasses' competitiveness for light but make them more vulnerable to grazing. In communities of such grazing-intolerant species, grazing usually increases diversity of plants by decreasing the ability of dominant species to competitively exclude others, and by creating gaps, freeing resources such as light and nutrients. In contrast, in semiarid grasslands with a strong evolutionary history of grazing, moderate herbivory appears to have a relative small effect on community composition {204}.

Today, there is much interest in using exotic species for pasture improvement {205}. Such pastures may be very productive initially, but often productivity declines in the long run due to changes in nutrient availability and reduced competition, leading to the invasion of undesirable weeds and native grasses {20, 74, 160, 172}.

Reversely, introduced fodder plants can develop a weed potential {160, 206}: Between 1947 and 1985, 463 exotic grass and legume species, represented by at least 2033 accessions, were intentionally introduced into northern Australia. Of these, 60 species (13 %) became listed as weeds: 21 were weeds of cropping, 20 were weeds of conservation and 19 were weeds of both sectors {206}. There is much concern that biodiversity in natural areas might be threatened by the introduction of exotic species eventually killing or competing with native species {183,

192} which could be essential components of balanced, co-evolved ecosystems. On the other hand, some authors claim that paleo-ecological and historical data show that species have continuously been added or removed from ecosystems, changing species composition and structure, but these exotics have rarely affected ecosystem functions {207}. However, the consideration of weed potential and competitiveness must be an integral part of current and future evaluation programs for selection of new pasture species {161, 192}.

Moreover, disturbances such as fire and diseases can greatly affect biodiversity {166}. Removal of fuel and organic matter by grazing can be considered as a factor reducing the incidence of fire {98, 182}.

Farming practices, grazing and changes in vegetative cover also influence the variety and abundance of the fauna {69, 98, 182, 198}. Tropical grasslands can harbor a rich community of above-ground insects {208} and of earthworms. In pastures established in formerly forested areas, species diversity of earthworms seems to be lower. Much depends on (i) the adaptive potentialities of the former forest species to take advantage of the new environment, and (ii) on the possibility for pantropical species to invade these new habitats {72, 82}. Similarly, introduced collembola prevailed in pastures where exotic plant species occur, whereas native collembola were predominantly restricted to natural pastures {69}. Increased grazing by sheep decreased species richness and increased uniformity of collembola in both pasture types {69}.

On the other hand, structural diversification and patchiness of landscapes may increase species richness. For instance, the presence of agricultural fields within unfarmed areas has been observed to increase the regional diversity of birds {209}. Appropriate grazing management can be a tool in regulating the types and quality of bird habitats {198}.

Preservation of species, genotypes, communities and ecosystems should not only be realized by creating wildlife reserves and parks. We must also learn to use land in a sustainable way and to manage pastures in such a manner that most of the biodiversity is retained {20, 183, 192, 210, 211}. Research is needed to identify keystone species and functional groups, which are important to maintain all ecosystem processes that are essential for sustainability {182, 183, 186, 192, 212}.

4.4 Atmosphere and global warming

Changes in the chemical composition of the earth's atmosphere which possibly lead to global and regional climatic changes have caused increasing concern during recent years. These changes seem to be related to activities of man such as energy consumption. Production and use of chemicals in the industrialized countries are probably far more significant than global agricultural production. The contribution of the latter to global warming has been roughly estimated to be 15-25 % {213}.

The major processes related to agriculture causing atmospheric changes are:

- Deforestation and biomass burning, causing net release of CO_2, CO and other relevant trace gases such as nitrous oxide (N_2O), ozone (O_3) and methane (CH_4) {214, 215, 216, 217, 218, 219, 220, 221, 222, 223};
- energy from fossil fuels used for fertilizer production (mainly nitrogen fertilizers) and machinery causes net CO_2 release {224};
- use of nitrogen fertilizers can enhance N_2O-release {84, 214, 217};
- soil degradation and destruction of organic matter produce net CO_2 release {213, 218, 224, 225};
- methane (CH_4) is released in paddy rice cultivation and by ruminants {214, 222, 226, 227, 228, 229, 230, 231, 232}.

The significance of pastoral activities in this context is rather complex:

When replacing native rainforest ecosystems in large areas, pastures tend to contribute to global warming in several ways {214}. Carbon stored in the forest biomass will be released by clearing, and although productive pastures can theoretically assimilate as much carbon as mature rainforest, many pastures in rainforest areas (especially in South America) have undergone a rapid process of degradation within less than 10 years, leaving extended areas of unproductive land {218}. Thus, forest clearing for pasture establishment leads to net CO_2 release due to biomass burning or decomposition, if pastures are not maintained productive by using external inputs and appropriate management. Furthermore, biomass burning increases concentrations of CO, NO_x and ozone in the surface-near atmospheric layer, NO_x being an important precursor of ozone, which apart from being toxic to plants also contributes to the greenhouse effect. Recent research has revealed that rainforest seems to be a globally important sink for ozone; thus rainforest clearing destroys at the same time the sink as more ozone and ozone precursors are produced {214, 215, 220}. Pastures could also produce more N_2O than the native forest, particularly when nitrogen fertilizers are used {84, 214, 217}. Increased cattle population would produce more methane {214, 226, 227, 228, 230, 231}.

Consequently, in view of global warming, replacement of native rainforest by pastures does not seem to be a desirable option (as well as from other points of view, see sections 4.1 and 4.3).

On the other hand, cultivation of improved pastures and forages can also counteract the current processes of climatic change. There are, for instance, indications that deep-rooted grasses store large amounts of organic carbon in the soil, and may therefore play a vital part in stabilizing the global cycle and minimizing the greenhouse effect of atmospheric CO_2 {233}.

The carbon stored worldwide in soil organic matter exceeds the amount retained in biomass {213}. Agricultural techniques which increase soil organic matter content can, therefore, create an important CO_2 sink. The role of fodder plants in integrated farming systems for restoration of soil organic matter content is well known (see section 3.1.1) as is the contribution of improved fallows, alley cropping and agroforestry systems. Pasture species can also be used for revegetation of degraded lands (section 4.2).

Of particular importance is the fact that legumes, when providing subsequent crops (or companion grasses in pastures) with biologically fixed nitrogen and by these means replacing mineral nitrogen fertilizer, can considerably reduce the consumption of fossil energy in intensive agricultural systems. It has been shown that nitrogen fertilizer use in average farms in Germany accounts for about 50 % of fossil energy consumed for plant production {224}. Strategies for reduction of atmospheric CO_2 are particularly efficient, if not only sinks for excessive CO_2 release from fossil sources are created, but if at the same time the use of the latter is substituted by solar energy assimilated by plants. This fact has been observed for forestry CO_2 strategies {219}, but would also be true for the case of biological N_2 fixation.

Little seems to be known about the amount of N_2O released from tropical soils. In some publications, the use of nitrogen fertilizer is reported to enhance the production of this greenhouse gas which occurs as an intermediate during denitrification, but there seem to be no publications about the amounts of nitrogen fixed by pasture legumes undergoing the same process. This is an area in need for further research.

Methane production by ruminants, particularly cattle, has been a matter of interest for many years, because of the nutritional energy loss involved. Methane is the second important greenhouse gas after CO_2. According to recent estimates, worldwide animal husbandry accounts for about 20 % of global methane production and contributes with about 4 % to the whole problem of global warming {231}. Methane emissions during rumen fermentation depend on diet composition and level of feeding {226, 227, 228, 229, 230, 231}. In general, methane release per unit animal product (milk, meat etc.) decreases with higher individual animal performance, so that some authors suggest that all measures improving individual milk and beef yields would be vital to control the methane problem. These measures include supplementation with urea, minerals, and high quality feed (sugar, proteins, starch, fat), chemical control of rumen microflora, chemical manipulation of volatile fatty acid formation in the rumen, etc. {227, 228}. Nevertheless, methane production is not the only point to be considered in order to determine ecologically adequate feeding levels and diet compositions for ruminants.

Energy requirements per kg milk produced decrease significantly if milk yield per cow is increased from 2000 to 5000 kg/year, but less for further increase to 8000 kg/year {234}. At this high level of performance, forage intake has to be progressively replaced by concentrates,

generally produced with fossil fuel inputs. Furthermore, a protein surplus is unavoidable in diets for very high production levels {83, 234}, creating new problems regarding nitrogen losses to groundwater and atmosphere. Medium feeding levels based on good-quality green fodder seem to be optimal from both the environmental and animal health point of view. Tropical pasture plants can probably significantly help to reduce methane emissions from cattle fed on low-quality roughage by increasing forage intake, digestibility, turnover in the rumen and individual animal performance, as reported in numerous publications. However, investigations about the benefits of tropical pasture legumes for animal production have so far not been evaluated with regard to global warming concerns.

In addition to affecting global climate, it is expected that an enriched CO_2 atmosphere will influence biotic interactions because of the critical role of CO_2 in photosynthesis. There are indications that plants may respond to enriched CO_2 environments by increasing growth and water use efficiency, whereas foliar nitrogen concentrations may decline {235}. The effects of such responses on plant-plant as well as plant-animal interactions are still poorly understood.

5 Conclusions

The degradation of natural resources in terms of soil fertility decline, erosion, desertification, species extinction and disturbance of the hydrological cycle through pastoral mismanagement, are testimony to the fact that current land use systems in tropical regions are often far from being sustainable. Up to the present time, scientists have not been successful in developing sound guidelines for the development and management of sustainable pastoral systems, as emphasis of most research activities has been put on improving short-term productivity. The way in which the farming system interacts with biotic and abiotic elements of the ecosystem and the implications of these interactions for the long-term stability has usually been neglected or has been studied apart from the farming system and without drawing conclusions with regard to management practices. However, critics of cattle husbandry would do well to note the importance of cattle referring to socio-economic aspects and human nutrition, and reconsider the role of cattle and pasture plants within diversified mixed farming systems.

Possible strategies towards the solution of the problem of grazing-induced land degradation are:

1) Increasing the longevity and stability of still productive pastures and arable land in order to avoid further deforestation and expansion of agriculture into intact natural landscapes;

2) restoring productivity of degraded pastures and abandoned land.

Progress towards sustainable pasture and land use systems will only be made if the implications of agricultural practices are studied in an integrative way and if they are understood as parts of the regional ecosystem.

The present literature review indicates that basic data on ecological effects of pasture establishment and livestock production are still scarce, especially in the case of long-term effects at the regional and global level, e.g.:

- Little is known about the contribution of tropical legumes to soil acidification and about the effects of pasture species on soil biology;
- future management research should include studies of the hydrological consequences of land use changes for pastoral purposes, and should consider the effects on water quality;
- biotic interactions and relationships between plants, animals and microbes need to be identified to enhance the probability that species will co-exist and thereby facilitate greater species diversity on a given site;
- a major research challenge is to identify keystone species and functional groups to sustain ecosystem processes;

- pastoral research should address the question as to how create a CO_2 sink to stabilize the global carbon cycle, e.g., by cultivation of deep-rooted species and by increasing soil OM content;
- methane emissions from cattle should be reduced by improving forage quality.

Technologies of pasture plant uses for other purposes than feeding livestock, e.g., for soil improvement or revegetation, still lack tropical experience to a large extent and are far from being fully developed. Future pastoral research should improve knowledge on the multipurpose potential of herbaceous and woody forage species. Researchable priority topics are, among others:

- The potential of pasture species to improve infiltration rates and water retention capacity, and to produce rougher surfaces for erosion control;
- selection of pasture species adapted to unfavorable edaphic and climatic conditions for restoration of degraded land;
- quantification of nutrient fluxes in integrated cropping systems and generation of further information on the spatial and temporal variation in recycling processes;
- further exploration of the potential of pasture plants for management of phytosanitary problems, including research on beneficial organisms and natural enemies in pasture ecosystems, and on IPM strategies to control pests and diseases of valuable pasture plants;
- influence of multipurpose trees and forage plants on microclimate.

Research topics should be addressed within multilocational research programs for a wide range of ecological and socio-economic conditions. It is important that techniques, which are feasible and socially acceptable to smallholders in the tropics, are put into practice as soon as possible if environmental degradation is to be halted or at least to be slowed down. Interdisciplinary research and interinstitutional collaboration will be indispensable to achieve the goal of successful development and implementation of sustainable land use systems.

6 References

1

Mulongoy, K. and Kang, B.T. (1986): The role and potential of forage legumes in alley cropping, live mulch and rotation systems in humid and subhumid tropical Africa. In: Haque, I., Jutzi, S. and Neate, P.J.H. (eds.), *Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16-19 September 1985.* Addis Ababa, Ethiopia: ILCA (International Livestock Centre for Africa), p. 212-231.

Keywords: legumes; alley cropping; live mulch; mulch; Africa; *Leucaena leucocephala*; weed control; maize; yields; nitrogen fixation; nematodes; pest control; improved fallow; erosion; weeds.

Abstract. Fragile, low activity clay soils, which are prone to erosion and are characterised by inherently low fertility, are common in humid and subhumid tropical Africa. On these soils, forage legumes play an important role in developing sustainable and low input crop production systems. Woody and herbaceous species such as *Leucaena leucocephala, Gliricidia sepium, Flemingia congesta* and *Sesbania rostrata* have shown good potential for inclusion in alley cropping systems. *Mucuna pruriens* var. *utilis* is one of the most promising sources of in situ mulch in small- and large-scale crop production. Live mulches of *Psophocarpus palustris* and *Centrosema pubescens* smother weeds effectively and have been shown to sustain high maize yields with little fertilizer N input. Despite the encouraging results obtained with forage legumes on less acid soils, further research is needed to select species that can be included in low-input crop production systems on strongly acid soils.

2

Sanchez, P.A. and Salinas, J.G. (1981): Low-input technology for managing Oxisols and Ultisols in tropical America. *Advances in Agronomy* 34:279-399.

Keywords: Oxisols; Ultisols; South America; low-input technology; tropics; fertilizers; sustainability; adapted germplasm; soil chemical properties; phosphorus; nitrogen fixation; soil acidity.

Abstract. Low-input technology for acid soils of the tropics can be defined as a group of practices that can produce about 80% maximum yields of acid-tolerant plant species and varieties with the most efficient use of soils and chemical inputs. The term "low" is used in relation to "high"-input technology where the application of fertilizers and amendments largely eliminate chemical soil constraints. The identification of plant species and ecotypes tolerant to the main acid soil stresses allows the development of low-input soil management systems for Oxisol-Ultisol regions where socioeconomic constraints prevent the widespread application of large quantities of lime and fertilizers. The basic approach is to use plants adapted to acid soil constraints, to maximize the use of fertilizers and lime needed to produce about 80% of their maximum yield, and to take advantage of favourable attributes of acid, infertile Oxisols and Ultisols. Several technology components are reasonably well identified and could be used as building blocks for specific management systems.

3

Fearnside, P.M. (1980): The effects of cattle pasture on soil fertility in the Brazilian Amazon: Consequences for beef production sustainability. *Tropical Ecology* 21:125-137.

Keywords: sustainability; cattle; Amazon region; soil chemical properties; degradation.

Abstract. Amazon rainforest is fast being replaced by cattle pastures as investors respond to financial incentives and the lure of the new highways. The Brazilian government's encouragement of pasture is linked to claims that pasture improves soil fertility and therefore represents a "rational" means of development in the Amazon. A review of information related to the ongoing debate concerning soil fertility changes under pastures casts doubt both on the claims of improved fertility for pasture growth, and on the presumption of indefinitely sustainable yields of beef cattle.

4

Atta-Krah, A.N. (1990): Alley farming with *Leucaena*: Effect of short grazed fallows on soil fertility and crop yields. *Experimental Agriculture* 26:1-10.

Keywords: improved fallow; yields; sustainability; legume trees; maize; alley cropping; *Leucaena leucocephala*; soil chemical properties.

Abstract. A long-term trial with *Leucaena leucocephala* was initiated in 1982 to test the sustainability of *Leucaena*-based alley farming compared to a conventional cropping system without trees and with continuous cultivation of maize. It assessed the integration of short grazed fallows in rotation within *Leucaena* alleys and their effect on soil fertility and crop yields. The various treatments had no effect on soil pH during the four-year period of the trial. The organic carbon and total nitrogen contents of the soils under conventional cropping were lower by the end of the fourth year than those under alley cropping and alley grazing treatments, whereas soil phosphorus levels were lower in the alley cropping and grazing plots. Foliage dry matter production of *Leucaena* under alley cropping management ranged from 6.0 to 6.7 t ha^{-1} a^{-1} under continuous cropping and reached 8 t ha^{-1} when alley cropping was preceded by a grazed fallow. Crop yields were consistently higher with alley cropping than with conventional cropping. Alley cropping plots in rotation with two year grazed fallows gave significantly higher crop yields during cropping years than those under continuous cultivation.

5

Gichuru, M.P. (1991): Residual effects of natural bush, *Cajanus cajan* and *Tephrosia candida* on the productivity of an acid soil in southeastern Nigeria. *Developments in Plant and Soil Science* 45:417-422.

Keywords: *Cajanus cajan*; intercropping; improved fallow; *Tephrosia candida*; legumes; nutrient cycle; Nigeria; shrubs; maize; yields; cassava; West Africa; soil chemical properties; nitrogen fixation.

Abstract. An experiment was established in 1986 to examine the contribution of *Tephrosia candida* and *Cajanus cajan* shrubs to improving the productivity of an acid soil. The main treatments were N levels (0 and 60 kg per ha) with subplots of maize/natural bush, maize/*Tephrosia candida*, maize/*Cajanus cajan*, maize + cassava/natural bush, maize +

cassava/*Tephrosia candida*, and maize + cassava/*Cajanus cajan*. In 1988, all plots were cleared and maize uniformly planted to study the residual effects of the treatments. No residual effects of N application were observed. *Tephrosia candida* and *Cajanus cajan* increased surface soil organic carbon and total N levels over the natural bush. However, only *Tephrosia candida* plots produced improved maize grain and stover yield. Highly significant correlations were found between maize grain yield and earleaf N (r = 0.73), grain N (r = 0.51), and stover N (r = 0.54) contents. These results suggest that *Tephrosia candida* increased N availability in the soil. Therefore, the shrub has potential for improving the productivity of acid soils under traditional systems, where N is limiting due to the absence of N_2-fixing legumes in the natural bush fallow.

6

Hussein, S.E.G. (1990): The influence of fallow under *Acacia senegal* (L.) Willd. on the C and N content of the soil. *Beiträge zur Tropischen Landwirtschaft und Veterinärmedizin* 28:217-222.

Keywords: natural fallow; shifting cultivation; soil chemical properties; legume trees; tropical savanna; Africa; fallow.

Abstract. The paper describes the origin, properties and utilization of the Goz sands. The soil is generally utilized in a shifting cultivation system: cultivation for 4 years, 12 to 15 years of bush fallow under *Acacia senegal* (L.) Willd. A comparative investigation of soil profiles exhibited a considerable accumulation of organic soil matter and nitrogen under fallow vegetation.

7

Prinz, D. (1986): Increasing the productivity of smallholder farming systems by introduction of planted fallows. *Plant Research and Development* 2:31-56.

Keywords: farming systems; legumes; improved fallow; soil chemical properties; yields; nutrient cycle; live mulch; mulch; alley cropping; ley farming; legume trees.

Abstract. The doubling of the population in the developing countries which is expected over the next 25 years makes it necessary, assuming that the same amount of land is available for cultivation, for productivity per unit land area to be at least doubled. Of the many possible methods offered by tropical crop science we have selected one, planted fallow, and have briefly described its potential in relation to peasant farming systems. Planted fallow is the targeted use of plant species in order to achieve one or more of the aims of bush fallow within a shorter time or on a smaller area. Two main forms can be distinguished: successive and simultaneous fallow, and two sub-forms: ley farming and multi-storey cropping. Apart from grasses, legumes are the plants chiefly involved in systems of planted fallow. A stable production system can be built up and an increase in area productivity achieved by using one or several forms of improved fallow combined. But if yields per hectare are to be doubled all the elements of "integrated plant nutrition" available will have to be used.

8

Nicholaides, J.J., Bandy, D.E., Sanchez, P.A., Benites, J.R., Villachica, J.H., Coutu, A.J. and Valverde, C.S. (1985): Agricultural alternatives for the Amazon Basin. *BioScience* 35:279-285.

Keywords: soil chemical properties; shifting cultivation; annual field crops; Peru; tropical forest; pastures; deforestation; Amazon region; fertilization; crop rotation; seeds; agroforestry; rice.

Abstract. As population pressure increases, shifting cultivation practices are considered to be one reason for deforestation in the rainforest areas of the Amazon basin. As an alternative, a technology for continuous cultivation using rotations of annual food crops such as rice-peanut-soybean, has been developed in Yurimaguas/Peru. The effects of this new technology, using improved seeds, fertilizers, lime, insecticides, plant-spacing and weeding techniques on soil properties, farmer acceptance and economic feasibility were examined. Other alternatives to shifting cultivation could be legume-grass pastures or agroforestry on sloping soils, and paddy rice on alluvial soils. Limitations and potentials for these improved technologies are discussed. (Abstract by bibliography authors)

9

Chheda, H.R., Babalola, O., Saleem, M.A.M. and Aken'ova, M.E. (1981): Sown grassland as an alternative to shifting cultivation in lowland humid tropics. *Proceedings of the XIV International Grassland Congress, Lexington (USA)*, p. 774-777.

Keywords: *Cynodon*; shifting cultivation; mixed farming; allelopathy; soil physical properties; soil chemical properties; erosion control; pest control.

Abstract. Agriculture based on existing forms of shifting cultivation will not be able to support and feed adequately the rapidly increasing human population of the lowland humid tropics of Africa. The forest and natural fallows have shortened and even disappeared in some areas because of rising food demands. Crop yields are low and continue to decline. What, then, are the alternatives? Using *Cynodon* as an example, an attempt is made to show that mixed farming offers an alternative whereby the nutrient status and physical properties of the soil can be maintained, erosion can be checked, weeds can be kept under control, and the buildup of pests and parasites minimized or avoided. A synthesis of several years of intensive breeding and agronomic research at the University of Ibadan indicates: 1. Availability of improved robust, nonrhizomatous *Cynodon* genotypes with an annual dry matter (DM) yield potential of around 15 tons (t)/ha, adequate for production of 650 kg/ha of live-weight gains of the local Zebu cattle when grazed from April to December. 2. Annual nutrient mobilization of over 122, 25, 175, 37, and 29 kg/ha of N, P, K, Ca, and Mg, respectively, by *Cynodon* pastures. Around 20% of the nutrients mobilized are "pumped up" from soil layers below 30 cm. 3. Possession by several *Cynodon* genotypes of high microbial population in the rhizosphere, capable of fixing varying quantities of N. IBX-7, an improved hybrid, is able to fix up to 2 kg/ha of N/week. 4. Increase in soil organic matter under temporary *Cynodon* pastures, replenishing a high proportion of the substantial loss of 63% in organic matter (OM) under 10 years of continuous cultivation. 5. Improvement of soil physical properties under *Cynodon* pastures as measured by soil aggregate size and aggregate stability, bulk density, and total porosity. 6. Protection against erosion with established *Cynodon*. *Cynodon*, when fully established, gives almost as much protection against erosion as does forest with closed

canopy. On a soil with 3% slope, water runoff from *Cynodon* plots was 5.3% of the total erosive rain of 155 cm. Soil losses under pasture during the growing season were less than 10% of those observed in maize and cowpea plots. 7. Ability of root exudates collected from several *Cynodon* improved genotypes, when placed with seeds of common tropical weed species, to inhibit germination or reduce seedling growth. Aqueous extracts of *Cynodon* roots showed similar inhibitory effects. The inhibition factor disappeared after 27 to 45 hours of storage. 8. Resistance of *Cynodon* genotypes to the root-not nematodes (*Meloidogyne* spp.). Growing of *Cynodon* in highly infested soils decreased the root-not nematode population appreciable in 6 months and eliminated the nematodes completely within 18 months. Consequently, tomato yields increased by about 300%.

10

Bishop, J.P. (1982): Agroforestry systems for the humid tropics east of the Andes. In: Hecht, S.B. (ed.), *Amazonia: Agriculture and land use research*. Cali (Colombia): CIAT (Centro Internacional de Agricultura Tropical), p. 403-413.

Keywords: agroforestry; deforestation; degradation; *Brachiaria humidicola*; *Desmodium ovali-folium*; legume trees; swine; cattle.

Abstract. The author suggests agroforestry systems that integrate animal production, fuelwood/timber and food crop production for small farms of the humid lowlands east of the Andes. In this region, colonization, deforestation and unstable forms of land use have led to accelerated soil degradation, weed/pest invasion and decreasing yields. Two examples of agroforestry systems developed in the Ecuadorian Amazon region are presented as possible solutions of land degradation problems. After two years of food crop production, the forage legume *Desmodium ovalifolium* is sown together with the root forage *Canna edulis*, a local banana variety (*Musa acuminata x M. balbisiana* ABB) and the fast growing native legume tree *Inga edulis*. Forages and banana serve for swine raising, which is economically important in the region, while legume trees improve soil fertility and provide fuelwood. The swine-fuelwood production represents a form of improved fallow within an 8-year rotation cycle and is considered to have a great potential to improve economic productivity and ecological stability of small farms. Another suggestion is the integrated cattle and timber production in order to maintain long-term productivity of pastures. The forage grass *Brachiaria humidicola* is intercropped with the forage legume *Desmodium ovalifolium* and the timber tree *Cordia alliodora*. Considering a 20-year period, the benefit from timber production could equal the income from cattle raising, thus improving both economic and ecological conditions as well as sociological viability of livestock production in the region. (Abstract by bibliography authors)

11

Humphreys, L.R. (1994): *Tropical forages: their role in sustainable agriculture*, Longman Scientific & Technical, Harlow, Essex, England, 414 p.

Keywords: sustainability; mixed farming; soil improvement; soil erosion; soil properties; trees; shrubs; pastures; intercropping; weeds; diseases; nutrient cycle.

Abstract. This comprehensive volume demonstrates how forages can sustain tropical cropping systems and be used to combat the environmental problems of deteriorating soils and declining crop yields associated with monocropping and the development of marginal lands.

'Tropical forages' begins by examining the advantages of mixed farming with animals and crops, which can improve soil structure and reduce soil erosion to enable more efficient use of environmental resources and help protect crops from disease. This added flexibility in turn leads to the diversification and stabilisation of farm income. The book moves on to consider the management of different cropping systems involving forages and the science on which they are based. These systems include: tree and plantation crops combined with pastures; shrub legumes grown with annual crops; ley systems in which pastures are rotated with annual crops; and the intercropping of annual crops with forage legumes. The author emphasizes the need to grow improved fodder crops to supplement existing feed resources. 'Tropical Forages':

- provides unique coverage of tropical plant-soil-animal systems in one volume
- explores key areas of current research such as resource management and thedevelopment of sustainable systems
- outlines the fundamental principles of agricultural management, illustrated with case studies
- includes a comprehensive list of over 800 references.

'Tropical Forages' is an essential reference for agronomists, tropical agriculturalists, development agencies and resource managers involved in both arable and animal farming, and for agricultural consultants and students of agriculture or crop science.

12

Adejuwon, J.O. and Adesina, F.A. (1990): Organic matter and nutrient status of soils under cultivated fallows: An example of *Gliricidia sepium* fallows from south western Nigeria. *Agroforestry Systems* 10:23-32.

Keywords: improved fallow; *Gliricidia sepium*; Nigeria; soil chemical properties; Africa.

Abstract. This paper examines the dynamics of organic matter and nutrients under planted fallows of *Gliricidia sepium* in south western Nigeria, as an investigation into the behaviour of soils under such fallows. Data on soil characteristics were collected from thirty fallow fields ranging in age from one to eight years. The data sets were described using the descriptive statistics. Furthermore, the relationships between the soil properties and the age of the fallow were evaluated with simple bivariate correlation analysis. Compared with published data and trends in natural fallow, the study shows that the progress of the planted fallow leads to greater organic matter build-up and increase in nitrate-nitrogen and potassium concentration in the soil. It also shows that the biomass retains greater amount of nutrients during the fallow.

13

Nnadi, L.A. and Haque, I. (1986): Forage legume-cereal systems: improvement of soil fertility and agricultural production with special reference to sub-Saharan Africa. In: Haque, I., Jutzi, S. and Neate, P.J.H. (eds.), *Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16-19 September 1985.* Addis Ababa, Ethiopia: ILCA (International Livestock Centre for Africa), p. 330-362.

Keywords: intercropping; cereals; nitrogen fixation; plant competition; West Africa; yields; annual field crops; maize; sorghum; legumes; undersowing.

Abstract. Intercropping forage legumes with cereals offers a potential for increasing forage and, consequently, livestock production in sub-Saharan Africa. But in such a system the yield depression of the cereal grain should be minimal, possibly not more than 15%, for it to be acceptable to the farmer. The time of sowing of cereal and legume is critical for the yield of each crop. Data so far available indicate that undersowing within 10 days of planting a fast growing cereal such as maize does not depress cereal grain yield significantly, but with slow-growing, long-season crops such as photosensitive sorghum, grain yield is greatly depressed. In the case of sorghum, high grain yield is obtained if the legume is sown 3-4 weeks after the cereal. Intercropping forage legumes and cereals generally results in higher fodder protein yield than cereal alone. However, fairly high yields of legumes are needed to augment the cereal residues in order to produce a feed composition capable of meeting the basal nutritional requirements of ruminants. The effect of intercropping on soil fertility varies with management practice. It is estimated that legume roots contribute between 5 and 15 kg N/ha to soil N under intercropping.

14

Onim, J.F.M., Mathuva, M., Otieno, K. and Fitzhugh, H.A. (1990): Soil fertility changes and response of maize and beans to green manures of Leucaena, Sesbania and pigeonpea. *Agroforestry Systems* 12:197-215.

Keywords: *Leucaena leucocephala*; *Cajanus cajan*; green manure; *Sesbania sesban*; agroforestry; maize; beans; yields.

Abstract. Three multipurpose tree species (MPTS), leucaena (*Leucaena leucocephala*), sesbania (*Sesbania sesban* var. *nubica*) and pigeonpea (*Cajanus cajan*), were pruned at a height of 60 cm above the ground every two months, and resulting plant biomass was incorporated into the soil as green manure. For comparison, maize (*Zea mays*) stover was also incorporated into some plots, while some other plots were left fallow. Varying quantities of plant biomass which were incorporated into the soil over a period of 12 months caused large changes in major soil plant nutrients, and it substantially improved soil fertility. To test for improved soil fertility, test crops of maize and beans (*Phaseolus vulgaris*) were grown on the test plots after six biomass incorporations of 4806, 13603, 16659 and 7793 kg ha^{-1} yr^{-1} for pigeonpea, sesbania, leucaena and maize, respectively. Responses of the test crops indicated that sesbania and leucaena green manures improved maize stover, cobs and grain yields; and bean haulms and grain yields by 77.6% when compared to fallow plots. Residual effects of green manures still resulted in significant ($P<0.05$) yield differences in the test crop in the third testing season. Economic significance of green manures in increasing food crop yields to small scale farmers is discussed.

15

Paningbatan, E.P. (1987): Alley cropping in the Philippines. In: Latham, M. (ed.), *Soil management under humid conditions in Asia (ASIALAND). Proceedings, 1st Regional Seminar on Soil Management under Humid Conditions in Asia and the Pacific, Khon Kaen, Phitsanulok, Thailand, 13-20 October 1986*. Bangkok (Thailand): IBSRAM (International Board for Soil Research and Management), p. 385-395.

Keywords: alley cropping; Philippines; shifting cultivation; *Leucaena leucocephala*; *Gliricidia sepium*; annual field crops; soil erosion; mineral nutrients; yields; agroforestry; *Alnus japonica*; erosion control; sustainability; South East Asia; establishment; shrubs; legumes; legume trees.

Abstract. Comparative tests of alley cropping vs. traditional shifting cultivation system have recently been carried out successfully in the Philippines. The main plants to be tested were *Leucaena leucocephala*, *Gliricidia sepium*, and *Alnus japonicum [A. japonica]*, and food crops were normally used between the hedgerows. An account is given of the establishment and management of the alley crops, and their beneficial effects on erosion and nutrient inputs. Alley cropping has proved attractive to farmers, providing as it does natural levelling, increased yields and an alternative source of income from the sale of dried leaves. However, the invest-ment involved is a problem. Research is needed to assess the long-term sustainability of specific alley cropping practices, to determine the effect of alley width and alternative alley managements on soil erosion, to screen acid-tolerant shrub legumes, and to make a socio-economic evaluation.

16

Bishop, J.P. (1983): Tropical forest sheep on legume forage/fuelwood fallows. *Agroforestry Systems* 1:79-84.

Keywords: tropical forest; sheep; legumes; fallow; agroforestry; agropastoral systems; Ecuador; South America; Amazon region; grazing; *Desmodium ovalifolium*; fuelwood; trees; *Inga edulis*; tropics; cassava; nitrogen; phosphorus; soil erosion; erosion; leaching; insects; diseases; weeds; fertility; crop residues; soil compaction.

Abstract. In Amazonian Ecuador, studies are being realized to intensify fallow periods by grazing African tropical forest type sheep (Red Afro-Colombian x Barbados Black Belly) on Asian tropical forest legume cover forage (*Desmodium ovalifolium*) under American tropical forest fuelwood trees (*Inga edulis*). The specific approach represents an innovative effort to address the complex problems associated with the pernicious use of less fertile lands by small-scale farmers and graziers in the humid tropics. The technologies developed are closely compatible with traditional socio-cultural patterns. For example, shifting cultivators are encouraged to plant contour strips of legume fuelwood trees in their cassava fields. With the cassava harvest, legume cover forage is planted between the fuelwood trees, to be grazed later by tropical forest sheep. Forage and fuelwood legumes increase soil aeration, organic matter, nitrogen and available phosphorus, control soil erosion and leaching, as well as provide a break in cropping that checks insect, disease and weed build-ups. Tropical forest sheep improve soil fertility by deposing organic matter which stimulates legume/*Rhizobium* symbiosis and by supplying fecal microorganisms which mineralize crop residues. In addition, tropical forest sheep cause little soil compaction and erosion, produce high quality food protein from legume cover forage, as well as generate cash income, capital and employment for small-scale farmers. Tropical forest sheep on legume forage/fuelwood fallows not only intensify land use under shifting field cultivation, but also form the basis for rehabilitating already degraded lands for further food crop production.

17

Cobbina, J. (1992): Herbage yield and soil fertility restoration potential of some tropical forage legumes. In: Mulongoy, K., Gueye, M. and Spencer, D.S.C. (eds.), *Biological nitrogen fixation and sustainability of tropical agriculture.* Chichester, UK: John Wiley & Sons, p. 455-462.

Keywords: soil improvement; fertility; soil chemical properties; soil organic matter; legumes; nitrogen; soil properties; sustainability; fallow; mixed farming; *Stylosanthes guianensis; Pueraria phaseoloides; Centrosema macrocarpum.*

Abstract. Interest in planted fallows as an alternative to shifting cultivation and related bush fallow rotation practices is gradually increasing. In mixed farming systems, adoption would be accelerated if the planted fallow crops contributed to the farmers' livestock feed requirements. This paper reports on a study in which forage legumes were compared over a 2-year period in terms of their herbage dry-matter yield and nitrogen content and their contribution to improved soil fertility. Over long- term growth periods (8-13 months) high herbage dry-matter yields (9-16 t/ha) were produced by *Stylosanthes guianensis* cultivars, *Pueraria phaseoloides* and *Centrosema macrocarpum*; the herbage nitrogen content was also very high (2.2%). Generally, there were significant improvements in soil organic carbon (90-170%) and total nitrogen (130-240%) but not in Bray I extractable phosphorus or exchangeable potassium. The paper recommends a management strategy which involves incorporating into the soil some of the herbage produced during the fallow period before reverting to cropping.

18

Ngiumbo, K.A.B. and Balasubramanian, V. (1992): Effect of fallow and residue management practices on biomass production, weed suppression and soil productivity. In: Mulongoy, K., Gueye, M. and Spencer, D.S.C. (eds.), *Biological nitrogen fixation and sustainability of tropical agriculture.* Chichester, UK: John Wiley & Sons, p. 463-473.

Keywords: fallow; weeds; nitrogen fixation; sustainability; natural fallow; yields; *Sesbania sesban;* maize*; Imperata cylindrica*; soil properties; fertility; Cameroon.

***Abstract*.** This paper presents the initial results of short-season planted fallow and residue management trials in progress in Cameroon. The aim of the trials is to assess the effects of planted vs. natural fallow and of types of fallow residue management on biomass production and nutrient contribution, weed suppression, and grain yields of associated and subsequent crops. The results indicate that the top growth of the fallow vegetation provided 22-67 kg N/ha to the soil/plant system. The leaves of *Chromolaena odorata*, the dominant fallow species at one site, contributed almost the same amount of nitrogen as *Sesbania sesban*. In the following season, the maize grain yield response to the two species was similar. The dominant fallow species at the second site, *Imperata cylindrica*, was poor in terms of its nitrogen contribution compared to the *S. sesban* intercrop treatment, and this was reflected in the response of the succeeding maize crop. Burning *I. cylindrica* gave a higher maize yield than incorporating or surface mulching. The *S. sesban* intercrop effectively shaded out the weeds for the succeeding maize crop; weed density in plots previously planted to maize/groundnut was only slightly higher than the *S. sesban* intercrop treatments, but far less than that in natural fallow where the treatments involved burning, incorporation or mulching. Trials are in progress to confirm these results and to design cost-effective planted fallow establishment methods for the forest zone of Cameroon.

19

Teitzel, J.K., Gilbert, M.A. and Cowan, R.T. (1991): Sustaining productive pastures in the tropics. 6. Nitrogen fertilized grass pastures. *Tropical Grasslands* 25:111-118.

Keywords: pastures; nitrogen; grasses; fertilization; Australia; sustainability; soil acidity; animal production.

Abstract. Nitrogen fertilized pastures are being used more in high rainfall areas as part of both beef and dairy production systems. Because of their productivity at critical times of the year, they have useful roles in reducing stress on other pasture types and boosting production from groups of cattle to match specific market requirements. On properties where cool-dry season management is critical, higher and less seasonal production can be attained by applying N fertilizer to a seasonally responsive grass on the deeper soils. On predominantly poorly drained properties N application to grasses resistant to trampling on high country, allows stock reduction on low areas during the wet season. The application of 200-300 kg/ha N annually gave near optimum milk and beef production per hectare in areas with annual rainfall greater than 800-1000 mm. Disadvantages of N fertilized pastures are high capital outlays in fertilizer and stock. However, under present economic conditions N fertilizer has a role in increasing productivity and sustainability of tropical and sub-tropical property management systems. Use on special purpose pastures can lead to substantial gains in farm profitability.

20

Myers, R.J.K. and Robbins, G.B. (1991): Sustaining productive pastures in the tropics. 5. Maintaining productive sown grass pastures. *Tropical Grasslands* 25:104-110.

Keywords: pastures; grasses; Australia; sustainability; soil chemical properties; animal production; tropics; subtropics; nitrogen; sown pastures; mineralization; legumes; earthworms; trees.

Abstract. Sown grass pastures in the tropics and subtropics are initially productive, but productivity declines with age, a process commonly referred to as run-down. Run-down is often associated with loss of desirable species. Nitrogen (N) deficiency is the major causal factor. The initially high production of sown pastures is a transient consequence of increased available N and water that accumulates during fallow, and the run-down condition is the normal equilibrium. The severe N deficiency in soils with apparently adequate total N is due to progressive immobilization of N and limited mineralization of humic material. To increase the productivity of run-down pastures, external N must be supplied or mineralization of N from either soil organic matter or plant residues must be enhanced. Most potential solutions require either external inputs or exploitation of finite soil reserves. Potential management options under investigation that may increase productivity by increasing N supply include rotations of pastures with annual crops, sowing pasture legumes, fertilizing with N, optimizing grazing management, renovating by cultivation, establishing earthworm populations, establishing beneficial shade trees, and changing to stoloniferous grass types. Another more simple solution is to accept that productivity run-down will inevitably occur and to reduce stocking rate if gain per head is to be maintained.

21

Dalal, R.C., Strong, W.M., Weston, E.J. and Gaffney, J. (1991): Sustaining multiple production systems 2. Soil fertility decline and restoration of cropping land in sub-tropical Queensland. *Tropical Grasslands* 25:173-180.

Keywords: fertility; cereals; yields; legumes; fertilizers; wheat; pastures; grasses; grass-legume pastures; farming systems; sustainability; ley farming; Australia.

Abstract. Fertile soil is the basis of sustainable agriculture. Continuous cultivation and cereal cropping lead to the depletion of soil fertility, low crop yield and poor grain quality. It is estimated that 1.2M ha of the total cropping area of 1.5M ha in southern sub-tropical Queensland are affected by soil fertility decline, with a consequent reduction in crop yield and grain quality valued at an output loss of $324M/yr. There is an urgent need to adopt fertility restorative practices to maintain economically viable farming enterprises. Legume based leys, grain legumes, fertilizer N and zero-tillage were compared for their effectiveness in restoring or maintainig soil fertility and for sustaining wheat yield and quality on a fertility-depleted brigalow soil at Warra on the western Darling Downs. Both annual N fertilizer application and zero tillage accompanied by N application maintained wheat yields although they are uncertain options for long-term fertility restoration. The grain legume, chickpea, provided a moderate level of N supply to the following wheat crop but is also an uncertain option for fertility restoration. Pasture leys based on annual and perennial legumes, with or without grasses, provide a useful option for fertility restoration. One year medic and lucerne leys contributed to soil N to a moderate level although lucerne leys may have an adverse effect on the moisture available for following crops. Grass-legume mixed pastures increased soil fertility as measured by an increase in soil total N. Of these options, pastures based on annual and perennial temperate legumes and tropical grasses have the potential to increase or maintain soil fertility. Legume leys and especially grass-legume pasture leys will play a key role in future ecologically and economically sustainable farming systems.

22

Reddy, K.C., Soffes, A.R. and Prine, G.M. (1986): Tropical legumes for green manure. I. Nitrogen production and the effects on succeeding crop yields. *Agronomy Journal* 78:1-4.

Keywords: legumes; green manure; annual field crops; nitrogen uptake; yields; nitrogen fixation.

Abstract. The energy shortage of the 1970s and knowledge that N prices may continue to escalate renewed interest in growing legume green manure crops to furnish N. The objective of this study was to evaluate the ability of selected green manure crops to furnish N to succeeding crops. This study evaluated seven tropical legumes and a marigold (*Tagetes erecta* L.) cv. "Cracker Jack" grown for different lengths of the summer under fumigation (F) and nonfumigation (NF) on Aredondo fine sand (loamy, siliceous, hyperthermic Grossarenic Paleudults) during 1979, 1980, and 1981. Spilt-plot and randomized complete block designs with five replications were used. In the basic experiment, fumigation and nonfumigation were main plots and tropical legumes and fallow were the subplots. The green manure crops were grown for three different periods, early summer, full summer, and late summer. Early and late summer plantings usually included only the legume crops and fallow in a randomized complete block design. Average top growth N yields in kg ha^{-1} were 40 for "PI 305070" mungbean (*Vigna radiata* (L.) Wilcz.), 250 for "Norman" pigeonpea (*Cajanus cajan* (L.)

Millsp.), 190 for "FL 81d" pigeonpea, 170 for showy crotalaria (*Crotalaria spectabilis* Roth.), 220 for hairy indigo (*Indigofera hirsuta* L.), 170 for jointvetch (*Aeschynomene americana* L.), 190 for velvetbean (*Mucuna deeringiana* (Bort.) Merr.), and 60 for marigold. The dry matter yield of legumes (harvested before seeding) with higher N yields usually exceeded 10000 kg ha^{-1} for full-season production in all three years. Fumigation increased dry matter yield of legumes and marigold, but not their N yield. The grass crops, rye (*Secale cereale* L.), ryegrass (*Lolium multiflorum* L.), maize (*Zea mays* L.), and wheat (*Triticum aestivum* L.) produced significantly higher dry matter (up to 100%) when planted after green-manure summer legumes than when planted after summer fallow. Calculated uptake of N from green manure by these grass crops was relatively low, averaging from -2 to 23 kg ha^{-1}. Applying 50 and 100 kg N ha^{-1} as ammonium nitrate to the green-manured plots did not increase recovery of N from green manure by wheat.

23

Palm, C.A. and Sanchez, P.A. (1991): Nitrogen release from the leaves of some tropical legumes as affected by their lignin and polyphenolic contents. *Soil Biology and Biochemistry* 23:83-88.

Keywords: nitrogen; legumes; lignin; polyphenolics; mineralization; live mulch; green manure; ground cover; mulch; chemical composition; manure; rice.

Abstract. Leguminous plant materials used as mulches, green manures and cover crops are generally assumed to provide a readily-available source of N to crops. However, little is known about the chemical composition and N release patterns of the variety of legumes being used in tropical agroecosystems. N release patterns from the leaflets of 10 tropical legumes and rice straw were determined in a laboratory experiment. Ground leaf material was allowed to decompose in an acid soil (pH 4.5) for 8 weeks and the soil was analyzed periodically for extractable NH_4^+-N and NO_3^--N. N release in the soil plus plant material were compared to that of the soil without plant material added and related to the N, lignin and polyphenolic concentrations of the leaflets. Three patterns of net N mineralization emerged during the 8 weeks. One pattern exhibited by the control soil, rice straw and leaves of two of the leguminous plants was a low, positive net mineralization. Another pattern showed much higher rates of mineralization than the control soil and the third pattern showed initial net immobilization followed by low but positive net mineralization rates. The amount of N mineralized during the 8 weeks as compared to the control soil ranged from +46 to -20% of the N added in plant material. Net mineralization was not correlated to % N or % lignin in the leaf material but was found to be negatively correlated to the polyphenolic concentration, r = -0.63, or the polyphenolic-to-N ratio, r = -0.75. Mineralization in excess of the control soil was found only for materials with a polyphenolic-to-N ratio <0.5. Mechanisms to explain the low mineralization by materials high in polyphenolics include the formation of stable polymers between polyphenolics and amino groups, and nitrosation, a chemical reaction of nitrite (NO_2^-) with polyphenolics. Our results show that leguminous plant material with a high polyphenolic content or polyphenolic-to-N ratio may not be a readily-available source of N.

24

Williams, W.A. (1967): The role of the Leguminosae in pasture and soil improvement in the Neotropics. *Tropical Agriculture (Trinidad)* 44:103-115.

Keywords: pastures; legumes; grassland; nitrogen; grasses; livestock; *Centrosema pubescen*s; *Pueraria phaseoloides*; *Stylosanthes*; green manure; manure; rice; soil improvement.

Abstract. The present use of tropical legumes in the western hemisphere is evaluated, and profitable areas for further investigation and development are outlined. Studies of soil organic matter from sites ranging from 4° to 20° N latitude show that many tropical soils developed under forest are well supplied with humus, and the use of Leguminosae for their nitrogen-fixing ability is not justified until the nitrogen-supplying power of the soil declines substantially. For pasture and crop production on grassland soils, well-adapted legumes should be considered along with alternate sources of nitrogen since grassland soils have a very limited nitrogen-supplying power. The use of legumes for pasture and forage crops merits special attention wherever there is an annual dry season that stops growth of forage grasses, thus reducing their protein below livestock requirements. Several promising legumes are being studied, and some are being planted commercially on a limited scale, e.g. *Centrosema pubescens, Glycine javanica, Leucaena glauca, Lotononis bainesii, Phaseolus atropurpureus, Pueraria phaseoloides*, and *Stylosanthes gracilis*. A useful role for legumes purely for soil improvement requires more extensive, positive evidence. An exception is the use of leguminous green manure in the production of paddy rice, where the reduced condition of the flooded soil provides a special advantage in highly efficient nitogen use. Soil improvement by legumes is also a worthwhile adjunct to their use primarily for pasture production or for shade in shade-grown crops. The symbiontic nitrogen-fixing ability of tropical legumes has received little attention in neotropical microbiology thus far. Investigations in this area will be rewarding for both practical and theoretical aspects of rhizobial biology.

25

IRRI (ed.) (1988): *Green Manure in Rice Farming. Proceedings of a symposium on sustainable agriculture*, IRRI, 25-29 May 1987. Los Baños (Philippines): IRRI (International Rice Research Institute), 379 p.

Keywords: rice; West Africa; legumes; Asia; soil chemical properties; green manure; farming systems; sustainability.

Abstract. This book contains the proceedings of a symposium on the role of green manure crops in rice farming systems held in 1987. General knowledge and technologies from different regions of Asia and West Africa are reported and the ability of several plant species to tolerate the soil and water conditions of flooded rice fields are discussed. Furthermore, the effects of green manure crops on soil fertility are analized, with emphasis on biological N_2-fixation, transformation of green manure nitrogen and changes in the physicochemical properties of irrigated rice soils. Detailed information is given about integrated use of legumes in rice farming systems and on the fields of seed production and collection of tropical legume germplasm.

26

Gibson, T. (1987): A ley farming system using dairy cattle in the infertile uplands. *World Animal Review* 61:36-43.

Keywords: ley farming; farming systems; cattle; tropical highlands; Thailand; crop rotation; pastures; yields; annual field crops; dairy cows; animal production.

Abstract. The rotation of sown pastures with crops (ley farming) increases crop yields. However, a substantial return from the pasture (ley) phase must be obtained if farmers in developing countries are to gain economically from this system. The author describes experiments in the infertile uplands of northeast Thailand, the poorest region of the country, where it has been shown that dairy cattle can be raised with a small cash input, and that the milk produced can be sold to generate income. To overcome sociological constraints, it is suggested that the ecologically sound ley farming system be introduced through milk production, the aim being eventually to extend the system to beef cattle and buffalo production, which are more widespread.

27

Haynes, R.J. (1983): Soil acidification induced by leguminous crops. *Grass and Forage Science* 38:1-11.

Keywords: soil acidity; legumes.

Abstract. Solution culture and greenhouse studies have both clearly demonstrated the ability of legumes to acidify their rooting medium. Furthermore, research workers comparing the pH beneath undisturbed sites versus all-legume pastures or all-grass versus all-legume (or grass-legume) pastures have observed a lower soil pH under the leguminous pastures. The processes leading to legume-induced soil acidification are reviewed and discussed. The growth of legumes which are fixing atmospheric N_2 involves the excess uptake of nutrient cations over anions from soil solution. This results in the net efflux of H_3O^+ ions from plant roots into the rhizosphere. When virgin lands are sown with legumes the accumulation of soil organic matter, with a consequent increase in cation exchange capacity and exchange acidity, is an important contributing factor to the long-term decline in surface soil (0-10 cm) pH. Nonetheless, such a phenomenon does not explain the decrease in pH below 10 cm soil depth nor the lower pH below leguminous than all-grass pastures. The efflux of H_3O^+ ions from the legume roots may have an important effect on the soil pH under such conditions. The loss of symbiotically fixed N_2 from the system through leaching of NO_3^--N may also contribute to soil acidification under leguminous pastures.

28

Godefroy, J. and Bourdeaut, J. (1972): Action des plantes de couverture sur les caractéristiques chimiques, biologiques et structurales d'un sol de verger de Côte d'Ivoire. *Fruits* 27:349-353.

Keywords: *Stylosanthes gracilis*; cover crops; soil chemical properties; soil physical properties; *Pueraria javanica*; plant competition; fruit orchards.

Abstract. The agro-pedological conditions of a soil under citrus plantation in relation to three different treatments were investigated. The treatments were natural vegetation cover,

Stylosanthes gracilis cover and *Pueraria javanica* cover. Chemical soil properties as well as microbial activity were more favourable under natural vegetation or *Stylosanthes* cover than under *Pueraria* cover. From the point of view of soil structure, both cover crops were superior to natural vegetation. Utilisation of *Stylosanthes* as a cover plant in fruit orchards seems to be interesting as it requires less labour than management of natural vegetation or *Pueraria* cover. (Abstract by bibliography authors)

29

Moore, A.W. (1962): The influence of a legume on soil fertility under a grazed tropical pasture. *Empire Journal of Experimental Agriculture* 30:239-248.

Keywords: legumes; fertility; pastures; grasses; grass-legume pastures; Nigeria; *Centrosema pubescens*; nitrogen; nitrogen fixation; phosphorus.

Abstract. Soil fertility under two-year-old grazed pure grass and mixed grass-legume pastures was studied at University College, Ibadan, Nigeria. The inclusion of 'centro' (*Centrosema pubescens*) in a giant stargrass (*Cynodon plectostachyus*) pasture resulted in significantly higher levels of organic matter, total nitrogen and nitrifiable nitrogen in the underlying soil. The total nitrogen content under the pasture containing the legume was 250 lb. nitrogen per acre-ft. per annum higher than that under the pure grass stand. This is attributed to symbiotic nitrogen fixation by the centro and is of the same order of magnitude as values reported for nitrogen fixation by temperate legumes. There were no differences in carbon: nitrogen ratios under the two pastures; this emphasizes the importance of a legume in tropical pastures and leys if they are to build up soil organic matter satisfactorily. No significant differences in available phosphorus, pH, or percentage of material finer than coarse sand, resulted from the inclusion of centro. The inclusion of centro raised the nitrogen content of the associated giant stargrass from 1.8 to 2.4 per cent. There were, however, no significant differences in phosphorus, calcium, magnesium, or potassium contents of the stargrass as a result of its association with centro.

30

De, R., Yogeswara Rao, Y. and Ali, W. (1983): Grain and fodder legumes as preceding crops affecting the yield and N economy of rice. *Journal of Agricultural Science* 101:463-466.

Keywords: legumes; fertilization; nitrogen uptake; rice.

Abstract. Experiments made for 2 years on a sandy-loam soil showed that previous grain crops of mung bean (*Vigna radiata*), cow pea (*V. unguiculata*) and black gram (*V. mungo*) increased the grain and straw yield of a subsequent crop of rice relative to previous fodder crops of maize or guar bean (*Cyamopsis tetragonoloba*) or a grain crop of *Phaseolus* bean (*Phaseolus vulgaris*). The benefits from preceding crops of mung bean, cow pea or black gram were equivalent to 36-67 kg N/ha of chemical fertilizer applied to the rice crop following a cereal. The legumes improved yield-contributing characters such as number of productive tillers/m^2, panicle length and number of grains/panicle. The yield increase from the preceding legumes was noted even when the rice crop was given increasing rates of fertilizer up to 90 kg N/ha.

31

Adil, M.L., Kathavate, Y.V. and Sen, A. (1966): Changes in soil associated with continuous growth of some vegetation. *Plant and Soil* 15:73-80.

Keywords: grasses; legumes; *Tephrosia candida*; *Medicago sativa*; nitrogen; soil pH; soil chemical properties; soil organic matter; soil physical properties; *Imperata cylindrica*; *Pennisetum orientale*; *Pennisetum polystachyum*; *Pueraria hirsuta.*

Abstract. From a study of the composition of the soil and the subsoil under three grasses, *Imperata cylindrica, Pennisetum orientale, Pennisetum polystachyum* and three legumes *Tephrosia candida, Medicago sativa* and *Pueraria hirsuta* and those of natural bare soil in the neighbourhood of each, it could be observed that the soils under vegetation contained more moisture, organic matter, organic nitrogen clay and soluble salts but had lower pH values than the bare soils. The soils under grasses had less moisture, lower pH and lower salinity but higher clay content and exhibited greater aggregation than the soils under legumes. Though the soils under grasses had significantly higher quantities of organic matter than the soils under legumes there was no significant difference in the organic nitrogen contents between them.

32

Yost, R.S., Evans, D.O. and Saidy, N.A. (1985): Tropical legumes for N production: growth and N content in relation to soil pH. *Tropical Agriculture (Trinidad)* 62:20-24.

Keywords: legumes; nitrogen fixation; soil acidity; yields; green manure; erosion control; live mulch; soil chemical properties; manure; maize; erosion.

Abstract. Growth rates, N accumulation, and soil cover potential of six green manure legumes were compared on a manganiferous Oxisol. Responsiveness of *Crotalaria juncea* L., *Mucuna* sp., *Lablab purpureus* (L.) Sweet, *Psophocarpus tetragonolobus* (L.) DC, *Sesbania grandiflora* (L.) Pers. and *Sesbania cannabina* Poir. to increasing soil pH (4.7-6.9) was examined in a field experiment. N content of the legumes was compared with that of *Zea mays* L. to estimate N_2 fixation by the legumes. Dry matter and N content increased with increasing pH to > 6.0. When N yield at pH 4.7 was expressed as a percentage of maximum N yield, *S. cannabina* was most sensitive to low pH (3%), followed by lablab (16%), crotalaria (20%), mucuna (36%), and maize (70%). N accumulation in the tops of *S. grandiflora* and *Crotalaria* ranged from 10 to 72 kg N/ ha, respectively, during the 10-week growth at soil pH of 5.8. Maize growth and N percentage indicated low levels of available soil N, suggesting that legume N content resulted primarily from the plant-rhizobia symbiosis rather than from N recovery from soil. High levels of soil Mn were probably the principal limitation to legume growth at pH < 5.3. Mucuna and lablab provided the greatest and most rapid initial soil cover and thus should be most effective in controlling soil erosion by rainfall.

33

Jayasinghe, C.K. (1991): The role of leguminous cover crops in soil improvement with special reference to the nitrogen economy of tropical rubber soils. *Bulletin of the Rubber Research Institute of Sri Lanka* 28:23-26.

Keywords: nitrogen; *Pueraria phaseoloides*; *Desmodium ovalifolium*; *Centrosema pubescens*; erosion; legumes; trees; nitrogen fixation; cover crops; Sri Lanka; *Mimosa invisa*; *Calopogonium mucunoides*; *Hevea brasiliensis*; live mulch; soil organisms; soil physical properties; soil chemical properties.

Abstract. The use of leguminous cover crops is standard practice in rubber plantations of Sri Lanka, in order to improve the biological, chemical and physical properties of the soil. Five cover crops are commonly used: *Pueraria phaseoloides, Desmodium ovalifolium, Mimosa invisa, Calopogonium mucunoides,* and *Centrosema pubescens*. Cover crops reduce soil erosion in sloping lands, shade the soil from direct sunlight, and add organic matter. Leguminous cover crops enhance the biological activity of the soil and fix most nitrogen. When rubber plants were grown in sown legume plots, the growth of the trees, and the dry weight and N content of the leaves were higher than those of rubber trees grown in plots with natural cover. Decomposition products of the cover crops improved the nitrogen economy of the soils. Leguminous cover crops grown with rubber trees imparted a beneficial effect on plantation soils.

34

Cadisch, G., Sylvester-Bradley, R. and Noesberger, J. (1989): ^{15}N-based estimation of nitrogen fixation by eight tropical forage-legumes at two levels of P:K supply. *Field Crops Research* 22:181-194.

Keywords: nitrogen; *Centrosema acutifolium*; nitrogen fixation; *Centrosema macrocarpum*; *Zornia glabra*; *Pueraria phaseoloides*; *Desmodium ovalifolium*; *Stylosanthes macrocephala*; *Stylosanthes guianensis*; *Stylosanthes capitata*; fertilizers; phosphorus; legumes; Colombia; micronutrients; grasses; Oxisols; yields.

Abstract. Ca, S, Mg, Zn, Cu, B and Mo, with or without 80 kg P + 70 kg K/ha were applied to *Centrosema acutifolium, C. macrocarpum, Zornia glabra, Pueraria phaseoloides, Desmodium ovalifolium, Stylosanthes macrocephala, S. guianensis* and *S. capitata* at the start of the rainy season one year after establishment and effects on growth and nitrogen fixation were evaluated under a cutting regime by using the ^{15}N dilution technique. Rooting pattern and nodulation were also evaluated. The relative N accumulation curves of the legumes and control (savanna grasses) were studied in a separate experiment. The legumes were established in furrows separated by native savanna in an Oxisol of the Eastern Plains of Colombia to give a density of 5-6 plants/m². With PK fertilizer, all legumes derived at least 70% of their N from the symbiosis (% N_{dfa}), whereas without PK both lower values and larger differences in the % N_{dfa} (44-84% N_{dfa}) between species were observed. The greatest effect of PK on % N_{dfa} was observed in *D. ovalifolium* (70 and 44% N_{dfa} with and without PK, respectively), but the effect on its yield was relatively small. *S. macrocephala* responded with a large increase in yield (380% with PK), although it was the only species in which PK did not have a significant effect on % N_{dfa}. Total shoot N derived from fixation with PK fertilizer ranged from 25 kg/ha for *D. ovalifolium* to 115 kg for *P. phaseoloides*, with three periods of growth over a total of 17 weeks. Without PK fertilizer, 11-48 kg N/ha were derived from fixation. Legume ranking for total N derived from fixation mostly reflected yield differences. However, *D. ovalifolium* ranked lower for total N from fixation than for yield due to its low % N_{dfa} and low N concentration.

35

Thomas, R.J. (1992): The role of the legume in the nitrogen cycle of productive and sustainable pastures. *Grass and Forage Science* 47:133-142.

Keywords: legumes; nitrogen; nitrogen cycle; pastures; fertilizers; nitrogen fixation; yields.

Abstract. The N cycle in grazed temperate and tropical pastures receiving no N fertilizer was studied by simulating N fluxes in different parts of the cycle. Estimates of N required to be fixed by legumes to balance the cycle without reducing soil organic N reserves ranged from 38 to 53% of aboveground herbage N (20-31% on a DM basis) for tropical pastures with pasture utilization levels of 10-40%. In intensively grazed temperate pastures with utilization levels of 50-70%, the N input required from legumes was 57-67% of the aboveground herbage N (35-45% on a DM basis). Variations in the amounts of internally cycled N would have the greatest impact on the requirement for N_2 fixation in poorly utilized pastures, whereas variations in the recovery of N in excreta would have the greatest effect in intensively grazed pastures. The amounts of biologically fixed N required to give sustainable herbage DM yields of 3-22 t DM/ha per year were calculated as 15-158 kg N/ha annually in tropical pastures. For intensively managed temperate pastures producing 6-15 t DM/ha per year with an N content of 3.5%, 120-352 kg fixed N/ha per year was required. It was suggested that legume contents of 20-45% of herbage DM could provide sufficient N for sustainable productive pastures.

36

Lal, R., Wilson, G.F. and Okigbo, F. (1979): Changes in properties of an Alfisol produced by various crop covers. *Soil Science Society of America Journal* 127:377-382.

Keywords: grasses; soil properties; *Stylosanthes*; soil organic matter; nitrogen; infiltration; fallow; soil bulk density; cation exchange capacity; *Brachiaria*; *Paspalum*; *Cynodon*; *Pueraria*; *Centrosema*.

Abstract. The effects of three grasses and five leguminous covers, grown on an eroded tropical Alfisol for two years, on soil properties were investigated. Improvements in soil characteristics under *Brachiaria, Paspalum, Cynodon* spp., *Pueraria, Stylosanthes, Stizolobium, Psophocarpus*, and *Centrosema* were compared with that of weed-fallow control. There were significant improvements in soil organic matter, total nitrogen, cation exchange capacity (CEC), infiltration rate, moisture retention at low suctions, and soil bulk density under various grass and leguminous fallow compared with control.

37

Yamoah, C.F. and Mayfield, M. (1990): Herbaceous legumes as nutrient sources and cover crops in the Rwandan highlands. *Biological Agriculture and Horticulture* 7:1-15.

Keywords: legumes; maize; live mulch; erosion control; tropical highlands; Rwanda.

Abstract. Herbaceous legumes were assessed for their suitability as nutrient sources and as ground cover for the northern highlands of Rwanda. There were three investigations which followed the Farming Systems Research (FSR) methodology. First, exploratory studies were conducted to measure biomass yield and percentage ground cover. Second, 12 legumes were screened on station for biomass production, nutrient yield and ground cover. Yields of maize (*Zea mays*) grown as a test crop following incorporation of the legumes were compared with

yields of maize grown at different nitrogen levels. Third, following farmers' comments on the second study's results, five legume species were chosen for multilocational testing on 11 farmers' fields. Preliminary studies showed high biomass yields and good ground cover for *Desmodium* sp., *Trifolium* sp. (red clover), Vetch and *Stylosanthes* sp., *Trifolium repens* (white clover) demonstrated a prostrate and complete ground cover - ideal characteristics for live mulch species. On-station experiments indicated significant accumulation of nutrients by the legumes, but with substantial site-species interaction. Legumes with high biomass yields decreased maize yields when compared with maize grown with no nitrogen. The multilocational testing confirmed the inconsistent performance of the species at different sites and led to the definition of three sub-regions (North, Central and South) for which different promising legumes were selected. Selection criteria such as vegetative yield, nutrient content and ground coverage resulted in the following selections by region and in order of preference: North: *Canavalia*, Lupin, *Mucuna*; Central: Vetch, Lupin; and South: *Mucuna*, Lupin and (on fertile soil) *Canavalia*. In terms of legume growth performance, this study suggests possible benefits from 1) moderate initial fertilization, 2) extended vegetative growth, 3) high sowing densities and 4) sowing in mixtures on infertile soils. Short-term crop yield losses due to net immobilization of soil nutrients by some cover crops (e.g. Vetch) may make legumes unacceptable to small-scale farmers. Research on decomposition and nutrient release is recommended prior to extension of legumes to farmers.

38

Brasil, E.C., Burger, D., Flohrschuetz, G.H.H., Lenthe, H.R., Stolberg-Wernigerode, A.Graf zu and Wollersen, T. (1991): Utilization of "Capoeira" as a source of organic fertilizer. In: *Studies on the utilization and conservation of soil in the eastern Amazon region*, Eschborn (Germany): Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), p. 199-216.

Keywords: Amazon region; mulch; improved fallow; legumes.

Abstract. The possibility of using "Capoeira" as a source of organic fertilizer without fire was studied in two experiments. In the first, on parcels where the "Capoeira" was felled but not burnt, it was verified that the soil's carbon content increased, and the chemical fertilizer applied (principally P and K) had more a positive effect than on the parcels where the "Capoeira" had been burnt. On the fertilized and unburnt parcels, the corn production was greater as of the second year than that of the fertilized and burnt parcels. This tendency was less pronounced with the cowpea production, where the unburnt and unfertilized parcels produced significantly more than the burnt and fertilized parcels only as of the fourth year. The system tested in the first experiment is not viable, because of the excessive amount of labour necessary for the preparation of the area and for its cultivation during the first few years, and also because of the unfavourable production of the first year. In the second experiment, various techniques and equipment for the preparation of "Capoeira" areas without fire were explored. The feasibility of felling "Capoeira" and not burning it was confirmed. Leguminous species were sown in order to cover the felled matter, facilitating the decomposition, and to increase the N-content of the biomass. This vegetation was cut down mechanically at the end of the year. A more detailed study of this technique was initiated on two farming areas. Various leguminous species were compared, as was the use of biomass cut up as mulch and mixed with the soil.

39

Burger, D. and Brasil, E.C. (1991): Production of organic fertilizers in the alley-cropping system. In: *Studies on the utilization and conservation of soil in the eastern Amazon region*, Eschborn (Germany): Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), p. 217-236.

Keywords: alley cropping; Amazon region; mulch; legumes; sustainability.

Abstract. The alley-cropping system aims to maintain the soil's fertility level through the application of organic fertilizer produced on the same location. Alternating rows of cash crops and strips of organic matter producers were planted. The latter were periodically cut to be applied as mulch to the cash crops. The experiment was set up in 1985 and 1986 on three locations in the municipality of Capitão Poço, PA, and on five locations in the municipality of Igarapé-Açu, PA. On three locations in the municipality of Igarapé-Açu, the legumes received an initial fertilization of 10 kg N/ha and 60 kg P_2O_5/ha. A total of 13 producer species of organic matter were tested, and with some, a large production of biomass was obtained within a mere 24 weeks: *Cassia rotundifolia* 9.2 t/ha, *Cajanus cajan* 7.9 t/ha, and *Crotalaria paulina* 7.7 t/ha in areas with chemical fertilizer, and *Cajanus cajan* 6.7 t/ha and *Crotalaria paulina* 6.1 t/ha in areas without chemical fertilizer. The quantity of phosphorus contained in the organic fertilizer produced was insufficient to meet the crop needs. On the other hand, large quantities of nitrogen and potassium were obtained with the organic matter harvested. In the unfertilized area, 222 kg N/ha and 159 kg K_2O/ha were obtained with *Cajanus cajan* in 58 weeks. The organic fertilizer produced with *Cajanus cajan* per hectare without chemical fertilizer in 24 weeks contained as much nitrogen as is removed with a 20 t/ha cassava harvest. The organic fertilizer produced in 40 weeks contained the equivalent of this harvest in K_2O. The organic fertilizer produced with this species in half a year contained the equivalent in nitrogen and K_2O of a 2.22 t/ha corn harvest. Thus the system demonstrated an excellent potential for maintaining the soil's fertility. The management of this system should be studied in greater detail, especially the cutting intervals, the distance between plant producers of organic matter and cash crops, the forms of application of organic matter, and the economics and ergonomics of the system.

40

Lascano, C.E. (1991): Managing the grazing resource for animal production in savannas of tropical America. *Tropical Grasslands* 25:66-72.

Keywords: animal production; pastures; cattle; tropical savanna; sustainability; Colombia; South America; grasses; grass-legume pastures; soil acidity.

Abstract. Research carried out to evaluate management options and animal production potential of native and improved pastures in savanna regions of tropical America is reviewed, with emphasis on Colombia's Eastern Plains. In areas with limited infrastructure, native grasses are the main forage resource and weight gains of cattle grazing these native pastures with burning and mineral supplementation vary from 70 to 90 kg/ha and from 15 to 20 kg/ha. As infrastructure improves, the strategic use of grass-legume pastures to complement the native savanna, together with the use of mineral supplementation, could increase individual weight gains by 40 percent. In savanna areas with good infrastructure, improved grasses adapted to acid soils replace the native vegetation and, together with mineral supplementation and appropriate grazing management, increase animal production/unit area 10 times compared

to native pastures. However, these pastures do not persist over time because of N deficiency and pests. The highest and more stable gains could be obtained with legume-based pastures, which, in turn, depend on high management inputs. On the acid soils of tropical American savannas, these legume-based pastures can play an important role in agropastoral systems.

41

Myers, R.J.K. (1976): Nitrogen accretion and other soil changes in Tindall clay loam under Townsville stylo/grass pastures. *Australian Journal of Experimental Agriculture and Animal Husbandry* 16:94-98.

Keywords: nitrogen accretion; pastures; *Stylosanthes humilis*; phosphorus; legumes; fertilizers; establishment; soil properties; Australia.

Abstract. Soil changes after 3-15 years of fertilized leguminous pastures on Tindall clay loam soil at Katherine, N.T. were studied by comparison of leguminous pasture soils with their native counterparts. Soil organic carbon, total nitrogen, C/N ratio and pH were unchanged by the presence of Townsville stylo (*Stylosanthes humilis*). Available phosphorus (bicarbonate extraction) was significantly higher under legume pasture, reflecting its fertilizer history, but there was no pattern of increase with time, nor with quantity of fertilizer. Available nitrogen (boiling water extraction) was higher under legume pasture, and both the absolute value under legume pasture and the change in amount were correlated significantly with the age of the pasture. Available nitrogen after three years of legume pasture was equal to that under unimproved pasture, suggesting that gains in this period merely balanced losses during clearing and establishment.

42

Tarawali, G. (1991): The residual effect of *Stylosanthes* fodder banks on maize yield at several locations in Nigeria. *Tropical Grasslands* 25:26-31.

Keywords: *Stylosanthes*; maize; yields; Nigeria; natural pastures; natural fallow; fodder banks; annual field crops; Africa.

Abstract. The response of maize to N on natural pasture (fallow), or following *Stylosanthes* pastures (fodder banks) was investigated at 4 locations in central Nigeria. Maize planted in the fodder banks outyielded that on the natural fallow at each level of applied N. Without applied N, the average grain yields were 1.7 t/ha in the fodder bank and 0.8 t/ha in the natural pasture areas. In well managed fodder banks, the maximum yield of maize was obtained at 60 kg/ha N in comparison with the recommended rate of 120 kg/ha N for a natural fallow or continuously cultivated soil. In the first year of cropping 45 kg/ha N had to be applied to maize grown outside the fodder banks to produce the same grain yield as unfertilized maize following a good *Stylosanthes* pasture. Grain yields of maize were lower in the second year but again, higher yields were obtained from inside than outside the fodder bank areas. The response of maize inside the *Stylosanthes* pastures was discussed in relation to land history and the way in which the pastures were managed.

43

Lloyd, D.L., Smith, K.P., Clarkson, N.M., Weston, E.J. and Johnson, B. (1991): Sustaining multiple production systems. 3. Ley pastures in the subtropics. *Tropical Grasslands* 25:181-188.

Keywords: pastures; subtropics; Australia; ley farming; sustainability; agropastoral systems; legumes; yields; annual field crops; grasses.

Abstract. During the 1990s, wheat protein and yield from many cropping soils (mainly vertisols) in the subtropical wheat belt will continue to decline as soil fertility is gradually depleted. One option for maintaining crop yield and quality is ley farming. It has had limited application when soil fertility has been adequate for crops and where the use of N fertilizer has been a viable option. Temperate legumes of the genus *Medicago* (lucerne and annual medics), and tropical grasses are available for use in leys, but there are currently no suitable tropical legumes. The increases in yield and quality of grain crops recorded after lucerne and annual medic leys in various experiments are reviewed and related to changes in soil N and other factors. Leys provide more enduring benefits to subsequent crops than does the application of fertilizer N. Ley farming is productive, suitable, and provides a greater hedge against climatic and economic risks than cropping alone. However, it requires a wider range of management skills, and the challenge remains to stimulate wider adoption of this system.

44

Fox, R.L., Hue, N.V., Jones, R.C. and Yost, R.S. (1991): Plant-soil interactions associated with acid, weathered soils. *Developments in Plant and Soil Science* 45:197-204.

Keywords: soil acidity; legumes; yields; soil chemical properties; leaching.

Abstract. Plant-soil interactions in weathered soils are so complex that unqualified statements about a suitable pH for plants are risky. Conventional experimental designs and statistical methods may not be appropriate for investigating such complexities. Lime experiments using continuous function designs and observation of plant response to indigenous variability in soil pH permit detailed observations of plant-soil interactions that are frequently not detected. A graphical boundary-line approach to interpreting data can make good sense out of apparent confusion. Increasing the pH of variable-charge soils by adding lime or by indigenous means increased CEC and retarded cation leaching, but Ca solubility changed very little over the range pH 5 to 6. N_2 fixation and yield was closely related to soil pH, soil Mn and Mn uptake by soybean. This result was clearly demonstrated regardless of numerous other limiting factors. Plant yield response curves resolved into distinct segments that corresponded with associated soil properties. Excess Al compounded by Ca deficiency is suspect in the pH range < 5. Excess Mn, and Ca deficiency probably limited yields in the pH range 5.0 to 5.7. Yields were stable, and Ca and P were constant in the pH interval 5.7 to 6.0. Yields abruptly increased in the pH interval 6.0 to 6.3. This was associated with elevated Ca concentrations in soil solutions.

45

Chamberlin, R.J., Peake, D.C.I., McCown, R.L., Vallis, I. and Jones, R.K. (1986): Competition for nitrogen between a maize crop and forage legume intercrops in a wet-dry tropical environment. In: Haque, I., Jutzi, S. and Neate, P.J.H. (eds.), *Potentials of forage*

legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16-19 September 1985. Addis Ababa (Ethiopia): ILCA (International Livestock Centre for Africa), p. 82-99.

Keywords: nitrogen; maize; forage legumes; legumes; intercropping; *Alysicarpus vaginalis*; *Stylosanthes hamata*; *Centrosema pascuorum*; plant competition; nitrogen uptake; yields; seed production; seeds.

Abstract. Growth and yield of maize as a sole crop was compared with that of maize with intercrops of *Alysicarpus vaginalis*, *Stylosanthes hamata* cv. verano, or *Centrosema pascuorum* under conditions in which soil water was adequate prior to physiological maturity of the crop. Data from three seasons are presented. In the first season, when only one N rate was used with a range of legume densities, maize yield varied inversely with legume yield. In the other two seasons N rate was varied, and ^{15}N was used to obtain more information on the competitive relationships between the components of the intercropping systems. Results show that when conditions are good for establishment and early growth of the legumes, competition between the legume intercrop and maize occurs. This effect was greatest at low N rates and less with verano stylo than with *A. vaginalis*. There was never any evidence of a positive contribution by any of the legumes to the N economy of maize. Legume seed production, essential for regeneration of the legume in the cropping system being studied, varied with species and seasonal conditions.

46

Boonman, J.G. (1993): From shifting cultivation to crop-grass rotations. In: Boonman, J.G. (ed.), *East Africa's grasses and fodders: ecology and husbandry*. Dordrecht/NL: Kluwer Academic Publishers, p. 65-85.

Keywords: shifting cultivation; grasses; Africa; cattle; fallow; weeds; yields; soil erosion; erosion; fertility; manure; livestock; mixed farming; pastures.

Abstract. Farmers in East Africa want cattle, but they need crops. In conventional subsistence agriculture a fallow period of long duration used to be employed to restore the productive capacity of the soil. As pressure on land increased, systems of husbandry processed from shifting cultivation to grass weed fallows which were grazed but on better soils to continuous cropping. Except on the most stable and fertile soils, continuous cropping rapidly leads to diminishing yields, nutrient depletition and soil erosion. The need to maintain fertility applies to all soils. In the 1930s attention turned to the positive role grass fallows were observed to play in conventional shifting cultivation. It was subsequently realized that cultivated grasses are able to restore fertility in a shorter time and more effectively then when land is abandoned to volunteer grasses which, by their very nature, are crop weeds (e.g. African Couchgrass). Cultivated grasses help to suppress these weeds. Grasses add effective fresh OM and N, and can draw up minerals from lower soil depth through a deep and extensive root system. A major effect is that of improving soil structure and consequent water economy through aggregate stability, permeability and root channels. The latter aspects distinguish grasses from organic manures. More rain water is trapped on the soil surface and subsequently held in the soil profile; the risk of erosion is reduced. Grasses can double the yield of following crops, while grazing is more beneficial to such crops than when grass is mown and removed. Measurable improvements in topsoil structure may vanish early but yield responses remain significant for a long period. Crops and livestock, via better grasses, benefit directly by crop-grass rotations, but the long-term beneficiary is the soil. Alternate husbandry is typical of

farming in East Africa, whether subsistance or commercial. Mixed-farming, based on alternating grazed pastures with crops, is still a solid platform from which efforts for sustained development can be launched, in the nearest possible harmony with the environment.

47

Vallis, I. (1983): Uptake by grass and transfer to soil of nitrogen from ^{15}N-labelled legume materials applied to a Rhodes grass pasture. *Australian Journal of Agricultural Research* 34:367-376.

Keywords: grass-legume pastures; nutrient cycle; nitrogen uptake.

Abstract. Unground legume materials labelled with ^{15}N were applied to the soil surface under a Rhodes grass pasture in south-eastern Queensland and the recovery of the applied ^{15}N was followed over periods of 1-3 years. Comparisons were made between two legumes, *Macroptilium atropurpureum* cv. Siratro and *Desmodium intortum* cv. Greenleaf, between leaf and stem materials of different nitrogen (N) concentrations (0.5-3.8% N), and between fresh and dried materials. After 1 year, ^{15}N in the applied materials had decreased by 25-91%, and 7-25% was discovered in the Rhodes grass. Except for leaf material of Greenleaf, these changes showed a positive, non-linear relationship to the percentage of N (% N) in the applied materials. The changes for leaves of Greenleaf were less than would be predicted from their % N. Drying Siratro leaves and stems before applying them to the soil surface did not significantly affect the above changes. For N-poor materials (0.5-1.8% N) applied at 380-1360 g dry matter/m², uptake of ^{15}N by Rhodes grass was greater in the second year than in the first year, whereas for N-rich materials (3.8% N) applied at 140 g dry matter/m² uptake of ^{15}N in the second and third years was only 23 and 12%, respectively of that in the first year.

48

Palm, C.A. and Sanchez, P.A. (1990): Decomposition and nutrient release patterns of the leaves of three tropical legumes. *Biotropica* 22:330-338.

Keywords: legumes; *Cajanus cajan*; *Erythrina*; *Inga edulis*; polyphenolics; Peru; nitrogen; alley cropping; lignin; soil organic matter; nitrogen cycle; legume trees; Amazon region; South America; mineralization; agroforestry; phosphorus.

Abstract. Information on decomposition and nitrogen release patterns of tropical legumes is scarce despite the important role of legumes in agroforestry systems. Decomposition patterns of the leaves of three tropical legumes *Inga edulis* Mart., *Cajanus cajan* (L.) Millsp., and *Erythrina* sp. were determined by a litterbag study in an alley cropping experiment conducted in the Peruvian Amazon. The leaflets of the three species had similar nitrogen concentrations but different lignin and polyphenolic concentrations. *Inga* and *Cajanus* decomposed at similar rates (k = 0.91 and 1.72 yr^{-1}, respectively) and had similar polyphenolic concentrations but differed in lignin. *Erythrina* had the lowest concentration of polyphenolics and decomposed the fastest (k = 3.45 yr^{-1}). Polyphenolics appeared to influence rates of decomposition more than percent nitrogen or percent lignin. It is proposed that the polyphenolics bind to N in the leaves forming compounds resistant to decomposition. These compounds may be precursors to stable forms of nitrogen in soil organic matter. Rates of nutrient loss followed the general trend potassium > phosphorus, nitrogen, and magnesium > calcium. It is apparent from this study that not all leguminous leaves decompose and release nitrogen quickly, despite high nitrogen concentrations in the leaves. Nitrogen release by legumes with high polyphenolic

concentrations will be slower than that by legumes with low polyphenolic concentrations and has important implications to nitrogen cycling and the selection of legumes for agroforestry systems.

49

Balasubramanian, V. and Sekayange, L. (1991): Effects of tree legumes in hedgerows on soil fertility changes and crop performance in the semi-arid highlands of Rwanda. *Biological Agriculture and Horticulture* 8:17-32.

Keywords: legume trees; Rwanda; manure; mulch; yields; beans; sorghum; maize; alley cropping; annual field crops; nutrient cycle; soil chemical properties.

Abstract. The soil fertility improvement potential of five tree legumes as alley hedges was studied on a Ultic Haplustox soil at a semi-arid highland site in Rwanda from 1983 to 1989. Tree species tested were *C. calothyrsus* Meissn., *C. spectabilis* DC, *L. diversifolia* (Lam.) de Wit., *L. leucocephala* (Lam.) de Wit. and *S. sesban* (L.) Merr.; they grew to a height of 1.01 to 2.15 m and 2.85 to 3.37 m, after 1 and 1.5 years respectively. *S. sesban* could not withstand intensive pruning (four times per year) and 83% of the trees died after six prunings. In contrast, *C. calothyrsus* lost only 28%, both species of *Leucaena* 9 to 10%, and *C. spectabilis* none of the trees after 18 prunings in 4.5 years. Above-ground biomass production increased steadily with the age of the trees. Mean values for 1984-89 were: 5.6 to 7.3 Mg/ha dry weight of leaf biomass and 3.7 to 5.0 Mg/ha of wood. Mean annual nutrient addition to soil through leaf biomass was: 72 to 119 kg/ha of N, 2 to 3 of P, 47 to 94 of Ca, 8 to 19 of Mg, and 29 to 60 of K, and it was equivalent to an application of 10 Mg/ha/year of cattle manure. Tree mulch application reduced the rate of soil fertility decrease due to cropping; percent increases over control were 2 to 20 for soil C, -3 to 7 for K, 4 to 51 for Ca, 7 to 31 for Mg, and 3 to 47 for exchange capacity in mulched plots. Combined applications of leaf biomass and manure increased the pH (water) by 0.4 to 0.5 units, K by 0 to 0.7 mmol, Ca by 10.8 to 17.6 mmol and Mg by 0.5 to 2.3 mmol and exchange capacity by 10.5 to 34.0 mmol above the level of soils cleared from the savanna vegetation. Mean nutrient export from the site in woody stems ranged from 17 to 28 kg/ha/year of N, 1 to 2 of P, 13 to 16 of Ca, 2 to 5 of Mg, and 17 to 34 of K. Grain yield increase of beans (*Phaseolus vulgaris* L.) and sorghum (*Sorghum bicolor* L.) to tree foliage application was the largest in *C. spectabilis* alleys, followed by the others. Crop yield increases due to tree mulch use were less in manured plots. Maize (*Zea mays* L.) response was poor. Tuber yield of sweet potato (*Ipomoea batatas* (L.) Lam.) decreased when planted in alleys, due to the lower tuber yield per unit crop area in alleys than in the control and a 14 to 32% yield fall off at the tree/crop interface.

50

Budelman, A. (1989): Effect of application of the leaf mulch of *Gliricidia sepium* on early development, leaf nutrient contents and tuber yields of water yam (*Dioscorea alata*). *Agroforestry Systems* 8:243-256.

Keywords: mulch; *Gliricidia sepium*; *Dioscorea alata*; yields; nutrient cycle; legume trees; Africa.

Abstract. This paper describes the effects of the leaf mulch of *Gliricidia sepium* on the development and yield of Water Yam, *Dioscorea alata*. Using leaf mulch, the time taken for the yam setts to sprout can be shortened by approximately 20 percent. Organic mulches

contain considerable quantities of plant nutrients. Increasing amounts of mulch improved the leaf nutrient contents of the yam crop and resulted in significantly higher tuber yields. Over a tuber yield range up to c. 15 tons ha^{-1} each additional ton DM *Gliricidia sepium* mulch applied resulted in a yield increment of about 2 ton yam tubers. A nutrient supply-nutrient extraction balance is discussed, comparing mulch applied and yam tubers harvested. Mulching as agricultural technique is a useful and affordable tool in adapting low external input cropping systems to local economic and environmental conditions.

51

Leach, G.J., Rees, M.C. and Charles-Edwards, D.A. (1986): Relations between summer crops and ground cover legumes in a subtropical environment. 2. Effects of sorghum and sunflower on the growth of *Vigna trilobata* and *Medicago scutellata*. *Field Crops Research* 15:39-55.

Keywords: legumes; ground cover; *Medicago scutellata*; *Sorghum bicolor*; *Helianthus annuus*; erosion control; seed production; subtropics; Australia; yields; annual field crops; *Vigna trilobata*; erosion; seeds.

Abstract. *Vigna trilobata* (L.) Verdc. is a low growing legume with potential as a ground cover for controlling soil erosion in cropping lands of the subhumid/semi-arid subtropics of northern Australia. When it was grown beneath sorghum (*Sorghum bicolor* (L.) Moench) and sunflower (*Helianthus annuus* L.) crops under well-watered conditions on a vertisol in southern Queensland it decreased their yields by about 20% in the first season. This paper reports the effects of competition from crops sown at a normal dryland density or at half the normal density on its growth. *Vigna trilobata* sown in pure stand in October produced 531 g m^{-2} of above-ground dry matter, and sown in January produced 323 g m^{-2}, by the time the grain crops sown at the same time were mature. Yields under mature sorghum sown at the normal density (10 plants m^{-2}) in October and January were 38% and 35% respectively of those from pure stands of ground cover sown at the same time. Under sunflower at the normal density (5 plants m^{-2}), corresponding values were 42% and 22%. The decrease in dry matter yield attributable to competition for water, nutrients and/or radiation from the main crops was proportional to the decrease in intercepted radiation. *V. trilobata* responded to shade in several ways, but a substantial increase in specific leaf area, together with some additional partitioning of dry matter to leaf, was sufficient to ensure that its leaf area index under crops was similar to that in pure stands. Seed yields of 116 and 84 g m^{-2} were obtained from pure stands of *V. trilobata* sown in October and January respectively. However, seed yields under crops sown at the normal density were only 4-18% of those measured in pure stands. Seed size was not affected by treatment. We conclude that, under well-watered conditions in southern Queensland, *V. trilobata* grown as a ground cover under crops of sorghum and sunflower should be able to produce sufficient biomass to decrease soil erosion, and also produce sufficient seed for regeneration in successive seasons. Its growth and suitability are also briefly compared with those of an alternative ground cover legume, *Medicago scutellata* (L.) Mill. (snail medic).

52

Brockington, N.R., Stobbs, T.H., Newhouse, P.W. and Wadsworth, G.A. (1965): The effects of leys on soil fertility in the annual cropping areas of Uganda. *Sols Africains* 10:473-481.

Keywords: fertility; nitrogen; legumes; animal production; yields; ley farming.

Abstract. Evidence is presented that grazing resting land is beneficial to subsequent arable crops. Organic carbon and total soil nitrogen are built up in the ley phase of the rotation and decline with cultivation. Addition of inorganic nitrogen and the inclusion of legumes in the ley greatly increase animal production but may depress the yields of following arable crops. This depression is commonly alleviated by the addition of single superphosphate and may be due to imbalance of plant nutrients.

53

Toledo, J.M. and Serrão, E.A.S. (1982): Pasture and animal production in Amazonia. In: Hecht, S.B. (ed.), *Amazonia: Agriculture and land use research*. Cali (Colombia): CIAT (Centro Internacional de Agricultura Tropical), p. 281-309.

Keywords: Amazon region; nutrient cycle; phosphorus; fertilization; cattle; degradation; pasture management; tropical forest; sustainability; pastures.

Abstract. This paper presents some results of research conducted on pasture and animal production in the Amazon region. Soils in the Amazon basin are heterogenous, although most are acid, deficient in P, have low base saturations and high Al levels. Land use potential for forestry, cattle ranching, agriculture and plantations should be evaluated according to soil conditions before developing settlement programs. In tropical rain forest ecosystems, most mineral nutrients are stored in biomass and detritus, and only to a smaller amount in the soil. Effective nutrient cycling, mainly between biomass and detritus, minimizes nutrient losses from the system. The authors suggest that well-managed pastures or plantations could maintain soil fertility in a similar way, and propose a model of sustainable pasture and animal production for rain forest areas. This model includes different methods of forest clearing according to local conditions and avoiding excessive soil compaction, and the establishment of pastures after a cropping period. Pastures should be adapted to soil conditions, consist of grass-legume associations and must be maintained by management measures such as liming, phosphorus fertilization and adequate stocking rates. Adapted cattle or buffalo breeds should be selected. The high potential of Amazonia for cattle production, compared with native savanna or cerrado pastures, is emphasized. (Abstract by bibliography authors)

54

Bolan, N.S., Hedley, M.J. and White, R.E. (1991): Processes of soil acidification during nitrogen cycling with emphasis on legume based pastures. *Developments in Plant and Soil Science* 45:169-179.

Keywords: nitrogen; legumes; pastures; nitrogen cycle; fertilization; nitrogen fixation; minerali-zation; soil acidity; soil chemical properties; pollution; leaching.

Abstract. In areas that remain unaffected by industrial pollution soil acidification is mainly caused by the release of protons (H^+) during the oxidation of carbon (C), sulphur (S) and

nitrogen (N) compounds in soils. In this review the processes of H^+ ions release during N cycling and its effect on soil acidification are examined. The major processes leading to acidification during N cycling in soils are: (i) the imbalance of cation over anion uptake in the rhizosphere of plants either actively fixing N_2 gas or taking up NH_4^+ ions as the major source of N, (ii) the net nitrification of N derived from fixation or from NH_4^+ and R-NH_2 based fertilizers, and (iii) the removal of plant and animal products containing N derived from the process described in (i) and losses of NO_3^--N by leaching when the N input form is N_2, NH_4^+ or R-NH_2. The uptake of excess cations over anions by plants results in the acidification of the rhizosphere which is a "localized" effect and can be balanced by the release of hydroxyl (OH^-) ions during subsequent plant decomposition. Nitrification of fixed N_2 or NH_4^+ and R-NH_2 based fertilizers, and loss of N from the soil either by removal of products or by leaching of NO_3^--N with a companion basic cation, lead to 'permanent' acidification.

55

Bromfield, S.M., Cumming, R.W., David, D.J. and Williams, C.H. (1983): Change in soil pH, manganese and aluminium under subterranean clover pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* 23:181-191.

Keywords: degradation; fertilization; legumes; soil acidity; soil chemical properties; sustainability.

Abstract. Changes in soil pH, manganese and aluminium as a result of long periods under subterranean clover pasture were examined in soils formed on granite, basalt and sedimentary rocks near Goulburn, New South Wales. Decreases in pH of yellow duplex soils formed on granite, sedimentary rocks and basalt had occurred to depths of 60, 40 and 30 cm, respectively. The smaller depth of acidification in the latter two soils is considered to be due to their shallower A horizons over well buffered, clay B horizons. Under the oldest pastures (55 years) the decreases exceeded one pH unit throughout the entire sampled depth (60 cm). In some soils, under old improved pastures, calcium chloride-extractable manganese had increased to more than 20 ppm throughout the 60 cm profile and to greater than 50 ppm in the surface 10 cm. These levels are considered toxic to sensitive plant species and the highest levels may be toxic to subterranean clover. The amounts of extractable manganese in soils appear to be determined by both pH and the amounts of reactive manganese. In general, the amounts of total and reactive manganese were appreciably higher in the soils of basaltic origin. Substantial increases in extractable and exchangeable aluminium had also accompanied the decrease in pH and, in the surface 10 cm, were greatest in the soils formed on sedimentary parent materials. In many of the soils under old improved pastures, exchangeable aluminium, as a percentage of the effective cation exchange capacity, now exceeds 12%, especially in the 5-10 cm layer, and is probably harmful to sensitive species. Increases in exchangeable aluminium also occurred below the surface 10 cm and, in the granitic soils under the oldest pastures, exchangeable aluminium accounted for 30-50% of the effective cation exchange capacity throughout the 5-50 cm soil depth. The adverse changes in pH, manganese and aluminium observed in this study can be expected to continue under many improved pastures and to generate soil conditions unsuitable for many agricultural plants. The use of lime to arrest or reverse these changes seems inevitable.

56

Williams, J. and Chartres, C.J. (1991): Sustaining productive pastures in the tropics. 1. Managing the soil resource. *Tropical Grasslands* 25:73-84.

Keywords: pastures; tropics; Australia; sustainability; degradation; soil chemical properties; soil acidity; soil salinity; deforestation; legumes; erosion control; watershed; grassland; trees; soil biology.

Abstract. The grazing of pasture systems has many of the elements essential to a sustainable agro-ecosystem wherein the soil resource is not degraded through time. Unfortunately there is increasing evidence that the soils of Australian tropical grasslands are suffering serious and permanent degradation through our inability to manage grazing pressure under the highly variable climatic regime which characterizes the Australian tropics. This paper details the evidence of soil degradation under our current rangeland management and illustrates how far these practices are from that of a sustainable system. The challenge to find grazing systems that are sustainable is shown to lie in recognizing that the soil-plant-animal ecosystem must be studied in an integrated way. Focus on short term animal productivity without consideration of the consequences to all other essential components of the ecosystem is shown to be a primary cause for degradation of the soil resource. Too often the consequences of a practice have not been considered because the components of the agricultural system have been studied in isolation. Both salinity and soil acidification are identified as soil resource management issues that must receive attention in the Australian tropics. The use of tropical legumes, the clearing of woodlands, and the use of introduced grasses are all managements that can radically alter the flux of water, nutrient and salt in the soil profile. The management of these factors is the key to control of both salinity, and soil acidification. The place and balance of the grass, legume, shrub and tree is fundamental. Progress in building sustainable grazing systems in the tropics requires integrated ecological studies with increasing emphasis of both the role of soil biology in the cycling of nutrients and the movement of water and solute in the system.

57

Cumming, R.W. (1991): Long-term effects of lime in extensive pasture areas of Australia. *Developments in Plant and Soil Science* 45:453-464.

Keywords: pastures; Australia; soil acidity; soil chemical properties; sustainability.

Abstract. Acid soils treatment in Australia, is an important part of extensive pasture and crop management systems. Under old improved pastures, calcium chloride-extractable manganese (Mn) and aluminium (Al) have increased to levels which restrict plant growth. Alternative treatments, using both topdressed and surface incorporated lime, have shown positive effects on the $CaCl_2$ extractable Mn and Al. Soil profiles from limed and unlimed pastures were sampled at 2 cm intervals to 20 cm depths, following single applications of lime 10 years ago. Aluminium was reduced by 100% (from 14.5 ppm Al) at the soil surface to 35% at 20 cm in granitic derived soils. In a less acidic basalt derived soil, a 100% reduction has been obtained to 20 cm (from 8.7 ppm Al). Manganese was reduced between 32.5% and 76% in the granite soils (from 12.6 ppm Mn) with basaltic soils having a 62% to 97% reduction in manganese levels (from 23.6 ppm Mn). Long term reduction in these toxic elements, has been mirrored by permanent changes in soil pH and changes in the exchangeable cations, particularly calcium, in a long term agronomic trial.

58

Ridley, A.M., Slattery, W.J., Helyar, K.R. and Cowling, A. (1990): Acidification under grazed annual and perennial grass based pastures. *Australian Journal of Experimental Agriculture* 30:539-544.

Keywords: grasses; pastures; soil acidity; carbon cycle; leaching; grass-legume pastures; soil chemical properties; Australia; sustainability.

Abstract. Soil samples to a depth of 60 cm were collected from adjacent, 39-year-old, phalaris-based and annual pasture fields on an acid soil at Rutherglen, north-eastern Victoria. The fields had similar histories of fertilizer application and stock enterprise. Minimum net acid addition rates were determined under both pasture types, and the soil under annual pasture showed greater acidification. Carbon cycle acid addition contributed 1.31 and 1.36 kmol H^+/ha and year to net acid addition on annual and phalaris pastures, respectively. Because slow alkaline soil reactions in the field contribute to buffering capacity on an acid soil and lead to underestimation of net acid addition rate and nitrate leaching, estimates of such reactions were made for both pasture types. If correct assumptions were used nitrate leaching was substantial under both pasture types but was reduced by 1.01 kmol H^+/ha and year under phalaris pasture. This suggests that perennial grass based pastures can be used to reduce acidification on pastoral soils. Alkali addition to counteract net acidification may be necessary on acid soils to maintain management options for growing aluminium-sensitive species.

59

Ridley, A.M., Slattery, W.J., Helyar, K.R. and Cowling, A. (1990): The importance of the carbon cycle to acidification of a grazed annual pasture. *Australian Journal of Experimental Agriculture* 30:529-537.

Keywords: carbon cycle; pastures; soil acidity; sheep; stocking rate; nitrogen cycle; Australia; production level; fertilization; nitrogen.

Abstract. Soil samples to a depth of 60 cm were collected from 3 fields of a 73-year-old experiment in north-eastern Victoria. One field (unfertilized) had never received fertilizer, whereas, the other two fields (fertilized) had received 4.5 t/ha superphosphate. One of the fertilized fields also had a lime application history (fertilized and limed). The fields were particularly useful for estimation of the amount of acid added by the carbon cycle as records of lamb, wool and hay removal over a long period were available. The soil pH of the fertilized field had declined relative to the unfertilized field to a depth of at least 30 cm. The field receiving fertilizer and lime had a similar pH profile to that of the unfertilized field. Pasture improvement resulted in much higher stocking rates and consequent product removal (hay, wool and meat) from the fertilized and limed fields compared with the unfertilized field (68, 72 and 12 kmol H^+/ha, respectively). Carbon and nitrogen cycle acidification accounted for 65 and 35%, respectively, of the net acid addition on the fertilized field. The acidification rates for the fertilised, fertilised and limed, and unfertilized fields over the 73-year period were 1.42, 2.37 and 0.16 kmol H^+/ha and year. These acid addition rates are likely to be underestimated because the laboratory pH buffering capacity method used did not account for slow buffering reactions in the field.

60

Coventry, D.R. (1992): Acidification problems of duplex soils used for crop-pasture rotations. *Australian Journal of Experimental Agriculture* 32:901-914.

Keywords: Australia; pastures; yields; ley farming; soil chemical properties; soil acidity; degradation.

Abstract. The acidification of duplex soils used for crop-pasture rotations has been reported widely in Australia in the winter dominant rainfall regions. At some locations induced soil acidity limits crop and pasture yield. The rate of soil acidification is affected by soil properties, agricultural management and rainfall. Rates of acid addition of 0.6-6 kmol H^+/ha and year have been measured from long-term crop-pasture rotation experiments; these rates are comparable with values reported from pastoral studies in higher rainfall areas. Components of both the carbon and nitrogen cycles contribute to this acid addition, with loss of nitrate-nitrogen below the rooting depth of these predominantly annual plant systems likely to be the main cause of acidification. Lime application has been recommended as a means of correcting acidification and improving crop and pasture yield. There is little information on the longevity of any beneficial effects of lime, the movement of lime in the soil and re-acidification of the soil in crop-pasture systems. A long term experimental site with rotation, deep tillage and lime treatments has been soil sampled throughout a 9-year period for changes in soil pH and aluminium. Soil pH decreased with increasing time after lime application. At lower lime rates (0.5-1.0 t/ha) there was no difference in pH or exchangeable Al after 9 years, compared with the unlimed soil. At the higher lime rates there was downward movement of the neutralizing effect of lime with time, as well as acidification of the soil. However, the yield responses obtained with all of the lime rates were maintained 9 years after 1 application of lime, even though the soil was strongly acid according to the measures used. Strategies for countering soil acidification may require an initial application of lime if acidity factors are restricting yield. Management systems which increase the permeability of the B horizon of duplex soils and which promote plant growth and a deep root system are essential for countering acidity in a crop-pasture rotation.

61

Diez, J.A., Polo, A., Cerri, C.C. and Andreux, F. (1991): Influência do pousio e da pastagem sobre a dinâmica de nutrientes em oxissolos recentemente desflorestados na Amazônia Oriental (Influence of fallow and of pasture on the nutrient dynamics in recently deforested Oxisols of Eastern Amazonia). *Pesquisa Agropecuária Brasileira* 26:77-83.

Keywords: fallow; pastures; Oxisols; deforestation; nitrogen; fertility; burnings; soil pH; Al decrease.

Abstract. The present paper deals with the effects of six and eight years of fallow and of nine years of cultivated pasture, on nutrient dynamics in deforested Oxisols of Eastern Amazonia. Electroultrafiltration (EUF) method was used, in order to propose efficient systems to improve soil fertility in this area. Forest burning brought about immediate increase of soil pH, whereas subsequent decrease in extractable EUF-Al and increase in exchangeable K and Ca were noticed. Pasture installation after deforestation has shown appreciable prospect to maintain an adequate level of soil fertility since it increases pH and reduces the EUF-Al content. As compared with the soil left under fallow for eight years, higher pH values, lower amount of

extractable Al, higher amounts of mobile P and K, higher biological soil activity, and stable amounts of available nitrogen were observed in the pasture soil.

62

Williams, J. (1991): Search for sustainability: Agriculture and its place in the natural ecosystem. *Agricultural Science* 4:32-39.

Keywords: sustainability; ecosystems; degradation; Australia; farming systems; nutrient cycle; soil erosion; soil salinity.

Abstract. Extensive land degradation in rural Australia is testimony to the fact that current farming systems are not sustainable. The current practices are both mining the reservoir of nutrients and carbon as well as perturbing the ecological and hydrological balances of our landscapes. Land degradation is so often the result of a failure to examine the whole farming system in the context of the hydrological or nutrient cycle in which it is cast. Progress towards sustainable agricultural practices will only be made while the implications of these practices are viewed and examined as part of the regional ecosystem. Agricultural scientists and the farming community must think beyond the farm gate to see how the farm is integrated with the catchment and the landscape as a whole.

63

Angers, D.A. (1992): Changes in soil aggregation and organic carbon under corn and alfalfa. *Soil Science Society of America Journal* 56:1244-1249.

Keywords: soil physical properties; soil organic matter; maize; fallow; *Medicago sativa.*

Abstract. Data on rates of changes in soil structure and organic matter under different cropping systems are necessary for the development of soil and water conservation strategies. Changes in C content and waterstable aggregation of a Kamouraska clay (fine, mixed, frigid Typic Humaquept) under continuus silage corn (*Zea mays* L.) and an alfalfa (*Medicago sativa* L.) stand were monitored monthly during five consecutive growing seasons. A bare soil (fallow) was included as a control. Under alfalfa, the mean weight diameter (MWD) of water-stable aggregates increased from 1.5 to 2.3 mm during the 5-yr period. An asymptotic regression explained 69% of the variation in MWD with time under alfalfa. This increase in MWD was largely attributed to an increase in aggregates >2 mm at the expense of the aggregates of 0.25 to 1.0 mm diameter. Also, under alfalfa, the C content increased following a sigmoidal shape from 26 g kg^{-1} in the first season to 30 g kg^{-1} in the last year. Changes in MWD were comparatively larger and took place more rapidly than those in C. A correlation coefficient of 0.74** (significant at the 0.01 probability level) was obtained between C and MWD. Under corn and fallow (bare-soil control), changes in the MWD and C content were minimal during the 5 yr. About one half of the temporal variation in MWD under corn and fallow could be explained by the variation in soil water content at time of sampling. Conversely, the absence of a significant relationship between water content and MWD under alfalfa suggests that the soil aggregates under this treatment were not subject to slaking.

64

Budelman, A. (1989): The performance of selected leaf mulches in temperature reduction and moisture conservation in the upper soil stratum. *Agroforestry Systems* 8:53-66.

Keywords: mulch; *Leucaena leucocephala*; *Gliricidia sepium*; *Flemingia macrophylla*; legume trees; soil physical properties.

Abstract. This paper reports on the effect of the leaf mulches of *Leucaena leucocephala*, *Gliricidia sepium* and *Flemingia macrophylla* on moisture content and temperature in the first 5 cm of the soil. The mulches were applied at a standard quantity of 5000 kg ha^{-1} DM. In order to characterise a mulch material two parameters are distinguished: the initial impact (Ii) and the effective lifetime (Te) of a mulch material. I is expressed in terms of percentage surplus moisture or degrees Celsius average temperature reduction. T quantifies the duration of the effect. Of the three mulch materials that of *Flemingia macrophylla* performs best in terms of moisture retention and lowering soil temperatures as well as in terms of longevity of the effect. *Leucaena leucocephala* mulch shows the smallest impact, over the shortest period.

65

Pereira, H.C., Chenery, E.M. and Mills, W.R. (1954): The transient effects of grasses on the structure of tropical soils. *Empire Journal of Experimental Agriculture* 22:148-160.

Keywords: grasses; crop rotation; *Paspalum notatum*; cover crops; *Pueraria phaseoloides*; infiltration; pore-space; *Chloris gayana*; soil structure.

Abstract. A detailed study was made of the differences in soil structure in a crop-rotation experiment on a tropical soil. Two different techniques of soil sieving were compared with volumetric measurements of pore-space, and with percolation and rainfall-acceptance tests on soil cores. Three grass species (*Pennisetum purpureum, Paspalum notatum, Chloris gayana*), three cover crops (*Pueraria phaseoloides, Ipomoea batatas, Leucaena glauca*), and three cultivated crops (*Arachis hypogaea, Crotalaria juncea, Manihot utilissima*) were each grown continuously for 3 years. All treatments were then given one year of intensive uniform cropping before the structure comparisons were made. The two tests for water-stable aggregation showed serious discrepancies, but they both agreed with the remaining tests in showing general differences between the groups of treatments after grass rest and those after continuous cultivation. Rainfall infiltration rates were comparatively low after only one year of arable cropping, indicating a rapid loss of the benefits built up under a grass rest. A similar set of tests, on adjacent areas of a rotation on a lateritized volcanic clay, showed even more rapid loss of physical structure after the breaking of grass. These results illustrate the need to measure rates of run-down as well as build-up of soil-structure, and the desirability of using physical tests more realistic than wet sieving.

66

Frost, W.E. and Edinger, S.B. (1991): Effects of tree canopies on soil characteristics of annual rangeland. *Journal of Range Management* 44:286-288.

Keywords: trees; grassland; soil physical properties; soil chemical properties; California.

Abstract. In the central California region of annual rangeland, herbage production beneath blue oak (*Quercus douglasii* Hook & Arn.) canopies is greater and production beneath the

canopies of interior live oak (*Quercus wislizenii* DC) and digger pine (*Pinus sabiniana* Dougl.) is less than that in adjacent open grassland. The objective of this investigation was to assess the impact of these major overstory species on soil-associated characteristics in an effort to explain this tree-herbage production relationship. Greater amounts of organic carbon (OC), greater cation exchange capacity (CEC), lower bulk density, and greater concentrations of some nutrients were found beneath blue oak canopies than in open grassland. This explains, at least in part, the increased herbage production beneath blue oak canopy.

67

Lal, R., Wilson, G.F. and Okigbo, B.N. (1978): No-till farming after various grasses and leguminous cover crops in tropical Alfisol. I. Crop performance. *Field Crops Research* 1:71-84.

Keywords: grasses; cover crops; soil properties; mulch; Nigeria; *Panicum maximum*; legumes; *Centrosema pubescens*; *Pueraria phaseoloides*; *Brachiaria*; *Stylosanthes guianensis*; maize; cowpea; *Cajanus cajan*; soybeans; cassava; nitrogen; soil physical properties; infiltration; soil bulk density; earthworms; yields; *Glycine wightii*; *Melinis minutiflora.*

Abstract: The effects of four grasses and four leguminous cover crops on soil properties, and on the applicability of zero-tillage technique for arable crop production with killed sod mulch, was investigated on tropical Alfisol near Ibadan, Nigeria. The cover crops consisted of four grasses, *Panicum maximum, Setaria sphacelata*, *Brachiaria ruziziensis*, and *Melinis minutiflora*, and four legumes, *Centrosema pubescens, Pueraria phaseoloides, Glycine wightii*, and *Stylosanthes guianensis*. Two years after establishing cover crops, arable crops were planted through chemically killed sod. The arable crops grown were maize (*Zea mays*), cowpea (*Vigna unguiculata*), pigeonpeas (*Cajanus cajan*), soybeans (*Glycine max*), and cassava (*Manihot esculenta*). Cover crops had a significant effect on soil chemical and physical properties. Organic carbon, total nitrogen, and CEC were higher under *Melinis minutiflora, Glycine wightii, Centrosema*, and *Pueraria* than with control and other cover crops. There were differences between cover crops in soil physical properties. Infiltration rate and soil bulk density were generally low under cover crops compared with control. Earthworm activity was related to the quantity and persistence of killed sod mulch under various cover crops. Maximum soil temperature under killed sod mulch was as much as 10°C lower than in control. Soil moisture storage was affected both by mulch cover and by the canopy cover of the arable crop grown on the killed sod. Soil moisture storage was generally high under killed sod mulch compared with control. There were significant differences in arable crop yield between various cover crops. Significantly higher crop yields were obtained under *Centrosema, Pueraria, Stylosanthes*, and *Brachiaria* than with control and other cover crops. *Brachiaria* sod was, however, difficult to eradicate and to plant in with zero-tillage technique. Maize and cowpea grain yield and cassava tuber yield were positively related to infiltration rate and negatively to soil bulk density.

68

Vera, R.R., Thomas, R., Sanint, L. and Sanz, J.I. (1992): Development of sustainable ley-farming systems for the acid-soil savannas of tropical America. *Anais, Academia Brasileira de Ciências* 64:105-125.

Keywords: ley farming; livestock; economics; Brazil; Colombia; pastures; rice; grasses; legumes; acid soil; Venezuela; sustainability; savanna.

Abstract. The paper reviews the evolution of the agricultural and livestock sectors in the neotropical savannas of Latin America, and their contribution to economic development and human nutrition. It is shown that the savannas are responsible for an increasing share of total agricultural production in Brazil, Colombia and Venezuela. The natural resources of these savanna lands are discussed, with emphasis on the physico-chemical characteristics of the soil, and the constraints that they impose on crop and pasture production. The development of acid-soil tolerant crops and forages is briefly summarized. Mechanisms of adaptation are described, and the contribution of adapted germplasm to soil enhancement is discussed. Lastly, the paper reviews studies conducted in Colombia to research crop-pasture integration in tropical ley-farming systems, using selected adapted rice lines and grass and legume forages as experimental models. Evidence collected over four consecutive years clearly shows the technical feasibility of developing alternative systems that combine annual crops and grazed pastures using low external inputs and enhancing soil characteristics. Ex-ante economic analysis reveal that these systems are also highly profitable.

69

King, K.L., Greenslade, P. and Hutchinson, K.J. (1985): Collembolan associations in natural versus improved pastures of the New England Tableland, NSW: Distribution of native and introduced species. *Australian Journal of Ecology* 10:421-427.

Keywords: improved pastures; pastures; Collembola; introduced species; Australia; phosphorus; soil fauna; biodiversity; species diversity.

Abstract. Native Australian species of Collembola dominated natural pasture in numbers of species present and in abundance, while introduced Collembola dominated fertilized pasture sown to exotic species. Those collembolan species which were restricted to one pasture type only were mainly epigeal and hemiedaphic species of the herbage and litter. Increased grazing by sheep decreased species richness and increased uniformity of Collembola in both pasture types. The abundance of introduced Collembola was positively associated with phosphorus content of litter.

70

Curry, J.P. (1987): The invertebrate fauna of grassland and its influence on productivity. 1. The composition of the fauna. *Grass and Forage Science* 42:103-120.

Keywords: grassland; invertebrates; soil fauna; soil biomass.

Abstract. The invertebrate groups which are of most significance in grassland are briefly reviewed. Factors influencing the abundance and composition of the fauna are considered together with the types of damage caused in grassland, the economic importance of such damage and beneficial effects on soil fertility.

71

Rushton, S.P. (1988): Earthworms in pastoral agriculture. *Outlook on Agriculture* 17:44-48.

Keywords: earthworms; pastures; soil chemical properties; soil physical properties; grassland; fertilization; pasture management; soil biology.

Abstract. It is well known that earthworms of various species, with widely differing feeding and burrowing habits, can have a considerable effect on the structure and composition of the upper levels of the soil. It is, however, often difficult to relate these effects to soil fertility in particular situations and to manipulate worm populations to produce beneficial results.

72

Baker, G., Buckerfield, J., Grey-Gardner, R., Merry, R. and Doube, B. (1992): The abundance and diversity of earthworms in pasture soils in the Fleurieu Peninsula, South Australia. *Soil Biology and Biochemistry* 24:1389-1395.

Keywords: pastures; Australia; earthworms; soil chemical properties; species diversity; nitrogen.

Abstract. Earthworms were surveyed in 113 pasture soils in the Mount Lofty Ranges, Fleurieu Peninsula, South Australia, in a region where annual rainfall is 600-1200 mm and the climate is mediterranean. The soils within these pastures included a variety of profile forms (e.g. sandy soils with yellow, brown or red clays in the B horizon; uniform coarse textured sands). The most widespread earthworm species were *Aporrectodea trapezoides* (found at 95% of sites), *Microscolex dubius* (61%), *Aporrectodea rosea* (38%) and *Aporrectodea caliginosa* (36%). These are all introduced species. The total densities of earthworms varied from 0 to 608 m^{-2} (mean = 169.2). At most sites (66%), densities were < 200 m^{-2}. Native earthworms were present at 40 sites but their total densities exceeded 100 m^{-2} at only 7 sites. The species richness and diversity of the earthworm communities were low; never more than 5 species were found in any one pasture (mean = 3.1). The abundance of the introduced species (all species combined) varied between soil profile forms, being least in the uniform sands. No such variation was found for native species. Several significant, but weak, correlations were obtained between the numbers and weights of earthworms and other environmental variables (e.g. rainfall, depth of A horizon, % sand, clay, nitrogen and carbon). Stepwise multiple regression of the numbers and weights of introduced species against these environmental variables suggested that % clay was the most important regressor. The potential for increasing the abundance and diversity of earthworms in Australian soils is discussed.

73

Knight, D., Elliott, P.W., Anderson, J.M. and Scholefield, D. (1992): The role of earthworms in managed, permanent pastures in Devon, England. *Soil Biology and Biochemistry* 24:1511-1517.

Keywords: earthworms; pastures; denitrification; mineralization; leaching; nitrogen; England; fertilization; cattle; hydrology.

Abstract. Studies were carried out on experimental pasture plots which are drained or undrained and receiving 0, 200 and 400 kg N ha^{-1} yr^{-1} as inorganic fertilizer. Earthworm populations (dominated by *Lumbricus rubellus* and *Aporrectodea caliginosa*) were lowest (71.0 ±11.4 g m^{-2}) on the undrained 0N plots and highest (100.3 ±13.4 g m^{-2}) on the undrained 200N plots. Deep burrowing species appear to be excluded from colonizing the drained plots by the high water-table during winter and spring. Aggregations of earthworms

beneath dung pats were recruited laterally peaking at a population equivalent of 417.5 ±60 g m^{-2} after 63 days. Local burrowing activities resulted in increased macroporosity over a period of 105 days. Earthworm casts were found to have 3-5 times higher denitrification rates than surrounding soil with lower endogenous rates of N_2O production. Denitrification was determined by cast NO_3^--N content and fertilizer applications. Earthworm casts may make a significant contribution to the heterogeneity associated with field measurements of denitrification. Lysimeter studies were also carried out using soil monoliths to investigate the effects of earthworms (including *Lumbricus terrestris*) on nutrient leaching from treatments receiving the equivalent of 200 kg N ha^{-1} as cattle slurry or inorganic fertilizer. Nitrate concentrations in leachates were low in the unfertilized treatments but earthworms increased losses three times. Nitrate losses were higher in the slurry treatments, possibly because of damage to the sward, with proportionally smaller earthworm effects. It is concluded that the moderate population densities of surface active species still have detectable effects on the hydrology and mineral N fluxes in intensively managed pastures although their effects on sward production are negligible in relation to the main plot treatments. Earthworm activity may be an important determinant of heterogeneity in the rates of soil processes.

74

Serrão, E.A. and Toledo, J.M. (1990): The search for sustainability in Amazonian pastures. In: Anderson, A.B. (ed.), *Alternatives to deforestation: Steps toward sustainable use of the Amazon rain forest*. New York: Columbia University Press, p. 195-214.

Keywords: sustainability; Amazon region; tropical forest; pasture management; fertilization; nutrient cycle; degradation; insect pests; fungal diseases; agroforestry; adapted germplasm.

Abstract. In the past three decades, cattle ranching has become a major source of deforestation in the Amazon Basin, largely as a consequence of government incentives that have proved to be both ecologically and socioeconomically dubious. It is currently estimated that at least ten million hectares of forest have been converted to highly unstable pastures, of which about 50 percent are now in advanced stages of degradation. In this essay, we emphasize the need to reduce the rate of forest clearing for cattle ranching by increasing the longevity of still-productive pastures and by reclaiming those pastures that have been severely degraded. This paper 1) examines nutrient cycling in pasture ecosystems as a basis for sustainability; 2) describes the causes of biotic instability in pastures during their first and subsequent cycles; 3) outlines present and potential technologies for increasing pasture stability and for reclaiming degraded sites; 4) analyzes the potential of low-cost technology based on newly adopted germplasm of grasses and legumes for open pastures and agrosilvopastoral systems; and 5) suggests research priorities for intensifying land management and increasing pasture sustainability.

75

Hecht, S.B. (1982): Agroforestry in the Amazon Basin: Practice, theory and limits of a promising land use. In: Hecht, S.B. (ed.), *Amazonia: Agriculture and land use research*. Cali (Colombia): CIAT (Centro Internacional de Agricultura Tropical), p. 331-371.

Keywords: agroforestry; erosion control; sustainability; Amazon region; nutrient cycle; tropical forest; shifting cultivation; deforestation; forage trees; cattle; pest control.

Abstract. This paper explores the potentials for agroforestry in the Amazon Basin and describes already established forms of this land use system in the region. The latter include combinations of commercial timber trees with annual food crops or with cocoa and coffee plantations; furthermore, existing silvopastoral systems, such as pastures under native or introduced timber trees, rubber trees, oil palm, fruit and nut producing trees or forage trees are discussed. Information is given about woody species of commercial interest as sources of timber, forage, oils, resins and medicinals. The importance of agroforestry for soil amelioration, erosion control, pest dynamics and efficient nutrient cycling, thus sustainability of the agricultural system as a whole, is outlined. The author emphasizes that the expansion of agroforestry in Amazonia is limited only in part by lack of technical experience. Land conflicts, the view that dramatic physical alteration of a landscape is a proof of 'progress' and the speculative character of land ownership interfere with a rational resource use in the Amazon region. (Abstract by bibliography authors)

76

Buschbacher, R.J. (1987): Deforestation for sovereignty over remote frontiers; case study No. 4: Government sponsored pastures in Venezuela near the Brazilian border. In: Jordan, C.F. (ed.), *Amazonian Rainforests: Ecosystem disturbance and recovery; Ecological Studies 60*. New York: Springer Verlag, p. 46-57.

Keywords: deforestation; nutrient cycle; Amazon region; phosphorus; *Brachiaria decumbens*; degradation; shifting cultivation; soil chemical properties; South America; tropical forest; pastures.

Abstract. Nutrient cycling and net primary productivity were investigated in an undisturbed rain forest site and two adjacent pasture sites under grazing conditions in the Amazon region near San Carlos, Venezuela. One of the pasture sites under investigation followed natural rain forest vegetation, whereas the other one had been a secondary forest following shifting cultivation. Both had simultaneously been cleared and burned, and a *Brachiaria decumbens* pasture was established without any fertilizer input. After pasture establishment, changes in the total nutrient stocks and particularly in the distribution of nutrients between ecosystem components were observed. In general, nutrient stocks in the living biomass decreased, while soil nutrient levels increased. The most important difference between pasture derived from primary forest and that from secondary forest was in the level of soil nutrients at the initiation of grazing, being much lower in the pasture from secondary forest than in the pasture formed from mature rain forest. The amount of available phosphorus in the soil increased after burning, but decreased quickly after 1 year in pasture. Total above-ground net primary productivity of the pasture formed from primary forest was very close to that of the undisturbed rain forest and was maintained during the three years under investigation. Above-ground net primary productivity in the pasture derived from secondary forest was about 50-60% of that derived from primary forest. The lower productivity was probably due to lower levels of calcium, potassium and magnesium in the secondary forest pasture. Furthermore, problems of animal production due to mineral deficiencies and possible restrictions to resilience of forest on abandoned pastures are discussed. (Abstract by bibliography authors)

77

Luizão, R.C.C., Bonde, T.A. and Rosswall, T. (1992): Seasonal variation of soil microbial biomass – the effects of clearfelling a tropical rainforest and establishment of pasture in the central Amazon. *Soil Biology and Biochemistry* 24:805-813.

Keywords: pastures; deforestation; tropical forest; *Brachiaria humidicola*; nitrogen cycle; mineralization; Amazon region; soil biomass; nitrogen.

Abstract. The effects of clearfelling a tropical rainforest and establishing pasture on soil microbial biomass and nitrogen transformations were assayed monthly over 1 yr in three adjacent systems in the central Amazon region; (1) virgin rainforest; (2) slashed-and-burnt forest; and (3) recently established pasture. The amounts of soil organic matter (SOM) and soil microbial biomass-carbon (biomass-C) were substantial in all systems. Total soil-C ranged between 1.9 and 5.2% depending on management and soil layer, whereas biomass-C ranged between 3.5 and 5.3% of total soil-C. The soil biomass-C decreased upon slashing-and-burning to 64% of its original value (1287 micrograms/g) in the forest (0-5 cm soil layer) and increased after establishment of pasture to 1290 micrograms/g, but remained unchanged in the deeper 5-20 cm soil layer. No significant seasonal variation was measured in any system or soil layer. Soil respiration responded to management like microbial biomass-C but varied significantly over the season with the smallest respiration found in the driest month (October) and the largest respiration at end of the rains in May. Pools of mineral N varied considerably in all systems and soil layers and displayed identical seasonal variations. The forest topsoil contained the highest amounts (on average 47 micrograms N/g) and the pasture soil the smallest amounts (on average 24 micrograms N/g). The transition of the forest ecosystem to a pasture resulted in increased NO_3^- concentrations. Net N-mineralization and net NO_3^- production monitored during short-term laboratory incubations were used as indices of N mineralization and nitrification. No significant differences in N-mineralization indices were measured between systems, but substantial within season variations were recorded in all systems and soil layers. The variations were synchronized in time with extreme net N-mineralization in September and net N- mineralization in October. Significant nitrification indices were measured in all systems. They were identical in the systems, except for small indices found in topsoil of the slashed and burnt area, where, on the other hand, certain localized areas with extreme nitrification rates were detected.

78

Eden, M.J., Furley, P.A., McGregor, D.F.M., Milliken, W. and Ratter, J.A. (1991): Effect of forest clearance and burning on soil properties in northern Roraima, Brazil. *Forest Ecology and Management* 38:283-290.

Keywords: Brazil; tropical forest; *Panicum maximum*; grasses; Amazon region; deforestation; soil chemical properties; soil physical properties; cattle; degradation; *Brachiaria humidicola*; pastures.

Abstract. Clearance of evergreen seasonal forest for cattle pasture was examined at a ranch 130 km NW of Boa Vista. Colonião (*Panicum maximum*) and kikuyu grass (*Brachiaria humidicola*) are commonly established on cleared forest land. Current rates of clearance are rather low as also is grazing intensity (1-2 animals/ha), but soil physical and chemical changes are occurring. Topsoil bulk density is increasing over time in new pastures; and available nutrients decrease from the enhanced levels that prevail after initial clearance and burning. In

particular, available P is low in the acid soils and, as elsewhere in Amazonia, probably limiting to pasture growth. For local ranchers, the best source of nutrients is the standing forest, so every incentive exists to continue forest destruction for new pasture.

79

Powell, J.M. (1986): Manure for cropping: A case study from central Nigeria. *Experimental Agriculture* 22:15-24.

Keywords: maize; farming systems; fertilization; mixed farming; tropical savanna; West Africa; manure.

Abstract. The traditional management of cattle manure in a cropping system in the savanna zone of central Nigeria is discussed in conjunction with the agronomic benefits and problems of manure use. Nitrogen and phosphorus contents of the manure varied seasonally. On-farm trials showed that maize grain yields were about 1 t ha^{-1} more and weed growth 90% greater in manured than in non-manured areas. It is important to reduce the competition between crops and weeds if grain crops are to obtain the full benefit of manure in such cropping systems.

80

McNaughton, S.J. and Stuart Chapin III, F. (1985): Effects of phosphorus nutrition and defoliation on C_4 graminoids from the Serengeti plains. *Ecology* 66:1617-1629.

Keywords: phosphorus; grassland; animal-plant interaction.

Abstract. *Kyllingia nervosa* (Cyperaceae) and *Digitaria macroblephara* (Poaceae), C_4 graminoids, were obtained from the Serengeti National Park of Tanzania. *Kyllingia* is most abundant on high pH, high calcium, low phosphorus, carbonatic ash-derived soils, and *Digitaria* is more abundant on neutral, lower calcium, higher P soils. Both species come from intensely grazed grasslands. Plant responses to different nutritional levels and defoliation were measured to evaluate potential limiting interactions between energy and nutrient flows in grazing ecosystems. Plants were grown hydroponically at solution phosphorus concentrations of 10 and 100 µmol/l and were either unclipped or clipped weekly to a height of 3 cm for 5 wk. At that time, the kinetics of P uptake were measured with ^{32}P, plants were harvested, and dry masses and the tissue concentrations of P and N were determined. Clipping and P concentration of the growth medium both had major effects upon yield of all plant components. Total yield of *Kyllingia* was highest in unclipped plants at high levels of P supply; yields under all other conditions were lower and undistinguishable from one another. In contrast, yield of *Digitaria*, which had been collected in areas with soils of higher phosphorus availability, was unaffected by defoliation but was almost 2½ times greater when plants were grown at the higher P level. Root growth of *Digitaria* was stimulated by defoliation when P was abundant. Maximum yield to grazers from *Kyllingia* under conditions of this experiment would be achieved if grazers foraged only at the end of the period; maximum yield of *Digitaria* to grazers would be achieved if grazers defoliated plants at frequent intervals. A variety of morphological changes associated with maintaining similar leaf areas whether clipped or unclipped were associated with *Digitaria*'s ability to compensate for simulated grazing. Yield to producers (the residual live biomass present at harvest) and yield to grazers were positively correlated, indicating that conditions promoting plant yield caused a proportional increase in yield to higher trophic levels. Further details about P and N uptake and tissue concentrations in relation to the different treatments are reported.

81

Hutchinson, K.J. and King, K.L. (1982): Invertebrates and nutrient cycling. In: Lee, K.L. (ed.), *Proceedings of the 3rd Australasian Conference on Grassland Invertebrate Ecology*. Adelaide: S.A. Government Printer, p. 331-338.

Keywords: invertebrates; nutrient cycle; insects; Australia; pastures; soil biology; grassland; animal-plant interaction.

Abstract. The contribution of cycling to the phosphorus economy of a grazed fertilized pasture at Armidale was estimated to be 40 kg P ha^{-1} yr^{-1}. The calculation was based on the difference between the total P in residues production and the yearly accumulation of organic P in the soil. 23% of the residues P was from invertebrate corpses and excreta. However the amount and availability of the mineral residues from invertebrates do not reflect the net functional contribution of these fauna to cycling. This depends largely on the ability to stimulate microbial activity. Progress in studies of the regulatory roles of invertebrates in cycling are reviewed. Mechanisms are grouped under the headings of particle reduction and abrasion, mixing, invertebrate dietary preferences, effects of microbial production, gut transactions and direct effects of invertebrates on plant growth. Computer based studies on combinations and sequences of cycling mechanisms may be useful for defining the efficient nutrient strategies which may operate in grazing systems. Challenges in laboratory microcosm studies of cycling include the choice of relevant invertebrate species, the inclusion of nutrient uptake by plants, the provision of a realistic spatial distribution of nutrients and the application of controlled environmental inputs to mimic the changes encountered in the field.

82

Lavelle, P. (1983): The soil fauna of tropical savannas. II. The earthworms. In: Bourliere, F. (ed.), *Ecosystems of the world 13: Tropical savannas*. Amsterdam-Oxford-New York: Elsevier Scientific Publishing Company, p. 485-504.

Keywords: soil fauna; tropical savanna; earthworms; pastures; species diversity; grassland.

Abstract. Tropical savannas can harbor a rich community of earthworms under favourable environmental conditions -- that is, when rainfall ranges from 1000 to 1500 mm, and is more or less evenly spread over the whole year. In such cases, up to ten to twenty species can occur together, adequately sharing the food resources of the soil environment. Competition is avoided by food and space partitioning, and the variety of niches goes hand in hand with different demographic structures and strategies. In man-made pastures located in formerly forested areas, species diversity is lower and much depends on the adaptive potentialities of the former forest species to take advantage of these new environments, as well as on occasion for pantropical species to invade these new habitats. In this perspective, the limited ability for dispersal of the earthworms is an obvious handicap. However, once established, the newcomers can play a very important role, as the amount of humic material produced from litter and roots in moist tropical pastures can be important, and as the water regime of such grasslands is much more favourable for earthworms than that of a forest. In drier savannas, the role of earthworms becomes much less important when rainfall decreases and becomes more and more seasonal and unpredictable. The long dry season of the Sahelian savannas makes permanent settlement by earthworms impossible.

83

Pfeffer, E. and Spiekers, H. (1989): Stickstoffbilanz in Milchviehbetrieben. *Der Tierzuechter* 41:246-247.

Keywords: dairy cows; nitrogen; nutrient cycle; production level; farming systems; yields; pastures.

Abstract. Nitrogen balances in farming systems have become a matter of interest due to potential groundwater pollution from N-fertilizer use or organic residues of intensive animal production. The nitrogen balance in dairy farms depends mainly on the production level (milk yield per cow), use of feed concentrates and the area of pasture needed per cow. Model calculations for several production levels (milk and pasture yields) are given and the effects on the nitrogen balance of the system are discussed. (Abstract by bibliography authors)

84

García-Méndez, G., Maass, J.M., Matson, P.A. and Vitousek, P.M. (1991): Nitrogen transformations and nitrous oxide flux in a tropical deciduous forest in Mexico. *Oecologia* 88:362-366.

Keywords: nitrogen; Mexico; nitrogen cycle; nitrous oxide; tropical forest; pastures; atmosphere.

Abstract. Emissions of nitrous oxide and soil nitrogen pools and transformations were measured over an annual cycle in two forests and one pasture in tropical deciduous forest near Chamela, Mexico. Nitrous oxide flux was moderately high (0.5-2.5 ng cm^{-2} h^{-1}) during the wet season and low (< 0.3 ng cm^{-2} h^{-1}) during the dry season. Annual emissions of nitrogen as nitrous oxide were calculated to be 0.5-0.7 kg ha^{-1} yr^{-1}, with no substantial difference between the forest and pasture. Wetting of dry soil caused a large but short-lived pulse of N_2O flux that accounted for <2% of annual flux. Variation in soil water through the season was the primary controlling factor for pool sizes of ammonium and nitrate, nitrogen transformations, and N_2O flux.

85

Elliott, P.W., Knight, D. and Anderson, J.M. (1990): Denitrification in earthworm casts and soil from pastures under different fertilizer and drainage regimes. *Soil Biology and Biochemistry* 22:601-605.

Keywords: denitrification; earthworms; pastures; fertilization; drainage; nitrous oxide; nitrogen.

Abstract. Laboratory incubations were carried out, with and without acetylene, of earthworm casts and soil cores collected in permanent pastures with different fertilizer and drainage regimes. Nitrous oxide production ($+C_2H_2$) was consistently higher from casts than soil material from all sites. In the undrained, unfertilized plot the mean rate of N_2O production from casts was nearly 5 times higher than from the soil. Moisture content was correlated with denitrification for casts but not for soils although both materials were near to saturation throughout the 8 week study. The proportion of endogenous N_2O production ($-C_2H_2$) was lower in casts than soils indicating the more complete reduction of nitrogen oxides to N_2

under aerobic conditions. Earthworm casts constitute important microsites for denitrification and contribute to the spatial heterogeneity of these gaseous-N fluxes.

86

Plamondon, A.P., Ruiz, R.A., Morales, C.F. and González, M.C. (1991): Influence of protection forest on soil and water conservation (Oxapampa, Peru). *Forest Ecology and Management* 38:227-238.

Keywords: Peru; hydrology; soil erosion; erosion control; tropical forest; pastures; water quality; soil chemical properties; *Brachiaria*; sustainability; watershed; nitrogen; phosphorus.

Abstract. The demarcation of protection forest is a practice used in the mountainous areas of the Peruvian tropical forest to maintain ecological equilibrium. In order to evaluate some of the ecological effects of protection forest compared with other land uses, the effects of different land uses (dense natural forest, a mosaic of crop/pasture/forest, and pasture) on soil fertility and water quality were assessed on three basins within the Oxapampa municipal watershed, near Cerro de Pasco. Samples were taken in dense forest, on a fresh clearcut, on a one-year-old regenerated site, on a site with regeneration cleared and burned, and crops and pastures at least 3 years old. Replacing the natural forest by pastures and crops reduced organic matter, nitrogen, phosphorus, and potassium content of the soil. In addition, the increase in exchangeable aluminium caused a substantial decrease in fertility three or more years after land clearance. Maximum suspended sediment concentrations reached 76, 226, and 771 mg/litre respectively, for the three basins covered by forest, crop/pasture/forest, and pasture. From streamflow measurements, annual soil losses were, respectively 121, 345, and 542 kg/ha. Water temperatures ranged from 13, 14, and 16 °C to a maximum of 14, 19, and 20 °C, respectively. Minimum dissolved-oxygen concentrations of 7.7, 6.6, and 5.9 p.p.m. and pH of 7.0, 6.5, and 6.0 were measured. The results stress the importance of maintaining forest cover on steep land.

87

Takar, A.A., Dobrowolski, J.P. and Thurow, T.L. (1990): Influence of grazing, vegetation life-form, and soil type on infiltration rates and interrill erosion on a Somalion rangeland. *Journal of Range Management* 43:486-490.

Keywords: erosion; infiltration; watershed; shrubs; hydrology; Somalia; grassland; grasses.

Abstract. Heavy communal grazing pressure and rapid phytomass decomposition reduce shrub interspace cover in Somalia from 100% at the end of the growing season to 5% at the end of the dormant season. Intense monsoonal rains, characteristic of Somalia and other areas of subsaharan Africa, combined with sparse vegetative cover at the beginning of the rainy season, may result on overland flow and excessive erosion, even where sand content of the soil exceeds 90%. Little watershed research has been conducted in this region other than to document that the problem is extreme. The objectives of this study were to assess the seasonal hydrologic responses as influenced by 2 soils (sand vs. clay), grazing intensity (exclusion vs. heavy communal grazing), and cover types (shrub understorey vs. interspace) in Somalia. Infiltration rate and interrill erosion on the sand site were significantly greater than on the clay site regardless of cover type or season. The clay site was dominated by annual forbs which rapidly decomposed. The sand site had greater annual and perennial grass cover which decomposed slower than forbs, providing longer and perhaps better protection from raindrop

impact energy. Three growing seasons of livestock exclusion did not significantly increase soil cover on shrub interspaces; consequently, infiltration rates and interrill erosion remained similar to the communally grazed sites. Interspace cover left by livestock was instead removed by termites and other microorganisms. Restricted ability of livestock to graze beneath thorny shrubs and increased phytomass from shrub leaf-fall resulted in a greater accumulation of cover and litter beneath shrubs, which aided infiltration on clay sites, regardless of season.

88

Lal, R. (1984): Soil erosion from tropical arable lands and its control. *Advances in Agronomy* 37:183-248.

Keywords: soil erosion; erosion; tropics; deforestation; land-use changes; cover crops; mulch.

Abstract. The objective of this article is to evaluate, review, and assess the available information on soil erosion in the tropics at its consequences, to identify knowledge gaps and define research and development priorities. In his study, Lal considers subjects, such as edaphic and climatic factors in relation to soil erosion, a comparison of soil erosion in tropical and temperate climates, slope characteristics and scales of measurement, deforestation and change in land use, soil erosion and crop productivity, soil loss tolerance and basic principles of erosion control.

89

Banzhaf, J., Leihner, D.E., Buerkert, A. and Serafini, P.G. (1992): Soil tillage and windbreak effects on millet and cowpea: I. Wind speed, evaporation, and wind erosion. *Agronomy Journal* 84:1056-1060.

Keywords: millet; erosion; deforestation; overgrazing; windbreaks; cowpea.

Abstract. Deforestation, overgrazing, and declining soil regeneration periods have resulted in increased wind erosion problems in dry areas of West African Sahel, but little is known about the bio-physical factors involved. This research was conducted to determine the effects of ridging and four different windbreak spacings on wind erosion, potential evaporation, and soil water reserves. A field trial was conducted from 1985 to 1987 on 12 ha of a Psammentic Paleustalf in Southern Niger. Millet, *Pennisetum glaucum* (L.), and cowpea, *Vigna unguiculata* (L.) Walp., were seeded in strips on flat and ridged soil. Windbreaks of savannah vegetation were spaced at 6, 20, 40, and 90 m. The effects of ridging on wind speed, evaporation, and wind erosion were small and mostly non-significant. However, average wind speed at 0,3 m above ground in the center of cowpea and millet strips was significantly reduced from 2.8 to 2.1 m/s as windbreak distances narrowed from 90 to 6 m. As a consequence, potential evaporation declined by 15% and the amount of wind blown soil particles by 50% in ridged and by 70% in flat treatments. Despite reduced potential evaporation, average subsoil water reserves were 14 mm smaler in the 6- than in the 20-m windbreak spacing indicating exessive water extraction by the windbreak vegetation. Thus, establishing windbreaks with natural savannah vegetation may require a careful consideration of agronomic benefits and costs to competing crops.

90

Nair, P.K.R. (1989): The role of trees in soil productivity and protection. In: Nair, P.K.R. (ed.), *Agroforestry systems in the tropics*. Dordrecht/NL: Kluwer Academic Publishers, p. 567-589.

Keywords: trees; agroforestry; nitrogen; legumes; farming systems; erosion control; legume trees; soil chemical properties; soil physical properties.

Abstract. Various aspects are covered: (1) suggested mechanisms of soil improvements in agroforestry (evidence from existing land-use systems, and the effect of trees on soils, including a table summarizing the potential benefits of trees to soils); (2) nitrogen fixing trees (including a table 'perennial legumes commonly used in Asian farming systems', which lists mainly nitrogen fixing trees); (3) nutrient cycling in agroforestry systems; (4) trees and soil conservation (the effects of trees on erosion factors, observed erosion rates under agroforestry practices, and examples of the use of agroforestry in erosion control); and (5) trees as windbreaks and shelterbelts (descriptions, species, benefits and examples).

91

Torssell, B.W.R. (1973): Patterns and processes in the Townsville Stylo-annual grass pasture ecosystem. *Journal of Applied Ecology* 10:463-478.

Keywords: degradation; grass-legume pastures; erosion; Australia; weeds.

Abstract. Ecological relationships between Townsville stylo (*Stylosanthes humilis* H.B.K.) and annual grass weeds were examined in a pasture on cleared Tippera clay loam in northern Australia. Changes in vegetation pattern over a 5-year period were found to be related to: (1) water run-off and infiltration modified by soil characteristics, plant cover and low amplitude relief; (2) surface transport of seed, soil and plant nutrients; (3) the effects of topsoil moisture on germination, seed mortality and seedling establishment; (4) the effects of soil water, soil fertility and grazing on competition between species. The stability of the vegetation pattern was expressed by a pasture stability index (PS) and by a real stability index for each component (RCS). Apparent component stability (ACS), based on net changes in component occupancy, was defined as an index to describe persistence of animal-carrying capacity. In most years pasture stability (PS) was maintained. A balance developed in the species distribution in which the grasses were characteristic of the depressions in the pasture and the legume characteristic of the slopes (slope gradient 1:400). In one year, however, following intensive grazing and intense rainfall, water runoff and the consequent transport of seed was so great that the pasture stability (PS) was substantially decreased. It has been possible to express the relations between the components of the pasture ecosystem diagramatically. The diagram is thought to reflect those principles generally applicable to annual legume-grass pastures in dry monsoonal environments and to give guide lines for research in the future. Examination of the factors contributing to pasture instability appears to be of high priority.

92

Leach, G.J., Rees, M.C. and Charles-Edwards, D.A. (1986): Relations between summer crops and ground cover legumes in a subtropical environment. 1. Effects of a *Vigna trilobata* ground cover on growth and yield of sorghum and sunflower. *Field Crops Research* 15:17-37.

Keywords: ground cover; legumes; *Vigna trilobata*; yields; *Sorghum bicolor*; *Helianthus annuus*; annual field crops; subtropics; erosion control; Australia; seeds; erosion.

Abstract. An annual form of *Vigna trilobata* (L.) Verdc., a semi-domesticated herbaceous legume, was used to provide additional ground cover under rainfed crops in a subtropical environment. This study reports effects of *V. trilobata* on growth and yield of sorghum (*Sorghum bicolor* (L.) Moench) and sunflower (*Helianthus annuus* L.). Crops were sown on a vertisol in south-east Queensland in October and January at densities of 10 and 5 plants m^{-2} for sorghum and 5 and 2.5 plants m^{-2} for sunflower, and with or without ground cover legume. Crop rows were 0.8 m apart. *V. trilobata* seed was broadcast at 150 seeds m^{-2} when the crops were sown. While a full profile of soil water at sowing, and 330 to 424 mm rainfall during crop growth, led to vigorous growth of both crops and ground cover, crops from both sowings experienced water stress from about anthesis to the middle of grain fill. At the higher crop density, yields of sorghum grain were 453 and 355 g m^{-2} and yields of sunflower seed were 161 and 227 g m^{-2} after sowing in October and January, respectively. Yields were decreased to 87%, 70%, 76% and 90% respectively in the presence of up to 330 g m^{-2} of dry matter of *V. trilobata*. Sorghum yields were marginally lower at the lower density and decreased relatively more in the presence of ground cover. Neither the yield of sunflower seed, nor the effect of ground cover on it, was affected by density. Competition from ground cover decreased radiation interception by crops through decreasing leaf area index. It did not appear to affect the efficiency of conversion of intercepted radiation to dry matter. Tiller number in sorghum was decreased by ground cover, except in the low density stand sown in October. Effects of ground cover on the contribution of tiller heads to yield were more severe, leading to a halving of their contribution at the lower density. Lower grain yields in the presence of ground cover were due to lower numbers of seeds m^{-2} in both crops. Seed size was also smaller in sunflower, but the percentage of oil was not affected. We conclude that under well-watered conditions in south-east Queensland the decreases in yields of summer crops in competition with *V. trilobata* are likely to be outweighed by the anticipated long-term benefit from using ground cover to decrease soil erosion. The need for information on the processes and consequences of competition under dryer conditions is emphasized, so that we can evaluate the broader potential for ground cover legumes in the subhumid tropics.

93

Costin, A.B. (1980): Runoff and soil and nutrient losses from an improved pasture at Ginninderra, Southern Tablelands, New South Wales. *Australian Journal of Agricultural Research* 31:533-546.

Keywords: pastures; infiltration; sheep; nitrogen; phosphorus; fertilizers; legumes; ground cover; livestock; improved pastures; soil erosion; Australia.

Abstract. Plot and catchment measurements of runoff and of soil and nutrient losses were carried out on a moderately to heavily grazed (12-30 sheep/ha) phalaris-subterranean clover pasture at Ginninderra. The effects of an intense summer storm were examined by applying artificial rains of 20 mm/15 min on 5.6 m^2 runoff plots in 1964. The pasture topsoils had high infiltration capacities (50-75 mm/h), and when dry could absorb more than 40 mm of water. Surface runoff and soil loss were inversely related to cover (as pasture, detached litter, and sheep dung). Cover values less than about 70% were associated with some large increases in runoff and soil loss, whereas at higher cover values there was relatively little reduction in runoff and soil loss. Most soil losses were small (<5 g/ m^2) when runoffs were less than about 15%, but increased rapidly with increasing runoff. Acceptable conditions of ground cover

were mostly maintained on the improved pasture but their potential for soil and nutrient losses was greater than on native pasture. Pasture renovation substantially reduced surface runoff. The effects of natural rains on runoff and soil and nutrient losses were measured from 1966 to 1971 on a 88 ha experimental catchment. The amount of runoff varied with the amount and season of rainfall, from less than 1 mm (0.2% of rainfall) in a dry year to 51 mm (7%) in a wet year, with an average of 29 mm (4%) per year. Most runoffs in autumn ad summer were relatively small, reflecting the high infiltration capacity of the surface soil when topsoil moisture storage was available. In spring and winter, when the topsoil was mostly wet, runoffs were greater, reflecting the much lower infiltration capacities (*c*. 5 mm/h) of the subsoil. Soil losses were related to the runoffs. They ranged from 4 kg to 376 kg/ha/year, with an average of 179 kg. Most of the soil was in fine suspension, little as bed load or coarse floating debris. Losses of nitrogen, phosphorus, potassium and sulfur were at average rates of 0.62, 0.12, 1.93 and 0.06 kg/ha/year. The present rate of soil loss is less than the estimated past rate of topsoil development, and the rates of loss of nitrogen, phosphorus and sulfur are less than the inputs from fertilizers and legumes. With management to retain adequate ground cover, the Ginninderra pasture effectively controls runoff and soil and nutrient losses, and could be used in similar environments as a standard for soil and water conservation, as well as livestock production.

94

Nitis, I.M., Lana, K., Suarna, M., Sukanten, W. and Putra, S. (1990): Three strata forage system for smallholder in dryland farming area. *Indonesian Agricultural Research and Development Journal* 12:23-28.

Keywords: grasses; legumes; *Leucaena leucocephala*; trees; annual field crops; cattle; fuelwood; soil erosion; agroforestry; *Gliricidia sepium*; *Ficus poacellii*; *Lannea coromandelica*; *Hibiscus tiliaceus*; Indonesia; economics; silvopastoral systems; erosion control; legume trees; shrubs; yields; natural pastures; pastures.

Abstract. The concept and development of a 3-strata forage system (grasses and ground legumes), shrubs (*Gliricidia sepium, Leucaena leucocephala*) and fodder trees (*Ficus poacellii, Lannea coromandelica, Hibiscus tiliaceus*) designed to provide year-round animal feed is described. Food, forage and fodder crop yields, liveweight gains of cattle, fuelwood production, changes in soil fertility, and farm labour and income, are summarized from 5.5 years (1984-89) of observations. Cattle production was higher, and soil erosion less, with the 3-strata system than with the traditional system of using natural pastures for tethered grazing. Constraints and possible improvements in the 3-strata system are outlined. (Abstract by bibliography authors)

95

Prinz, D. and Rauch, F. (1987): The Bamenda model. Development of a sustainable land-use system in the highlands of West Cameroon. *Agroforestry Systems* 5:463-474.

Keywords: sustainability; farming systems; erosion control; trees; agroforestry; *Eucalyptus*; manure; shrubs; fallow; legumes; grasses; Cameroon; mixed farming; energy balance; cassava; beans; pastures; fruit trees; oil palms; annual field crops.

Abstract. Since 1980 in the western highlands of Cameroon, on the Bamenda plateau, the so-called Bamenda model has been developed. This model is an attempt to build up, essentially

with local resources, an ecologically stable and economically attractive land use system. Key elements are the introduction of draught oxen, the implementation of integrated plant nutrition systems, erosion control with contour bunds, the avoidance of soil-turning ploughing, and the integration of trees and shrubs into the system. The model uses the autochthonous experiences of the population, leads to the integration of the male population into food production, and alleviates the work load through emphasis on animal traction. A typical model farm comprises: (1) an agroforestry sector (planted with: oil palms, *Elaeis guineensis*; raffia palms, *Raphia hookeri*; *Albizia* and *Eucalyptus* species; various fruit trees; coffee; and other crops such as plantain, papaya, pineapple, bitterleaf and taro); (2) homestead and cattleshed with roofed-over manure deposit; (3) house garden or women's plot; (4) leguminous hedges; (5) planted fallow plot; (6) contour bunds (sometimes planted with plantain, coffee, cassava or perennial legumes); (7) field strips between the bunds under mixed cropping (e.g. beans, taro); (8) improved pasture (planted with high-yielding grasses and grazing legumes). Other elements include animal husbandry (pigs, goats, poultry, rabbits), the use of traditional crops, and the supply of fuelwood and construction timber. Energy balance and labour aspects of the system are analysed.

96

Benge, M.D. (1987): Multipurpose uses of contour hedgerows in highland regions. *World Animal Review* 64:31-39.

Keywords: reforestation; agroforestry; dry-season feed; erosion control; forage trees; legume trees; legumes; sustainability; tropical highlands.

Abstract. The important element of contour hedgerow systems, presented in this article, is the use of multipurpose woody perennials on steep areas for the production of forage for livestock, and of large amounts of vegetatively propagated planting stock for large-scale reforestation as well as increased crop yields, added soil organic matter, reduced erosion and water runoff, increased ground-water infiltration, and fuelwood.

97

Gardener, C.J., McIvor, J.G. and Williams, J. (1990): Dry tropical rangelands: solving one problem and creating another. *Proceedings of the Ecological Society of Australia* 16:279-286.

Keywords: rangeland; livestock; degradation; stocking rate; improved pastures; feed supplements; overgrazing; shrubs; soil erosion.

Abstract. The open woodlands of northern Queensland have been grazed by domesticated livestock for approximately 120 years. Botanic shifts occurred, but there was relatively little degradation during the first 100 years. The main limitation to cattle production was poor quality herbage. Stocking rates were low to enable maximum selection of the most nutritious plants. Mortalities in the British breeds were high during droughts and subsequent herd build up was limited by poor breeding performance. To improve cattle nutrition, graziers adopted feed supplements and better-adapted zebu cattle. This resulted in greatly improved survival and growth rates, with an accompanying increase in herbage consumption and grazing pressure. Some pastures, particularly in the "better" areas (e.g., Burdekin catchment) are now suffering from severe overgrazing with loss of herbaceous cover, shrub invasion and soil erosion. Only a reduction in grazing pressure can prevent rapid expansion of this problem. Pasture improvement can only help solve the problem if stocking rates are not again increased

to recoup the investment. In the Burdekin catchment, silt and suspended colloids in the dam, irrigation aquifers and water filtration plants will lead to pressures to moderate land use.

98

Ellison, L. (1960): Influence of grazing on plant succession of rangelands. *The Botanical Review* 26:1-78.

Keywords: animal-plant interaction; overgrazing; degradation; ecological impacts; fire ecology; soil erosion; mulch; microclimate; USA; plant succession; rangeland.

Abstract. This review is concerned with secondary succession as a result of human management of the range resource, whilst primary succession refers to natural changes of plant cover through action and interaction of organisms and the environment. Successional trends by major plant types of the United States are examined, beginning with the true prairie of the Great Plains and moving westward. Rather than dwelling on the generally known destructiveness of overgrazing, the effects of light or moderate grazing shall be evaluated, in order to build a picture of the ecological influence of grazing on plant composition. In addition, the effects of herbage removal on the individual plant and on the environment are examined, with the objective of learning to what extent grazing can be considered a constructive ecological force. (Abstract by bibliography authors)

99

Stephenson, G.R. and Veigel, A. (1987): Recovery of compacted soil on pastures used for winter cattle feeding. *Journal of Range Management* 40:46-48.

Keywords: pastures; cattle; soil compaction; soil physical properties.

Abstract. Soil bulk density measurements were taken from pastures used for winter feeding to determine the effects of different stocking rates on soil compaction and recovery. Samples were taken from paired ungrazed (control) pastures, normally grazed pastures (10 head per ha), and pastures grazed 4 times normal. Results show that significant differences occur in soil bulk density with increased stocking rates, and that 2 growing seasons with protection from grazing and trampling are insufficient time for complete recovery.

100

Pinzón, A. and Amézquita, E. (1991): Compactación de suelos por el pisoteo de animales en pastoreo en el piedemonte amazónico de Colombia. *Pasturas Tropicales* 13(2):21-26.

Keywords: Colombia; *Brachiaria decumbens*; pastures; cattle; soil physical properties; soil compaction; tropical forest; South America.

Abstract. The effect of grazing animals on some soil physical properties was measured at the Centro de Investigaciones ICA-Macagual (piedmont of Caquetá), at 1°37' N and 75°36' W, within the tropical rain forest ecosystem. Measurements were made on geomorphological positions of slightly hilly areas (clay Typic Hapludult), low terrace (clay typic Dystropept), and valley plain (clay-loam-silt Fluvaquentic Dystropept), with *Homolepis aturensis* and *Brachiaria decumbens* pastures grazed for 10 years. Measurements were also made for native forest. Animal trampling modifies soil physical characteristics. In clay soils, compaction was

greater, and in some cases soil loss occurred in the first 15 cm. The apparent density increased as soil depth increased, independently from the geomorphological position, which decreases internal movement of water in the soil. These changes were more drastic in *H. aturensis*. To the contrary, *B. decumbens* improved soil filtration because of a better structure and distribution of macroporosity. The results suggest that in the piedmont of Caquetá, Colombia, cattle raising should be done with improved species that favour the existing soil structure.

101

Alegre, J.C. and Lara, P.D. (1991): Efecto de los animales en pastoreo sobre las propiedades físicas de suelos de la región tropical húmeda de Perú. *Pasturas Tropicales* 13(1):18-23.

Keywords: tropical forest; Peru; pastures; cattle; soil physical properties; soil compaction; South America.

Abstract. On a sandy loam Ultisol, since 1980 at the San Ramón Experiment Station (humid tropical forest), Loreto, Peru, pasture productivity has been evaluated in: *Centrosema pubescens* CIAT 438, *Brachiaria humidicola-Desmodium ovalifolium, B. decumbens-D. ovalifolium, Andropogon gayanus-Stylosanthes guianensis*, and *A. gayanus-C. macrocarpum*. Some measurements of these pastures were taken after five years to determine the effect of grazing animals on the physical properties of the soil. It was found that (1) The infiltration rate was greater in the crown area of the soil under *A. gayanus* plants (> 16.5 cm/hour) than among the grass plants where animals normally walk. (2) Conical resistance of the soil under associations was greater than that of soil under forest, but less than that under overgrazed native pasture. (3) The apparent density in the first 10 cm of the soil increased 17.5%, on average, in the soil under associated pastures, and 29.1% under native pasture in relation to the secondary forest. The results show that animals grazing on humid tropical forest soils reduce the infiltration rate and increase the apparent density.

102

Wilcox, B.P. and Wood, M.K. (1988): Hydrologic impacts of sheep grazing on steep slopes in semiarid rangelands. *Journal of Range Management* 41:303-306.

Keywords: sheep; infiltration; hydrology; soil physical properties; semiarid zones.

Abstract. Infiltration, sediment concentration of runoff, and sediment production from lightly grazed and ungrazed semiarid slopes were compared using a hand-portable rainfall simulator. The study slope was located in the Guadelupe Mountains of southeastern New Mexico. Average slope steepness was 50%. The objective of this study was to determine the impacts of light grazing by sheep (10 ha/AU) on steep slope infiltrability and sediment production. Infiltrability on the grazed slopes was 12-17% lower than on ungrazed slopes. These results are comparable to what has been reported from moderate slope gradients. Sediment concentration of runoff from the lightly grazed slopes was significantly higher than from the ungrazed slopes only at the end of the dry run (45 min). Sediment production was significantly greater from the grazed slopes for the dry run, but not the wet run. Percentage difference of sediment production between the grazed and ungrazed slopes was well within the range published for moderate slope conditions. These data give no indication that steep slopes (30-70%) in semiarid regions are any more hydrologically sensitive to light grazing than are moderate slopes (<10%).

103

Warren, S.D., Blackburn, W.H. and Taylor Jr., C.A. (1986): Soil hydrologic response to number of pastures and stocking density under intensive rotation grazing. *Journal of Range Management* 39:500-504.

Keywords: pastures; rotational grazing; stocking rate; hydrology; soil physical properties; livestock; infiltration.

Abstract. Infiltration rate and sediment production were measured for 2 years on 3 pastures from an intensive rotational grazing system. The pastures were 32, 24 and 16 ha in size. Stocking rate was held constant but stocking density at any given point in time varied due to pasture size. Stocking densities were 0.68; 0.51; and 0.32 ha/AU, respectively. Within the respective treatments, midgrass interspaces exhibited significantly higher infiltration rates and lower sediment production than shortgrass interspaces. Overall, the pasture grazed at the highest stocking density produced the lowest infiltration rates and the greatest sediment loss. However there was no consistent trend in hydrologic responses over time and the differences appeared to be the result of stocking density. Regardless of whether the pasture grazed at the highest stocking density was in similar or poorer hydrologic condition in terms of treatment response, the data do not support the hypothesized beneficial hydrologic advantages of increased stocking density via manipulation of pasture size and numbers. Rest, rather than intensive livestock activity, appears to be the key to soil hydrologic stability. The potential for altering the length of the rest period is greatest where the number of pastures is small. Therefore, very little benefit in terms of soil hydrologic condition should be expected from large increases in the number of pastures within rotational grazing systems.

104

Akobundu, I.O. and Okigbo, B.N. (1984): Preliminary evaluation of ground covers for use as live mulch in maize production. *Field Crops Research* 8:177-186.

Keywords: legumes; grasses; live mulch; maize; weed control; earthworms; erosion control.

Abstract. Several ground covers were assessed over a 2-year period to determine their effects on weed competition and maize yield. Maize was planted directly into established ground covers of *Axonopus compressus* (Sw.) Beauv., *Desmodium triflorum* (L.) DC, and *Indigofera spicata* Forsk. Planting rows in *Arachis repens* Handro plots were marked by manually pulling of stem segments of the legume cover. While *Paspalum notatum* Fluegge cover was first killed with glyphosate (3.6 kg/ha) before planting maize, several legume management methods that included slashing and spraying with either paraquat or a hormone were evaluated for use in *Centrosema pubescens* Benth. and *Psophocarpus palustris* Desv. Weed infestation was heaviest in *Axonopus compressus*, *Desmodium triflorum*, *Indigofera spicata* and no-tillage; moderate in the *Arachis repens* and maize stover; and very low in *Centrosema pubescens* and *Psophocarpus palustris*. Maize yield was highest in the maize stover and poorest in the *Indigofera spicata*. Good maize yield was obtained in the live mulch in which weed competition was minimized by the legume cover. This technique promises to eliminate or significantly reduce weeding since over 40% of farmers' time in the humid tropics is devoted to weeding.

105

Kang, B.T., Reynolds, L. and Atta-Krah, A.N. (1990): Alley Farming. *Advances in Agronomy* 43:315-359.

Keywords: deforestation; degradation; tropics; Africa; trees; legumes; mulch; green manure; livestock; erosion control; Asia; alley cropping.

Abstract. Rising demand for food and feed has resulted in increased deforestation and land degradation in many parts of the tropics. In sub-Saharan Africa food production relies mainly on area expansion and the use of traditional farming methods that depend on inherent soil fertility. In the 1980s research attention has been focused on the development of low input technologies for sustainable food production for smallholder farmers. One such technology is alley farming. Alley farming involves the cultivation of food crops between hedgerows of multipurpose trees. Use of woody legumes provides N-rich mulch and green manure to maintain soil fertility and enhance crop production, and protein-rich fodder for livestock. On sloping land, hedgerows planted along the contours greatly reduce soil erosion. Within the forest zone, and particularly in the forest-savanna transition areas of Africa with nonacid soils, on-station and on-farm trials have shown that alley farming with *Leucaena* and *Gliricidia* allows a higher level of production than the traditional system. Similar results have also been obtained in comparable agro-ecological zones in Asia and the Pacific regions.

106

Vásquez, S.S. (1991): The establishment of forage legumes under field conditions in the Colombian coffee zone. *Dissertation Abstracts International* 52:2361B-2362B.

Keywords: establishment; legumes; *Centrosema macrocarpum*; *Pueraria phaseoloides*; *Desmodium ovalifolium*; *Leucaena leucocephala*; grasses; Colombia; erosion; *Centrosema pubescens*; *Arachis pintoi*; *Brachiaria decumbens*; ground cover; live mulch; soil erosion.

Abstract. In 1988, 6 legumes (*Centrosema macrocarpum* CIAT 5065, *C. pubescens* CIAT 438, *Pueraria phaseoloides* CIAT 9900, *Arachis pintoi* CIAT 17434, *Desmodium ovalifolium* CIAT 350 and *Leucaena leucocephala* CIAT 17481) were assessed for their ability to establish (cover the ground) and grow (produce DM) either alone or in combination with the grass *Brachiaria decumbens*, using minimum soil disturbance, at 2 sites in Colombia (1708 and 2500 mm precipitation). *A. pintoi* was the best legume in terms of soil cover and DM production. No inoculation response was found for most of the legumes except *C. macrocarpum* CIAT 5065 inoculated with *Rhizobium* strain CIAT 3101. The establishment time under these conditions was 3 months. Legume DM production and cover were affected by continuous cutting close to the ground. The establishment of legumes other than *A. pintoi* was slower and needed more weeding, increasing cost and the risk of soil erosion. *D. ovalifolium* and *L. leucocephala* could not be established by seed directly in the field because of their low competitive abilities against native grasses. Data from runoff plots set up in 1989 showed that it was possible to establish grass-legume mixtures among the native grass (*Paspalum* spp.) without causing soil disturbance and increasing erosion. No variation in N content of grass and legumes was found between blocks, but soil cover and DM production differed between blocks located along and across the slope.

107

Leihner, D.E., Buerkert, A., Banzhaf, J. and Serafini, P.G. (1993): Soil tillage and windbreak effects on millet and cowpea: II. Dry matter and grain yield. *Agronomy Journal* 85:400-405.

Keywords: windbreaks; millet; cowpea; yields; West Africa; Africa; ground cover.

Abstract. In the West Africa Sahel, sand storms occurring early in the growing season may severely damage emerging crops. This study was conducted to determine the influence of ridges and windbreaks on growth, water use and grain yield of millet, *Pennisetum glaucum* (L.), and cowpea, *Vigna unguiculata* (L.) Walp. A field trial was carried out from 1985 to 1987 on a Psammentic Paleustalf in southern Niger using 12 ha of land fallowed over the previous 5 yr. Treatments for millet and cowpea were flat and ridged soil preparation and windbreaks spaced at 6, 20, 40, and 90 m. Total annual rainfall was 558, 641, and 363 mm in the 3 yr of the experiment; onset and distribution of the rains varied. Millet total dry matter (TDM) increased as total water use increased from 250 to 400 mm. Ridging did not change total dry matter or grain yield in millet but increased cowpea grain yield by 90 and 300 kg/ha in 2 of the 3 yr. Protection by windbreaks spaced 6 and 20 m apart resulted in a 48 to 90% increase in early millet TDM and a 74 to 89% improvement of cowpea ground cover. However, these early effects were not sustained throughout the growing perod. Average TDM at maturity and grain yields were similar in all windbreak spacings for millet and cowpea. Although windbreaks may not increase yields of two important Sahelian crops, they may help to stabilize longterm crop production by conserving the soil and providing additional marketable commodities if an appropriate selection is made of type of windbreak and species planted.

108

Renard, C. and Vandenbeldt, R.J. (1990): Bordures d'*Andropogon gayanus* Kunth comme moyen de lutte contre l'érosion éolienne au Sahel. *Agronomie tropicale* (Paris) 45:227-231.

Keywords: erosion control; annual field crops; millet; *Andropogon gayanus*.

Abstract. In the Sahel zone, wind erosion is one of the major problems due to the sandy soil texture and the incomplete vegetation cover. The problem is further aggravated by strong winds occurring at the beginning of the rainy season. The sands transported during these events destroy or cover crop seedlings. In 1986, an investigation was started about the potential of a perennial grass, *Andropogon gayanus* Kunth, to reduce wind erosion and protect millet crops. 10 m large *Andropogon*-strips had no positive effect on grain yields of millet, but protected well against the violent winds at the beginning of the growing season. These strips captured more than 2000 t/ha of sand within three years. The use of this pasture species for demarcation of field boundaries is proposed.

109

Fedoseev, A.P., Gringof, I.G., Nurberdyev, M. and Reizvikh, O.N. (1982): Environmental effect of phytomeliorative plantings on pastures. (In Russian). *Problemy Osvoeniya Pustyn 6:27-33.*

Keywords: pastures; deserts; Turkmenistan; trees; shrubs; microclimate; erosion control; moisture collection; marginal lands.

Abstract. Differences between the meteorological parameters of natural and artificial desert vegetation and landscapes were examined on the basis of field investigations in the desert zone of Turkmenistan. Artificial tree and shrub plantings reduce wind speed and daily ranges of soil and air temperature changes. They have a noticeable effect on the redistribution of rainfall, particularly by interception and trunk runoff which can be 1-25% of total precipitation. The depth of wetting the soil under tree crowns increased on the windward side and decreased on the leeward. These characteristics of the hydrometeorological regime under the crowns of plantings have an effect on the formation of unique plant associations and forage productivity of pastures increases. (Abstract by bibliography authors)

110

Atta-Krah, A.N., Sumberg, J.E. and Reynolds, L. (1986): Leguminous fodder trees in the farming system - an overview of research at the humid zone programme of ILCA in southwestern Nigeria. In: Haque, I., Jutzi, S. and Neate, P.J.H. (eds.), *Potentials of forage legumes in farming systems of sub-Saharan Africa. Proceedings of a workshop held at ILCA, Addis Ababa, Ethiopia, 16-19 September 1985.* Addis Ababa, Ethiopia: ILCA (International Livestock Centre for Africa), p. 307-329.

Keywords: trees; Nigeria; forage trees; West Africa; legumes; *Gliricidia sepium*; adapted germplasm; *Leucaena leucocephala*; intercropping; legume trees; alley cropping; mulch; annual field crops; yields; animal production; sheep; farming systems.

Abstract. The potential of leguminous fodder trees in farming systems of humid West Africa is considered in the light of research work carried out by the Humid Zone Programme of the International Livestock Centre for Africa (ILCA) at Ibadan, Nigeria. ILCA's agronomy research effort focuses on the leguminous species, *Leucaena leucocephala* and *Gliricidia sepium*. The paper reviews a variety of research trials ranging from the improvement of germplasm materials to the development of fodder production systems, and concludes with a recommendation for more research and development attention on the integration of fodder trees within existing farming systems.

111

Cameron, D.M., Gutteridge, R.C. and Rance, S.J. (1991): Sustaining multiple production systems. 1. Forest and fodder trees in multiple use systems in the tropics. *Tropical Grasslands* 25:165-172.

Keywords: Australia; sustainability; silvopastoral systems; alley cropping; agroforestry; degradation.

Abstract. The benefits of introducing or maintaining a tree component in land use systems are becoming attractive for land rehabilitation and sustainable production purposes. Increasing evidence supports the view that multiple production systems involving trees have some beneficial economic and environmental consequences in many land use programs throughout Australia. Coordinated research to support these approaches and to demonstrate their implementation and potential is now needed to complement fragmentary research throughout the country. Government policy towards forestry and agroforestry requires redefinition to

provide production incentives to increase the impact of the environmental thrust. Trees have often been included in farm planning for amenity purposes, particularly around farm houses and buildings but less frequently to provide shade and shelter for animals, crops and pastures or to reduce the harmful effects of rising watertables, especially those containing salt. Advantages and disadvantages of including trees in multiple land use systems are listed and their role and potential discussed. There is considerable potential to expand private timber production in agroforestry systems to offset the very large import bill for timber and forest products.

112

Walker, B.H. (1974): Ecological considerations in the management of semi-arid ecosystems in south-central Africa. *Proceedings, 1st International Congress of Ecology.* Wageningen: Centre for Agricultural Publishing and Documentation, p. 124-129.

Keywords: ecosystems; Africa; infiltration; grasses; species diversity; trees; grazing; cattle.

Abstract. There are four significant ecological characteristics of semi-arid ecosystems in south-central Africa which have an important bearing on their management. i) They have a low erratic rainfall which is closely correlated with primary production. ii) The rate of water infiltration is critical and is determined by the percentage litter cover and herbaceous basal cover. On sandy loam soils it is nine times faster through soil under litter than through a bare soil surface. iii) Species composition varies markedly according to the proportions of perennial and annual grasses, the palatability of the perennials, and species diversity. Annual grasses increase interseasonal variation in production. Seasonal production is positively correlated with an increase in species diversity. iv) There is evidence that clearing woody vegetation can lead to increases of up to 400% in grass growth, but this must be balanced against a number of benefits derived from the presence of trees. Five management principles are discussed. i) The ration of grazing to browsing should approximate the ratio of grass to available browse. ii) Area selective grazing should be overcome by five suggested means. iii) Cattle should be managed using multi-paddock, short duration grazing systems. iv) The use of fire, especially on lithosols, should be avoided. v) In National Parks and game reserves, animal numbers and fires should be controlled, but the introduction of artificial water supplies into characteristically dry areas should be avoided.

113

Lenné, J.M., Turner, J.W. and Cameron, D.F. (1980): Resistance to diseases and pests of tropical pasture plants. *Tropical Grasslands* 14:146-152.

Keywords: diseases; pests; pest resistance; pastures; pest control; genetics; breeding; adapted germplasm.

Abstract. In recent years, increasing numbers of pathogens and pests have been reported from major centres of tropical pasture research. Damage is often severe and controls are needed. Diseases and pests may be controlled chemically, biologically, culturally and genetically. In pasture plants, genetical resistance is the most practical and economical control method and, as a component of integrated pest management, has considerable potential in controlling pests. Tropical pasture plants have been artifically selected for only a short time. Vast sources of genetic variation exist in their centres of diversity. This natural variation should be utilized in selecting for resistance before initiating long term breeding programmes. Evaluation of

resistance to diseases and pests of tropical pasture plants requires understanding of the plant, the pathogen or pest, the environment and their interactions. Primary germplasm evaluation for resistance in plant centres of diversity is strongly recommended and high priority should be given to understanding resistance mechanisms. The importance of multidiscipline collaborative research on resistance to diseases and pests of tropical pasture plants is stressed.

114

Ceccarelli, S., Valkoun, J., Erskine, W., Weigand, S., Miller, R. and van Leur, J.A.G. (1992): Plant genetic resources and plant improvement as tools to develop sustainable agriculture. *Experimental Agriculture* 28:89-98.

Keywords: genetics; Asia; Africa; wheat; pastures; genetic erosion; livestock; insects; insect pests; pests; diseases; yields; ecosystems; biological control; germplasm; sustainability.

Abstract. This paper addresses the current and future contributions of plant genetic resources and plant improvement to sustainable agriculture with reference to the activities of the International Center for Agricultural Research in the Dry Areas (ICARDA) in association with national programmes in West Asia and North Africa. These regions constitute the primary centres of diversity of crops (wheat, barley, chickpea, lentil) and a number of pasture and forage species. Genetic erosion is being curtailed by germplasm collection and preservation. Selection for low-input cultivars of barley is conducted under low input conditions, and new cultivars of lentil and barley are often intentionally heterogeneous to stabilize their performance in dry rainfed areas. The importance of genetic differences in the cultivars on subsequent crops in the rotation and on straw quality for livestock is under study. Insect pests and diseases contribute to yield instability. Because of the potential adverse impact of pesticides on the fragile ecosystems of the region, integrated control strategies based on agronomic management, host plant resistance, biological control agents and strategic use of selective insecticides are being developed.

115

Atu, U.G. and Ogbuji, R.O. (1984): Effect of cover plants in fallow lands on root-knot nematode population. *Beiträge zur Tropischen Landwirtschaft und Veterinärmedizin* 22:275-280.

Keywords: Nigeria; improved fallow; cover crops; pest control; pest resistance; nematodes; *Meloidogyne incognita*; legumes.

Abstract. In southern Nigeria, cover plants were evaluated for their resistance to root-knot nematode, *Meloidogyne incognita* race 2. In glasshouse and field experiments, *Crotalaria retusa, Arachis hypogaea, Stylosanthes gracilis, Tagetes patula,* and *T. erecta* were found to be highly resistant; *Centrosema* sp., *Panicum maximum, Eupatorium odoratum* and *Aspilia latifolia* exhibited a medium degree of resistance, and *Calopogonium* sp., *Cajanus cajan, Vigna unguiculata,* and *Cynodon dactylon* were susceptible. Planting cover crops that suppress root-knot nematodes in fallow lands could become a way of field pest management practice.

116

Rodriguez-Kabana, R., King, P.S., Robertson, D.G., Weaver, C.F. and Carden, E.L. (1988): New crops with potential for management of soybean nematodes. *Nematropica* 18:45-52.

Keywords: soybeans; nematodes; *Aeschynomene americana*; *Meloidogyne arenaria*; *Heterodera glycines*; *Alysicarpus vaginalis*; legumes; sorghum; green manure; pest control; crop rotation.

Abstract: American jointvetch (*Aeschynomene americana*), 'Florida 101' hairy indigo (*Indigifera hirsuta*), and 'Iron' cowpeas (*Vigna unguiculata*) were more effective in reducing root-knot nematodes (*Meloidogyne arenaria* and *M. incognita*) and soybean cyst nematode (*Heterodera glycines*) race 4 in a greenhouse experiment than were alyceclover (*Alysicarpus vaginalis*), Kobe lespedeza (*Lespedeza striata*), Korean lespedeza (*Lespedeza stipulacea*) and Davis' soybean (*Glycine max*). The effects of American jointvetch and hairy indigo on soil populations of the three nematode species were also studied in a field in Baldwyn County, Alabama. Soils from plots with the two legumes was essentially free of juveniles of root-knot and cyst nematodes throughout the growing season. Juvenile populations in these plots were as low as those in plots planted to 'Pioneer 8222' sorghum (*Sorghum bicolor*). Plots with 'Kirby' soybean had large juvenile populations (150 juveniles/100 cm^3 of soil) of root-knot nematodes 1 month before harvest; numbers of *H. glycines* juveniles averaged 85/100 cm^3 of soil. Results suggest that American jointvetch and hairy indigo may be forage or green manure crops with potential for the management of soybean nematodes in Alabama.

117

Domínguez-Valenzuela, J.A., Marban-Mendoza, N. and de la Cruz, R. (1990): Leguminous crops associated with tomato var. "Dina guayabo" and their effect on *Meloidogyne arabicida* Lopez and Salazar. *Turrialba* 40:217-221.

Keywords: *Pueraria phaseoloides*; *Arachis pintoi*; *Centrosema pubescens*; *Desmodium ovalifolium*; *Centrosema acutifolium*; legumes; nematodes; *Meloidogyne arabicida*; tomatoes; intercropping; *Centrosema macrocarpum*; pest control.

Abstract. When *Pueraria phaseoloides*, *Arachis pintoi* and *Centrosema pubescens* were co-cultivated with tomato var. Dina guayabo in greenhouse pot tests, a significant reduction in galling caused by *M. arabicida* was observed on tomato. The leguminous plants *Desmodium ovalifolium*, *Centrosema acutifolium*, *C. pubescens* and *C. macrocarpum* generally gave a lesser degree of root galling under the same conditions. All legumes tested caused a slight reduction in the vegetative growth of tomato plants. However, growth was significantly reduced when compared to plants infested only with *M. arabicida* (control treatment). Consequently, it is thought that reduced plant size was primarily due to competition between legumes and tomato plants. The plants associated with *A. pintoi*, which reduced root galling by almost 50%, did not gain in vegetative growth. Only *C. pubescens* and *C. acutifolium* developed a few small-sized (1.2 mm) galls (1%) and did not support *M. arabicida* females.

118

Rodriguez-Kabana, R., Weaver, D.B., Robertson, D.G., Young, R.W. and Carden, E.L. (1990): Rotations of soybean with two tropical legumes for the management of nematode problems. *Nematropica* 20:101-110.

Keywords: legumes; nematodes; yields; *Meloidogyne arenaria*; soybeans; *Heterodera glycines*; *Aeschynomene americana*; *Indigofera hirsuta*; annual field crops; pest control.

Abstract. The effects of two tropical legumes, American jointvetch (*Aeschynomene americana*) and hairy indigo (*Indigofera hirsuta*), in rotations with soybean on populations of root-knot (*Meloidogyne arenaria*) and cyst (*Heterodera glycines*) nematodes and on soyabean yields were studied in 2-year field experiment. End-of-season juvenile soil populations of *M. arenaria* and *H. glycines* were reduced by 95-100% where either of the tropical legumes was grown. Yields of 7 soybean cultivars (Braxton, Centennial, Gordon, Kirby, LeFlore, Ransom, Stonewall) increased significantly in plots planted with jointvetch or indigo the previous year. The magnitude of the yield increment depended on the soybean cultivar; the average increases in yields for all cultivars were 46% and 55% following jointvetch and indigo, respectively. At-plant application of aldicarb (17 g a.i./100 m of row in a 20-cm-wide band) was most effective in increasing yields of soybean grown in monoculture but was generally ineffective in soybean grown in rotation. The suppressive effect of the tropical legumes on end-of-season juvenile soil populations of *M. arenaria* and of *H. glycines* was short-lived; end-of-season juvenile populations in plots with soybean planted with either jointvetch or hairy indigo the previous year were equal or greater than the populations found in plots with continuous soybean.

119

Reddy, K.C., Soffes, A.R., Prine, G.M. and Dunn, R.A. (1986): Tropical legumes for green manure. II. Nematode populations and their effects on succeeding crop yields. *Agronomy Journal* 78:5-10.

Keywords: legumes; green manure; nematodes; pest control.

Abstract. The effects of tropical legumes, grown as summer green manure crops, on populations of 4 plant-parasitic nematodes were compared with fallow and 'Cracker Jack' marigold (*Tagetes erecta*) in fumigated (with 1,2-dibromethane) and nonfumigated plots in 1979, 1980 and 1981 on an Arrendono fine sand (loamy, siliceous, hyperthermic, Grossarenic Paleudult). Long-term effects of summer legume green-manuring on nematode populations and yield of succeeding crops was determined using several cereals and legumes grown in the succeeding autumn, winter and spring seasons. One cultivar, 'Norman', and one line, 'F181d', of pigeonpea (*Cajanus cajan*), showy crotalaria (*Crotalaria spectabilis*), hairy indigo (*Indigofera hirsuta*), jointvetch (*Aeschynomene americana*), velvet bean (*Mucuna deeringiana*) and marigold reduced soil populations of *Meloidogyne incognita* in each year planted; 'PI 305070' mungbean (*Vigna radiata*) did not. Fumigation, fallowing and rotation with jointvetch, hairy indigo and crotalaria reduced *Belonolaimus longicaudatus* populations. Rotation with hairy indigo or marigold consistently reduced *Pratylenchus brachyurus* in all the succeeding crops. Fumigation generally reduced *Criconemoides* spp. populations. *M. incognita* and the incorporated green manure had the greatest influence on snap bean (*Phaseolus vulgaris*) cv. 'Blue Lake Bunch' dry matter yield.

120

Wildermuth, G.B. and McNamara, R.B. (1991): Effect of cropping history on soil populations of *Bipolaris sorokiniana* and common root rot of wheat. *Australian Journal of Agricultural Research* 42:779-790.

Keywords: legumes; grasses; crop rotation; wheat; *Cochliobolus sativus*; fungal diseases; Australia; annual field crops; fallow; disease control.

Abstract. Six winter and 4 summer crops, 2 pasture legumes and 2 pasture grasses, were grown in rotation with wheat in soil naturally colonized with *B. sorokiniana* (*Cochliobolus sativus*). Soil populations of *C. sativus* under the different rotations were measured at the beginning of winter and of summer between 1982 and 1986. Populations increased under wheat, barley and triticale, remained static under oats, safflower and chickpea, and declined under buffel grass, cocksfoot, lucerne, mung bean, snail medic, sorghum, sunflower and White French millet. Populations also declined under a fallow, and propagules of the fungus were still present after 4 years. Where populations had declined owing to cropping history, they were effectively restored to their previous levels after one wheat crop. Severity of common rot in wheat caused by *C. sativus* was reduced from that occurring with continuous wheat when wheat was planted after safflower, sorghum, mung bean, snail medic, lucerne and buffel grass. Disease levels in wheat following barley, triticale, oats, chickpea, millet, sunflower, cocksfoot or a fallow were not significantly different from that of continuous wheat. When a second wheat crop was planted, severity of common root rot was high in all treatments, irrespective of the previous cropping history. The implications of these findings in developing control strategies for common root rot by crop rotation are discussed.

121

Mullenax, C.H. (1979): The use of jackbean (*Canavalia ensiformis*) as a biological control for leaf-cutting ants (*Atta* spp.). *Biotropica* 11:313-314.

Keywords: leaf-cutting ants; *Canavalia ensiformis*; insect-plant interaction; biological control; insect pests; South America; Colombia.

Abstract. Savanna-dwelling leaf-cutting ant colonies (*Atta* spp.) in the Department of Meta, Colombia, were offered freshly cut leaves of jackbean (*Canavalia ensiformis*) during the rainy season. Five to 15 kg of leaves were placed nightly on top of and around mounds covering an area of 25 to 100 m^2 for three consecutive nights. A single three-night "treatment" usually resulted in complete cessation of ant activity for periods ranging from four months to five years. It is presumed that the effect of jackbean on leaf cutting ant colonies is due to the action of fungicides contained in jackbean leaves on the ants' fungus gardens.

122

Panizzi, A.R. (1992): Performance of *Piezodorus guildinii* on four species of *Indigofera* legumes. *Entomologia Experimentalis et Applicata* 63:221-228.

Keywords: legumes; insect pests; soybeans; South America; *Indigofera hirsuta*; *Piezodorus guildinii*; *Indigofera endecaphylla*; *Indigofera suffruticosa*; *Indigofera truxillensis*; Brazil; biological control; pest control.

Abstract. The performance of the pentatomid *Piezodorus guildinii*, a major pest of soybean in South America, on 4 species of *Indigofera* was tested in the laboratory at 25°C, 65% RH and

LD 14:10. Nymphal survival was 88, 15, 70 and 40% on *I. endecaphylla, I. suffruticosa, I. hirsuta* and *I. truxillensis*, resp. The fastest development (22 days) from the 2nd to the 5th instar occurred on *I. endecaphylla* and *I. truxillensis*, and the slowest (29 days) on *I. suffruticosa*. Fresh body weight at emergence was highest for nymphs fed on *I. endecaphylla* and *I. truxillensis*. Adult survival of *P. guildinii* after 40 days was >70% on *I. truxillensis* and *I. endecaphylla*, and <20% on *I. suffruticosa*. Females oviposited on all *Indigofera* species, but <30% were observed to lay eggs on *I. suffruticosa*. Body weight gain during the 1st week was greater for adults feeding on *I. endecaphylla* and *I. hirsuta*. Insects lost weight on *I. suffruticosa*; at the end of day 15 no differences in percentage change in body weight among the food plants tested were observed. Field surveys conducted on *I. truxillensis* and *I. suffruticosa*, the 2 most abundant species in northern Paraná, indicated a greater number of nymphs, adults and egg masses on the former host. On both hosts, *P. guildinii* was more abundant during April-May, after soybean harvest, suggesting movement of the populations from soybean to *Indigofera*.

123

Sutherst, R.W., Wilson, L.J., Reid, R. and Kerr, J.D. (1988): A survey of the ability of tropical legumes in the genus *Stylosanthes* to trap larvae of the cattle tick, *Boophilus microplus* (Ixodidae). *Australian Journal of Experimental Agriculture* 28:473-479.

Keywords: cattle; *Stylosanthes viscosa*; *Stylosanthes scabra*; *Stylosanthes guianensis*; *Boophilus microplus*; insect-plant interaction; animal-plant interaction; pastures.

Abstract. *Stylosanthes viscosa* and *S. scabra* cvv. Fitzroy and Seca have previously been shown to trap host-seeking larvae of the cattle tick *Boophilus microplus* and could provide a means of controlling cattle ticks in improved pastures. We assessed the ability of 229 accessions from 22 species of the genus *Stylosanthes* to trap larvae of *B. microplus* or to prevent them from ascending plant stems. The 3 species that were most effective were *S.viscosa*, *S. scabra* and *S. guianensis*. Only accessions which produced sticky secretions were able to trap tick larvae, but the extend of this ability was related primarily to the density and length of bristles on the stems rather than to the degree of stickiness. The highest percentage of larvae were trapped when stylo stems had short, dense bristles of average stickiness or long sticky bristles of average density. These features were also most effective at preventing larvae from ascending stems. A high density of fine, non-glandular hairs, in conjunction with average stickiness, also prevented larvae from ascending stems.

124

Staver, C. (1989): Shortened bush fallow rotations with relay-cropped *Inga edulis* and *Desmodium ovalifolium* in wet central Amazonian Peru. *Agroforestry Systems* 8:173-196.

Keywords: fallow; *Inga edulis*; *Desmodium ovalifolium*; Peru; trees; rice; weeds; natural fallow; cassava; yields; establishment; regeneration; shrubs.

Abstract. In the Palcazu Valley alluvial Inceptisols are relay-cropped with maize-cassava-plantain in rotation with 2-5 years of tree fallow. These lands, of limited extent, yet important for Yanesha Indian subsistence production, are being cropped even more intensively as population increases and land is converted to other uses. The relay-planting of the tree-thicket combination *Inga edulis* with *Desmodium ovalifolium* into the on-farm crop sequence was evaluated as a means to accelerate fallow recovery and thereby shorten fallow rotations. Three

experiments with *Inga/Desmodium* planted with cassava-plantain and one with rice under different weeding regimes after a *Desmodium* fallow were conducted. *Inga* and *Desmodium* were not chopped back or pruned during these experiments. *Desmodium/Inga* suppressed herbaceous weeds from one year after planting. *Desmodium/Inga* accumulated more woody biomass than natural fallows. Cassava yields were unaffected by the presence of *Desmodium/Inga*, while plantain yields were greater under *Desmodium/Inga* compared to natural weeds. *Desmodium/Inga*, while promising for shortening fallow rotations, demonstrated potential difficulties; increased labor for establishment, tendency of *Desmodium* to weediness in later crop cycles, and suppression of the natural regeneration of trees and shrubs.

125

Budelman, A. (1988): The performance of the leaf mulches of *Leucaena leucocephala, Flemingia macrophylla* and *Gliricidia sepium* in weed control. *Agroforestry Systems* 6:137-145.

Keywords: mulch; *Leucaena leucocephala*; weed control; *Gliricidia sepium*; *Flemingia macrophylla*.

Abstract. The performance of leaf mulches of *Leucaena leucocephala, Gliricidia sepium* and *Flemingia macrophylla* in weed control has been tested in two trials. The length of the period during which a mulch layer yields significantly less weed biomass compared to the control plots is called the 'effective life-span' of the mulch. Of the three mulch materials only that of *F. macrophylla* shows promise in retarding weed development. In the second trial *F. macrophylla* leaf mulch was applied at rates of 3, 6 and 9 tons dry matter per ha. The effective life-span of a mulch layer of 3 tons is between 12 and 13 weeks. The treatments 6 and 9 tons have effective life-spans of over 14 weeks. For moderate quantities (up to 5 tons of dry leaf mulch per ha) the effective life-span is estimated at about 100 days. The value of mulching in weed control is limited to the control of weed species that multiply by seed. Regrowth originating from roots or stumps from former vegetation is unlikely to be checked by a mulch layer.

126

Chou, C.H. (1988): Effects of pasture-forest interaction in Taiwan. In: Allen, P. and van Dusen, D. (eds.), *Global perspectives on agroecology and sustainable agricultural systems: Proceedings of the sixth international scientific conference of IFOAM*. Santa Cruz: Agroecology Program, University of California, p. 327-340.

Keywords: deforestation; grasses; weeds; allelopathy; *Pennisetum clandestinum*; agroforestry; tropical highlands.

Abstract. A possible allelopathic interaction of a pasture-forest intercropping system was evaluated by experiments conducted in field and laboratory assays. After deforestation of *Cunninghamia lanceolata* (Chinese fir), a split plot design of four treatments (litter removed, litter retained, litter removed and kikuyu grass planted, and litter retained and kikuyu grass planted) was imposed. Field experiments showed that fir litter left on the ground only slightly inhibited the growth of weeds in the first four months after deforestation, while kikuyu grass significantly suppressed the growth of weeds longer than four months. Both fir litter and kikuyu grass did not reduce growth of fir seedlings. Aqueous extracts of fresh fir leaves, fir

litter, and kikuyu leaves were bioassayed by lettuce and rice seeds and stolon cuttings of *Brachiaria mutica*. Bioassays showed that fresh fir leaves produced significant phytotoxicity while fir litter and kikuyu grass revealed limited toxicity. Nine phytotoxic phenolics and many unidentified flavonoids were found in the plant materials. A good correlation between the degree of phytotoxicity and phytotoxins was established, indicating that allelopathic mechanisms may contribute to the interaction of forest-pasture intercropping systems, thus potentially reducing the need for herbicides and lessening the labour cost of weed control. Experiments were also conducted to evaluate the competitive and allelopathic nature of cover grasses. Results showed that among nine leachates of grass soils, only four of the leachates (*Dactylis glomerata*, *Bromus catharticus*, *Lolium multiflorum* and *Eragrostis curvula*) stimulated growth of pear. The growth performance of cover grasses, namely rescue grass, kikuyu grass, Italian rye grass, orchard grass and white clover was compared. Kikuyu grass and white clover grew more agressively than the others; however, when the two grasses grew together, white clover invaded the kikuyu grass plot faster than the kikuyu grass invaded the white clover plot. This finding suggests that biochemical interactions such as allelopathy may be involved.

127

Lenné J.M. (1989): Evaluation of biotic factors affecting grassland production - history and prospects. *Proceedings of the XVI International Grassland Congress, Nice (France),* p. 1811-1815.

Keywords: grassland; pastures; diseases; grasses; legumes; grazing; pests; weeds.

Abstract. This paper summarizes trends in research on biotic factors affecting grassland production with respect to papers presented at International Grassland Congresses during the past twenty years and discusses problems associated with evaluation of biotic factors in diverse perennial pastures. The number of papers on biotic factors has grown impressively since 1970 reflecting increasing awareness among pasture scientists of the importance of biotic factors to grassland production. Of particular note is the increased emphasis on diseases of tropical pasture plants and the new and rapidly developing studies of endophytes in temperate grasslands. Biotic factors affecting mixed grassland communities are difficult to evaluate. Much existing methodology has been only slightly modified from that used for grass and legume monocultures. Limited appropriate evaluation methodology has been developed for dynamic heterogenous perennial pastures. Initial evaluation in small monoculture plots is usually done in the absence of grazing animals. Use of associated species and simulated swards which may be grazed, however, is more relevant to the pasture environment. Surveys provide valuable information on disease, pest and weed incidence and distribution under grazing. Transects, strategically rather than randomly placed quadrats and marked plants are useful techniques for measuring biotic factors severity and sampled plants facilitate evaluation of reaction to individual factors. The importance of long-term periodic evaluations of biotic factors affecting the seedling component of perennial pastures to the understanding of changes in productivity and persistence is emphasized. Determination of economic loss by measuring decreases in pasture yield and quality and changes in botanical composition provides an assessment of potential animal losses only. Knowledge of the direct effect of pasture diseases on animal production is necessary for deciding whether control strategies are needed. The complexity of the diverse perennial pasture environment with its potential for multiple interactions between biotic and environmental factors necessitates a multidisciplinary approach to evaluation. Development of general evaluation methodology which can be readily

modified and applied to specific problems will foster imaginative and efficient approaches to evaluation. Plant population biology techniques, already greatly utilized in weed evaluation, have considerable application to studies of grassland pathogens and pest. More on-farm evaluation of the importance of diseases, pests and weeds to perennial pasture production and persistence is needed.

128

Chaluat, M.M. de and Perris, S. (1994): Hongos patógenos en semillas de especies forrajeras tropicales. *Pasturas Tropicales* 16(1):41-43.

Keywords: seeds; grasses; *Chloris gayana*; legumes; *Leucaena leucocephala*; *Glycine wightii*; diseases; *Panicum*; *Paspalum*; introduced species.

Abstract. The most common seed-borne fungi of several introduced forage species in Argentina were identified and their level of incidence established by the Phytopathology Laboratory, Faculty of Agronomy, University of Buenos Aires. To identify these fungi, 400 seeds of each species were placed on filter paper and incubated at 20±3°C in alternate cycles of 12 hours each of light and darkness. In grass seeds, the most common fungi were (1) in *Panicum: Phoma* sp., *Fusarium, Alternaria*, and *Epicoccum*; (2) in *Setaria anceps: Cladosporium, Phoma*, and *Fusarium*; (3) in *Chloris gayana: Drechslera sorokiniana, Drechslera* sp., and *P. sorghina*; and (4) in *Dichanthium aristatum* and *Paspalum urvillei: Phyllosticta* sp., *Curvularia* sp., and *Drechslera* sp. In legume seeds, the most common fungi were (1) in *Leucaena leucocephala: Cladosporium cladosporioides*; (2) in *Dolichos lablab: Aspergillus, Penicillium*, and *Fusarium*; and (3) in *Glycine wightii: Aspergillus flavus, Curvularia* sp., and *Penicillium* sp.

129

Lenné, J.M. and Stanton, J.M. (1990): Diseases of *Desmodium* species - a review. *Tropical Grasslands* 24:1-4.

Keywords: *Desmodium ovalifolium*; pastures; nematodes; fungal diseases; *Meloidogyne* spp.; diseases.

Abstract. Fungal pathogens representing 36 genera and over 70 species, one bacterium, mycoplasma-like-organisms, at least six viruses, five races of root-knot nematodes and six other nematodes have been recorded on 18 *Desmodium* species of agronomic interest throughout tropical regions. Although limited information precludes a definitive discussion of the relative importance of many diseases, 2 fungal diseases - *Synchytrium desmodii* and *Phanerochaeta salmonicolor* - causing wart and pink disease, respectively, of *Desmodium ovalifolium* and several nematode pathogens including races of the root-knot nematodes *Meloidogyne arenaria, M. hapla, M. incognita* and *M. javanica* of *Desmodium* species and stem gall nematode *Pterotylenchus cecidogenus* of *D. ovalifolium* are presently regarded as important pathogens. Awareness of the range and distribution of fungal pathogens recorded on *Desmodium* species as well as the existence of potentially seed-borne bacteria and potyviruses is regarded as essential for preventing global transmission of these pathogens and serious disease problems in the future. This is the first time that the great diversity of information available on diseases of *Desmodium* species has been summarized. It should provide a useful reference for many tropical pasture scientists.

130

Stanton, J.M., Siddiqi, M.R. and Lenné, J.M. (1989): Plant-parasitic nematodes associated with tropical pastures in Colombia. *Nematropica* 19:169-175.

Keywords: nematodes; pastures; Colombia; legumes; *Pueraria phaseoloides*; grasses; *Arachis pintoi*; *Hyparrhenia rufa*; *Stylosanthes*.

Abstract. A survey of 3 regions of Colombia revealed a total of 31 species of plant-parasitic nematodes associated with tropical pasture legumes and grasses. Seventeen of these nematode species had not been recorded previously in Colombia. There were also newly reported associations of plant-parasitic nematodes on tropical pasture legumes and grasses. The nematode species found most commonly and abundantly were *Helicotylenchus* spp., *Pratylenchus* spp. especially *P. brachyurus, Monotrichodorus monohystera* and *Xiphinema* spp. The plant species surveyed were *Andropogon gayanus, Arachis pintoi, Brachiaria* spp., *Centrosema* spp., *Desmodium* spp., *Hyparrhenia rufa, Melinis* sp., *Pueraria phaseoloides, Stylosanthes spp.*, and *Zornia* sp.

131

Martínez-Mojena, A. and Medina, N. (1989): Los insectos como enemigos de los pastos y forrajes. Su combate. *Pastos y Forrajes* 12:199-207.

Keywords: insect pests; pests; pest control; biological control; pastures; legumes; grasses; insects; rotational grazing; *Leucaena leucocephala*.

Abstract. This paper presents the most important insect pests of pastures in Cuba. Possibilities of integrated pest management, including biological control and control by rotational grazing, are outlined.

132

Calderón C., M. (1981): Insect pests of tropical forage plants in South America. *Proceedings of the XIV International Grassland Congress, Lexington (USA),* p. 778-780.

Keywords: insect pests; South America.

Abstract. The objectives of this continuing research are to make a general survey of the insect populations occurring in tropical forage plants in South America and to identify the most important pests. To realize this investigation, pure stand plots 5 x 5 m were sampled every 14 days during 2 years using a D-Vac vacuum sampler. The following information was obtained: - Most important families and/or genera of insects in tropical forage legumes and grasses. - Insect group frequency for each season. - Insect group frequency for each plant ecotype under study. - Preliminary data on insect preference. - Preliminary data on relationships between insects on forage plants and viral, fungal and bacterial diseases. - Most important pests in South America. The important pests include stemborer (*Caloptilia* sp.), leafhoppers (*Cicadellidae*, several genera), and leafeating beetles (*Crisomelidae*, several genera). Chinchbug (*Pentatomidae, Lygaeidae*) and sucking planthoppers (*Membracidae*) are under investigation as disease vectors; seed-eating beetles (*Curculionidae*) and budworms (*Stegasta bosqueella*) reduce seed production. In grasses, spittlebug (*Zulia, Aeneolamia*, and *Deois* spp.) causes serious damage, and seed-feeding leafhoppers (*Cicadellidae*) reduce seed production. This ongoing research provides essential information about the most important insect pests, pests of secondary importance, potential pests, and beneficial insects of tropical forage plants

in five countries in South America. This is the first complete study of the insect fauna of tropical forage plants, so it is an important one.

133

Wallace, M.M.H. (1970): Insects of grasslands. In: Moore, R.M. (ed.), *Australian grasslands*. Canberra: Australian National University Press, p. 361-370.

Keywords: grassland; pastures; insect pests; insect-plant interaction.

Abstract. Most of the insect pests of pastures and grazing lands in Australia are indigenous. Populations of some native insects have increased enormously as agricultural and pastoral activities have modified their environments and raised their food levels. Small numbers of introduced insects have also found the changed conditions favourable and, in the absence of some or all of their natural enemies, have reached pest proportions in some places. In the tropics and sub-tropics, where the establishment of highly productive pastures is relatively recent, insects are not generally deleterious to grassland production. But new species of grasses and legumes are being introduced and it would be surprising if some of the native insects and mites now able to sustain only low numbers in the near-original environment do not increase as a result of higher levels of pasture production. This chapter describes the ways insects or mites affect botanical composition and growth of pastures and attempts to show how man's agricultural activities create and aggravate insect pest problems. Only the commoner and more important species are discussed.

134

Fowler, H.G. and Saes, N.B. (1986): Dependence of the activity of grazing cattle on foraging grass-cutting ants (*Atta* spp.) in the southern Neotropics. *Journal of Applied Entomology* 101:154-158.

Keywords: cattle; grasses; grassland; Brazil; Paraguay; leaf-cutting ants; insect pests; pastures.

Abstract. In Paraguayan and Brazilian pastures with the grass-cutting ants, *Atta bisphaerica, A. capiguara, A. laevigata* and *A. vollenweideri* present, cattle were found to limit their grazing activity to areas in which grass-cutting ants were not actively cutting. Cattle confined to areas in which grass-cutting ants were actively cutting grazed significantly less and walked significantly more than cattle confined to areas free of cutting ants. Forage offered to cattle in which workers of grass-cutting ants were placed was consumed significantly less than control treatments, suggesting that the thoracic spines, which are well developed in *Atta* spp., may be adaptive in the defense of vegetative resources against large mammalian herbivores, as well as serve other assumed adaptive functions. These results suggest that the impact of grass-cutting ants on Neotropical cattle production is more complex than estimates on their grazing potential indicate.

135

Schultze-Kraft, R. (1994): El "psyllid" de *Leucaena* también puede ser un problema en América tropical. *Pasturas Tropicales* 16(2):48-50.

Keywords: South America; Asia; insects; insect pests; pests; biological control; Colombia; *Leucaena leucocephala*; *Heteropsylla cubana*.

Abstract. A brief account of the *Leucaena* psyllid *Heteropsylla cubana,* its damage to *L. leucocephala* and economic importance in Southeast Asia, and the research steps taken to find a solution to the problem is presented. In tropical America, the *Leucaena* psyllid has not been considered to be an insect pest of major importance because of natural biological control, apparently mainly through predators. However, significant damage and economic loss have been observed on farms in the Valle del Cauca department, Colombia. Damage can be particularly severe during the dry season when psyllid infestation leads to wilting and death of shoots, with subsequent interruption of foliage production and, when defoliation coincides with another severe stress, even to the death of otherwise drought-resistant plants. Further, intensified monitoring of the psyllid situation in tropical America is suggested and a series of research steps is recommended.

136

Abramsky, Z. (1983): Experiments on seed predation by rodents and ants in the Israeli desert. *Oecologia* 57:328-332.

Keywords: seeds; deserts; pests; granivory; ants; rodents.

Abstract. Utilization of non-native seeds by seed-eating rodents and ants was studied experimentally in the field. It was found that patterns of granivory in the Israeli deserts are very similar to those reported for the same groups in the deserts of North America. Rodents are more efficient than ants at finding and harvesting seeds. Only rodents can find and harvest seeds that occur below the soil surface. The two taxa appear to rank barley particles on the basis of size. Big seeds are utilized first and the shift to small seeds occurs only after most of the big seeds have been utilized. This result agrees with the prediction of optimal diet theory.

137

Ofuya, T.I. and Bamigbola, K.A. (1991): Damage potential, growth and development of the seed beetle, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae), on some tropical legumes. *Tropical Agriculture (Trinidad)* 68:33-36.

Keywords: legumes; seeds; Coleoptera; *Callosobruchus maculatus*; pest development.

Abstract. The damage potential, growth and development of *Callosobruchus maculatus* on eight different tropical legumes was investigated under laboratory conditions in Akure, Nigeria. One or more larvae of *C. maculatus* caused significant weight loss in single seeds of pigeon pea (>14%), cowpea (>10%), soya bean (>5%) and African Yam bean (>3%), whereas two or more larvae caused significant weight loss in a Bambara groundnut seed (>4%). *C. maculatus* did not grow and develop on the seeds of winged bean and mucuna bean and only a few adults could be reared from lima bean. Developmental period was longer in soya bean and African yam bean than in Bambara ground nut, pigeon pea and cowpea. The heaviest females were reared from seeds of Bambara groundnut and the lightest from soya bean. Females reared from Bambara groundnut were most fecund and lived longest.

138

McFadden, M.W. (1988): The *Leucaena* psyllid: An ecological catastrophe. *Healthy Forests, Healthy World: Proceedings of the 1988 Society of American Foresters National Convention, Rochester, New York, October 16-19,* p. 321-323.

Keywords: Asia; pests; *Leucaena leucocephala*; *Heteropsylla cubana*.

Abstract. In conclusion, the author points out that although the biological time bomb represented by the broadly distributed, narrow genetically based leucaena exploded over a fantastically large geographical area with devasting effects on agricultural economies, the response by the scientific community in SE Asia was equal to the task. From the first meeting in Hawaii in November, 1986 until August, 1987, a mere 10 months, five national IPM plans had been developed and a national coordinator selected to coordinate research activities in each country. A regional IPM plan had been prepared and approved and a regional coordinator selected to insure integration of research activities across the region. The regioanl IPM plan may be the largest multi-country effort ever developed to coordinate and integrate research on a major pest problem and it offers considerable promise for resolution of the psyllid problem.

139

Lenné, J.M., Vargas, A. and Torres, C. (1985): Damaging fungal diseases of promising pasture legumes in the tropical American lowlands. *Proceedings of the XV International Grassland Congress, Kyoto (Japan)*, p. 807-809.

Keywords: fungal diseases; diseases; legumes; disease resistance; pastures; *Stylosanthes* spp.; *Centrosema brasilianum*; *Zornia latifolia*; *Desmodium ovalifolium*; nematodes; Colombia; adapted germplasm.

Abstract. The most damaging fungal diseases in pasture legumes in the major ecosystems of the tropical American lowlands are discussed. Detailed evaluations during the past seven years in major screening sites and more than 100 RIEPT sites have identified more than 30 diseases of tropical pasture legumes caused by fungi, bacteria, mycoplasmas, viruses and nematodes. Of these, four fungal diseases are the most damaging: Anthracnose caused by *Colletotrichum* spp., is the most widespread and damaging disease of *Stylosanthes*. Dry matter losses of 26 to 100% have been recorded in several species. Foliar blight caused by *Rhizoctonia solani* is also widespread; 10 to 30% dry matter losses have been recorded in *Centrosema brasilianum* in Colombia. Dry matter losses of 55% have been recorded in *Zornia latifolia* by *Sphaceloma zorniae*, the causal agent of scab, while false rust, caused by *Synchytrium desmodii*, has caused considerable damage to *Desmodium ovalifolium* in Colombia. Resistance, the most practical and economic management approach, is being sought to these diseases in an on-going multi-disciplinary, multi-institutional and multi-locational screening and selection research strategy. Understanding of the plant, pathogen, environment and their interactions is considered essential to effective evaluation and utilization of selected resistance.

140

Lenné, J.M. and Trutmann, P. (eds.) (1994): *Diseases of tropical pasture plants.* Wallingford, Oxon, UK: CAB International, 404 p.

Keywords: diseases; pastures; legumes; grasses; nematodes; Australia; USA; South America; Asia; Africa.

Abstract. Increasingly, diseases are being identified as major constraints to the productivity and persistence of improved tropical pastures. This book provides a comprehensive review of diseases of tropical pasture legumes and grasses. After an introductory chapter, nine chapters review the main fungal, bacterial and mycoplasma diseases and a further two consider viral and nematode diseases of legumes and grasses such as *Stylosanthes*, *Centrosema*,

Desmodium, Leucaena and *Andropogon*. Five chapters then describe regional experience in Australia, the Southern USA and Caribbean, Central and South America, Southeast Asia and the Pacific, and Africa. The final part of the book covers general management of diseases, molecular techniques for characterization and diagnosis of pathogens, and international cooperation and future research. The book represents a comprehensive, fully referenced sourcebook for plant pathologists and pasture agronomists.

141

Lenné, J.M., Thomas, D., Andrade, R.P. and Vargas, A. (1984): Anthracnose of *Stylosanthes capitata*: implications for future disease evaluations of indigenous tropical pasture legumes. *Phytopathology* 74:1070-1073.

Keywords: pastures; legumes; Colombia; Brazil; *Stylosanthes capitata*; South America; fungal diseases; *Colletotrichum gloeosporioides*; disease resistance.

Abstract. During field screening from 1978 to 1981 of 121 accessions of the tropical pasture legume *Stylosanthes capitata* at two sites in Colombia and at Planaltina in Brazil, 94.2% of the accessions were resistant to anthracnose (caused by *Colletotrichum gloeosporioides*) in Colombia while 85.1% were susceptible in Brazil. In comparative seedling pathogenicity studies with isolates from both countries, isolates pathogenic to a wide range of accessions of *S. capitata* were only found in Brazil. Results strongly suggest that specialized isolates of *C. gloeosporioides* pathogenic to *S. capitata* exist in Brazil (the native habitat and probable center of diversity of this legume) and not in Colombia where *S. capitata* is an exotic species. This implies the need to screen indigenous tropical pasture legumes for desease resistance in their native habitats and the need for international collaborative disease screening trials in the future.

142

Lenné, J.M. (1989): Problems associated with evaluation of diseases of perennial pasture plants - some recommendations. *Proceedings of the XVI International Grassland Congress, Nice (France),* p. 695-696.

Keywords: diseases; pastures; evaluation methods; yields.

Abstract. The complexity of the perennial pasture environment, the potential for multiple interactions between pathogens and pests, as well as environmental factors, and the grazing animal, necessitates a multidisciplinary approach. Techniques used in plant population biology have great application to pasture pathology. More information is required on the practical importance of diseases at the farm level and the effect of diseases on perennial pasture plants over time. Diseases can greatly affect plant persistence, evaluation of which is essential to any determination of whether diseases cause significant reduction in animal production and whether control strategies are needed. (Abstract by bibliography authors)

143

Toledo, J.M. and Nores, G.A. (1986): Tropical pasture technology for marginal lands of tropical America. *Outlook on Agriculture* 15:2-9.

Keywords: pastures; marginal lands; low-input technology; adapted germplasm; acid soil.

Abstract. CIAT's Tropical Pastures Program is concerned with solving the problems of low productivity in acid, marginal, and frontier lands by developing new, low-input technology based on adapted germplasm. Its tropical pasture germplasm collection is the world's largest for acid soils in tropical humid and sub-humid areas.

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Scott, D.R. (1970): Feeding of *Lygus* bugs (Hemiptera: Miridae) on developing carrot and bean seed: Increased growth and yields of plants grown from that seed. *Annals of the Entomological Society of America* 63:1604-1608.

Keywords: insect pests; insect-plant interaction; seed production.

Abstract. To determine the effect of lygus bugs, *Lygus hesperus* Knight and *Lygus elisus* Van Duzee, feeding on developing carrot seed on the plants grown from that seed, adult lygus bugs were caged on carrot umbels. Some of the seed was then germinated and growth of the shoot was measured. Other seed was planted in the field, growth of the plants was measured, and weight of the roots was determined. Bean seed was sorted as to the number of lygus punctures per seed, then weighed and planted. Growth of the plants and seed yields were determined. Shoot growth from carrot seeds exposed to feeding by lygus bugs during development is reduced and varies inversely with the bug population. Plants grown from such seeds later surpass plants from seeds protected from lygus bugs during development and produce heavier roots. Bean plants grown from seeds with lygus bug punctures surpassed plants from seeds not fed on by lygus bugs. Although bean seeds were significantly lighter in weight when fed on by lygus bugs, they produced plants which grew significantly faster and yielded significantly heavier amounts of seed. Three possible explanations are discussed: (1) destruction of an inhibitor (possibly dormin) present in the seed; (2) injection of a plant auxin (possibly beta-indolyl acetic acid) into the developing seed during the feeding process; and (3) change of the protein-carbohydrate ratio in the seed as a result of feeding by lygus bugs.

145

Dyer, M.I. and Bokhari, U.G. (1976): Plant-animal interactions: Studies of the effects of grasshopper grazing on Blue Grama Grass. *Ecology* 57:762-772.

Keywords: grassland; insect pests; insect-plant interaction; grasses; grasshoppers.

Abstract. Results of a laboratory experiment where we measured the influence of grasshoppers (*Melanoplus sanguinipes*) feeding upon leaves of hydroponically grown blue grama grass (*Bouteloua gracilis*) are presented. Performance of both the plant and animal conditions are given: growth rate of the plants held at three temperatures, amount of food ingested by the grasshoppers, digestive efficiencies, weight change of grasshoppers, the amount of litter cut, and the pH change of the root medium. The experiment indicates that there are plant processes triggered by grasshopper feeding which result in increased energy transport levels within the plant. Moreover, regrowth potentials of the plants on which grasshoppers had been feeding is much higher than for plants that had simply been clipped. Hence, we suggest that perhaps the largest single effect displayed by aboveground insect grazers on grassland ecosystem plants (viz., grass) is the increase in belowground respiration and root exsudation.

146

Marshall, D.L., Levin, D.A. and Fowler, N.L. (1985): Plasticity in yield components in response to fruit predation and date of fruit initiation in three species of *Sesbania* (Leguminosae). *Journal of Ecology* 73:71-81.

Keywords: yield components; insect-plant interaction.

Abstract. (1) Changes in the components of yield in response to artificial predation and to date of fruit initiation were measured in three species of *Sesbania*. (2) The removal of fruits, which mimicked damage by chewing insects, resulted in significant changes in seed weight but not in seeds produced per fruit. Injection of alcohol into developing seeds, which mimicked damage by hemipterans, resulted in selective abortion of more heavily damaged fruits and of younger fruits. (3) The nature of the response to predation depended on its timing because responses become less flexible as development proceeds. (4) Differential responses to predation among the species appeared to be related to the investment in seeds versus pods, since *S. vesicaria*, which had the highest quotient of seed weight to fruit weight, had the highest rate of fruit abortion. (5) Fruits initiated on later dates were less likely to mature in all three species. Late fruits had an unchanged number of ovules but reduced seed size in *S. macrocarpa* (annual), reduced ovule number but unchanged seed size in *S. vesicaria* (annual), and unchanged ovule number and seed size in *S. drummondii* (perennial). (6) The differences among species in response to date of fruit initiation suggest that each annual species holds most constant the yield component most closely related to fitness, while the perennial is less responsive to stress because its stored reserves provide a buffer.

147

Kretschmer Jr., A.E., Sonoda, R.M. and Snyder, G.H. (1980): Resistance of *Desmodium heterocarpon* and other tropical legumes to root-knot nematodes. *Tropical Grasslands* 14:115-120.

Keywords: forage legumes; nematodes; Florida; breeding; pest resistance; pest control.

Abstract. Carpon desmodium (*Desmodium heterocarpon* cv. Florida), a long-lived, high seed producing, perennial tropical forage legume for grazing, was released for commercial use in south Florida in 1979. It is susceptible to root-knot nematodes (*Meloidogyne* spp.). A greenhouse and a field experiment were used to assess root-knot nematode resistance or tolerance of other carpon desmodium accessions, to determine resistance of several commercial tropical legumes, and to compare first-season productivity of tropical legumes. Two of eight carpon desmodiums, *Desmodium adscendens*, greenleaf desmodium (*Desmodium intortum* cv. Greenleaf), centro (*Centrosema pubescens*), siratro (*Macroptilium atropurpureum* cv. Siratro), stylo (*Stylosanthes guianensis* cv. Cook), Caribbean stylo (*S. hamata* cv. Verano), and jointvetch (*Aeschynomene americana* cv. American) were apparently resistant to *Meloidogyne* spp. No galls were noted on roots of these species from nematode infested soil. Moderate to severe galling was found on roots of Florida and four other carpon accessions, and on a *Centrosema pascuorum* accession. Very slight galling was found on roots of one carpon desmodium accession and on calopo. Yield and survival of affected plants were less than those of plants from inoculated or fumigated plots. In the absence of root-knot, yields of the two resistant carpon desmodiums were considerably less than that of Florida carpon while in the presence of root-knot their yields were significantly higher. Finding nematode resistance in carpon desmodium is encouraging for future selection and breeding programmes.

148

Hardy, S.R.L. (1987): The relationship between *Aeschynomene americana* L. and root-knot nematodes (*Meloidogyne* spp.). *Dissertation Abstracts International. Section B. The Sciences and Engineering* 48:924B-925B.

Keywords: *Aeschynomene americana*; nematodes; *Meloidogyne* spp.; pest resistance; legumes; USA; breeding; Florida.

Abstract. An improvement programme for *A. americana* was initiated in Florida, USA to develop desirable agronomic traits and expand its commerical uses. To precisely transfer traits between genotypes an artificial hybridization technique was developed. The method involved the removal of the stamens followed by controlled pollination. The risks of self pollination or contamination were minimized and the success rate was maximized. The success rate was not affected by the female or male parent used. A population of *A. americana* genotypes was individually examined for their responses to *M. incognita* race 1 and 3; *M. javanica*; and *M. arenaria* race 1. The population was found to contain a wide range of responses from resistant to susceptible. Three plant genotypes with different responses were used to examine the effects of the genotype on the life cycle of *M. incognita* race 3 under two different day length and temperature regimes. The plants were examined weekly and the different nematode life cycle stages counted after staining. Development to maturity was reduced in the more resistant genotypes in both environmental regimes. Under long days and higher temperatures, surviving females in resistant genotypes could reproduce as well as those in the susceptible genotypes. Two resistant and 2 susceptible plant genotypes which had uniform nematode responses were selected for the examination of the genetic system controlling the responses of 3 root-knot nematode species. They were crossed and their first filial generation used to create 2nd filial generations and backcrosses. All the generations were tested with each nematode species. The data from all the families and generations for the 3 nematode species were combined; there appeared to be one dominant gene for resistance common to all 3 species. There was evidence for other genes being involved which seemed to be partially dominant, and probably specific to the individual nematode species.

149

Lamprecht, H. (1977): Structure and function of South American forests. In: Muller, P. (ed.), *Ecosystem research in South America*. The Hague: Junk, p. 1-15.

Keywords: ecosystems; South America; tropical forest; hydrology; soil erosion; species diversity.

Abstract. The study deals mainly with the tropical evergreen forests and moist forests of northern South America. The basal area of these intensely mixed natural forests with many species reaches its minimum in the tropical tropophytic forest and its maximum in the Andean cloud forest. The curve of diameter distribution is typical of a selection forest. As far as protective functions are concerned these forests are satisfactory, but their productive functions are insufficient. The task of forestry is to convert these unproductive natural stands into productive commercial forests without decreasing their protective and social functions.

150

Lal, R. (1981): Deforestation of tropical rainforest and hydrological problems. In: Lal, R. and Russell, E.W. (eds.), *Tropical Agricultural Hydrology*. Chichester: Wiley, p. 131-140.

Keywords: deforestation; hydrology; soil erosion; erosion; Nigeria; shifting cultivation; *Pueraria phaseoloides*; *Stylosanthes guianensis*; *Centrosema pubescens*; tropics.

Abstract. In spite of the adverse environmental consequences, vast areas of tropical forest will have to be developed for food production. The objectives of this report are to describe the effects of methods of deforestation and of post-development soil management on runoff rate and amount, sediment density and soil erosion in a tropical catchment in southwest Nigeria. Data presented indicates that other than shifting-cultivation treatment, manually cleared plots produce less water runoff and soil loss than using heavy machinery for clearing. To ensure sustained productivity, it is important to develop appropriate soil management systems that will minimize the adverse effects of deforestation by mechanical means. Care must be exercized not to remove all roots, stumps and other biomass. Crop covers (such as *Pueraria phaseoloides, Stylosanthes guianensis, Centrosema pubescens,* etc.) may play an important role in the management of soils in the humid tropics.

151

Gentry, A.H. and López-Parodi, J. (1980): Deforestation and increased flooding of the upper Amazon. *Science* 210:1354-1356.

Keywords: deforestation; watershed; Peru; Ecuador; hydrology; Amazon region; flooding.

Abstract. The height of the annual flood crest of the Amazon at Iquitos has increased markedly in the last decade. During this same period, there has been greatly increased deforestation in the upper parts of the Amazon watershed in Peru and Ecuador, but no significant changes in regional patterns of precipitation. The change in the Amazonian water balance during the last decade appears to be the result of increased runoff due to deforestation. If so, the long-predicted regional climatic and hydrological changes that would be the expected result of Amazonian deforestation may already be beginning.

152

Nordin, C.F. and Meade, R.H. (1982): Deforestation and increased flooding of the upper Amazon. *Science* 215:426-427.

Keywords: deforestation; flooding; Amazon region; hydrology.

Abstract. Comment on the report "Deforestation and flooding in the upper Amazon" by Gentry and López-Parodi (reference no. 151), who concluded that the height of the annual flood crest of the Amazon at Iquitos has increased during the last decade as a result of increased runoff due to deforestation: Nordin and Meade criticize that the aforementioned authors have considered neither the relation between water discharge and stage nor changes in the configuration of the sandy stream bed. Also the effects of spatial and temporal distribution of precipitation have not been taken into account. Finally, Nordin and Meade argue that the t-test, used by Gentry and López-Parodi, should not be applied to such hydrologic data. (Abstract by bibliography authors)

153

Dudal, R. and Purnell, M.F. (1986): Land resources: salt affected soils. *Reclamation and Revegetation Research* 5:1-9.

Keywords: soil salinity; revegetation; regeneration; improved pastures; silvopastoral systems.

Abstract. Although the world as a whole has enough land to support its projected population, many countries do not have the resources to be self-sufficient in food and fuel. The increase in production necessary to meet increasing demand must come from higher yields, intensified production and development of potentially productive wasteland. Salt affected soils occupy about 7% of the world's land area. Studies of the distribution, classification and productive potential of these soils are required to plan their development on a global scale. Achieving the full potential of salt affected land also requires the consideration of social and economic conditions.

154

Bari, M.A. and Schofield, N.J. (1992): Lowering of a shallow, saline water table by extensive eucalypt reforestation. *Journal of Hydrology* 133:273-291.

Keywords: reforestation; groundwater level; pastures; water salinity; groundwater; Australia.

Abstract. Land and stream salinisation in Western Australia has occurred as a result of the clearing of native vegetation for agricultural development. One approach to controlling the salinisation, extensive reforestation, has been tested on a site which was 35% cleared and converted to pasture in the 1950s. By 1979 saline ground water was discharging in the valley where the clearing had taken place. At that time 63 *Eucalyptus* and two *Pinus* species were planted in 0.5 ha blocks across the site, covering some 70% of the cleared land. The reforestation has been successful in substantially lowering the saline groundwater table across the site. Over the 1980-1989 period, the average minimum groundwater levels beneath reforestation declined by 5.5 m relative to the ground level and by 7.3 m relative to a nearby pasture control site. After the first 3 years the rate of decline was near-uniform with time. The average salinity of the ground water beneath reforestation decreased by 11%.

155

Bell, R.W., Schofield, N.J., Loh, I.C. and Bari, M.A. (1990): Groundwater response to reforestation in the darling range of Western Australia. *Journal of Hydrology* 119:179-200.

Keywords: groundwater; reforestation; Australia; deforestation; water salinity; pastures; annual field crops; groundwater level.

Abstract. Replacement of deep-rooted perennial vegetation with annual crops and pastures has led to rising groundwater tables and transport of previously stored salts to streams in southwest Western Australia. Trials to determine the potential of various reforestation strategies to reverse this process by lowering the groundwater table were commenced in 1976-1981. Results are reported from six experimental sites for the period 1979-1986. Despite the mean annual rainfall of the experimental period being 10% below the 1926-1986 mean, groundwater levels under pasture rose by up to 1.2 m. The change in groundwater levels beneath reforestation ranged from a 0.6-m increase to a 3-m decrease relative to the ground surface. Groundwater levels under reforestation in all cases decreased relative to groundwater levels under pasture. The magnitude of this reduction was shown to increase with the proportion of cleared area reforested and with the crown cover of the reforestation. The salinity of the water table decreased by 12% under reforestation and by 32% under pasture over the period 1979-1986.

156

Pereira, C. (1981): Rehabilitating eroded hill lands in the People's Republic of China. *World Crops* 33:96-99.

Keywords: trees; watershed; revegetation; *Medicago sativa*; soil erosion; reforestation.

Abstract. This is a report of an extensive road tour of active rehabilitation work in 2 seriously eroded provinces, Shaanxi and Jiangxi. Methods of restoration were initiated in 1950, but during the ten years of the Cultural Revolution work was severely set back, with many planted trees felled. Rehabilitation of small watersheds is now being resumed on a basis of local initiative. Restoration by conventional means, including the planting of 15 million trees (100 per capita of resident population) and by new technology, applying aerial seeding for the revegetation of bare hills, using 2.25 kg of lucerne (*Medicago sativa*) seeds/ha are recorded. In addition the reafforestation of sub-tropical hills is also discussed.

157

Sharma, P.D. and Minhas, R.S. (1993): Land use and the biophysical environment of Kinnaur district, Himachal Pradesh, India. *Mountain Research and Development* 13:41-60.

Keywords: India; pastures; livestock; hydrology; reforestation; tropical highlands; overgrazing.

Abstract. The extensive alpine pastures of Kinnaur in the Indian Himalaya are an invaluable resource, with fertile soils that provide high-quality pasturage above treeline. However, today these pastures are being degraded by excessive livestock pressure and lack of good management. This is weakening animal husbandry programs and upsetting the normal hydrological functioning of the upland river catchments. The forested area in the Kinnaur District is small and only half is under well protected forest. Within the forest infiltration and water retention rates are high and help to effect regular sediment-free water yields to the rivers, but there is growing pressure from the local people who claim that they need a large proportion of the annual yield of the forest. The cultivable waste lands that cover a large area should be used by social forestry to augment the vegetation cover and reduce the pressure on the present forest land. The cultivated area is limited and produces low yields of less remunerative crops. The agricultural land in the forest and alpine belts on steep slopes is being severely eroded and may become completely unstable.

158

Rechcigl, J.E., Payne, G.G., Bottcher, A.B. and Porter, P.S. (1992): Reduced phosphorus application on bahiagrass and water quality. *Agronomy Journal* 84:463-468.

Keywords: phosphorus; *Paspalum notatum*; yields; water pollution; soil chemical properties; Florida; fertilization; pastures.

Abstract. Phosphorus is considered to be the major factor causing eutrophication of Lake Okeechobee and other waterways in Florida. An important source of P for Lake Okeechobee is runoff of soluble P fertilizer applied to bahiagrass (*Paspalum notatum* Flugge) pastures. A study was conducted to ascertain whether P application levels could be reduced below current agronomic recommendations without affecting pasture yields or quality and to determine the effects of P application on surface water quality. A field study was conducted on a bahiagrass pasture to assess the yield response of bahiagrass to five annual rates of P (0, 6, 12, 24, and 48

kg ha^{-1}) and two application times (dry season and wet season). Fertilizer treatments were arranged in a randomized complete block design with four replications on an Immokalee fine sand (sandy, siliceous, hyperthermic Arenic Haplaquods). Results indicate that P fertilization rates could be reduced from 48 to 24 kg P ha^{-1} without affecting yields or quality of bahiagrass. Yields in 1989 averaged 11.4, 14.7, and 10.4 Mg ha^{-1} for the 48, 24, and 0 kg P ha^{-1} treatments, respectively. Time of P application had no effect on yields or quality of bahiagrass. There was a linear increase in Mehlich I extractable P in the A and E horizons and a quadratic increase to P in the Bh horizon in 1989. Extractable P ranged from 3.8 to 22.5, 1.3 to 2.5, and 21 to 55 mg P kg^{-1} for the A, E, and Bh horizons, respectively. Phosphorus concentrations in surface water runoff was reduced from 33 to 60% as P application rates were decreased from 48 to 12 kg P ha^{-1} while total P loss was reduced from 17 to 78%, respectively. Recommended reductions in P application should result in substantial cost savings to producers and also reduce P inputs into surface water.

159

Thorburn, P.J., Cowie, B.A. and Lawrence, P.A. (1991): Effect of land development on groundwater recharge determined from non-steady chloride profiles. *Journal of Hydrology* 124:43-58.

Keywords: groundwater; Australia; pastures; annual field crops; groundwater level; deforestation; soil salinity.

Abstract. The effect of clearing and subsequent crop and pasture growth on recharge to ground waters was investigated in three experimental catchments in the brigalow (*Acacia harpophylla*) lands of north-eastern Australia. Recharge was calculated from soil chloride data, using a simple transient solute mass balance model. Clearing had a substantial initial effect on groundwater recharge, with average recharge rates of 29 to 70 mm $year^{-1}$ in two cleared catchments, compared with 7 mm $year^{-1}$ in an uncleared catchment. These results were attributed to record high rains that fell while both cleared catchments were bare of vegetation, before crops or pastures were established. The effect was only short lived, however, with no significant recharge occurring in any of the three catchments during the period in which crops and pastures were fully established. This lack of recharge was contrary to the general belief that clearing and establishment of crops or pastures causes a sustained increase in groundwater recharge. The low recharge rates at this site were attributed to the slowly permeable soils and the climate of the study site, where potential evaporation exceeds average rainfall in all months, and to the water use characteristic of brigalow. Brigalow is shallow-rooted, and at this site generated lower soil water deficits than either crops or pastures. Clearing is unlikely to result in high water-tables in these soils under pastures or opportunity cropping systems under the average climatic conditions of the region. The simple transient solute mass balance model used to estimate recharge rates gave important and significant differences in recharge when compared with a more commonly used steady-state model. All recharge rates calculated with the steady-state model were less than or equal to 1.8 mm $year^{-1}$ (most < 0.3 mm $year^{-1}$), and so this model could not identify the gross short-term recharge response to clearing at this site.

160

Burrows, W.H. (1991): Sustaining productive pastures in the tropics. 11. An ecological perspective. *Tropical Grasslands* 25:153-158.

Keywords: pastures; Australia; natural grassland; sustainability; ecosystems; degradation; soil salinity; legume trees; animal production; trees; water salinity.

Abstract. Opportunities for continued utilisation of Australia's tropical pasture systems are explored and some of the ecological constraints leading to breakdown of the systems discussed. The need to evaluate basic range management concepts for managing the extensive areas of native and naturalised pastures is highlighted.

161

Shelton, H.M., Lowry, J.B., Gutteridge, R.C., Bray, R.A. and Wildin, J.H. 1991. Sustaining productive pastures in the tropics. 7. Tree and shrub legumes in improved pastures. *Tropical Grasslands* 25:119-128.

Keywords: pastures; trees; shrubs; Australia; sustainability; *Leucaena leucocephala*; legume trees; animal production; silvopastoral systems; agroforestry.

Abstract. Among tropical legumes, the tree species *Leucaena leucocephala* has demonstrated a high potential for increasing liveweight gain. Expansion of its use is limited by damage from the psyllid (*Heteropsylla cubana*) and the slow rate of establishment of *Leucaena* seedlings in some environments. These problems with *L. leucocephala* have given impetus to the search for alternative varieties and species of tree legumes with similar features. These features include longevity and versatility of management once established, high animal production potential, tolerance of a wide range of climatic and edaphic environments, and potential for a use in a range of agroforestry applications because of their deep rooted habit. The shading effect of tree canopies can have a positive effect on understorey grass yield and quality due to improved nutrient cycling. There is potential for selection of higher yield, improved psyllid and high temperature tolerance within the *Leucaena* genus. Other promising genera of tree legumes include *Calliandra, Gliricidia, Albizia* and *Sesbania*. However, there are problems of lower nutritive value and acceptance in some of these genera and further evaluation is required. Also it is not known how well these other tree legumes can tolerate direct grazing. The future acceptance of tree legumes by graziers will depend on the improved availability of suitable germplasm, a practical knowledge of their establishment and management requirements, and a clear demonstration of their potential economic benefits.

162

Anderson, G.W., Moore, R.W. and Jenkins, P.J. (1988): The integration of pasture, livestock and widely-spaced pine in South West Western Australia. *Agroforestry Systems* 6:195-211.

Keywords: pastures; livestock; Australia; economics; trees; silvopastoral systems; soil salinity; soil erosion.

Abstract. This paper expands on a short voluntary presentation, by the first two authors, to the 18th IUFRO World Congress held at Ljubljana, Yugoslavia, in September 1986. It describes management procedures and incorporates biological and economic data, from a number of agro-silvo-pastoral trials in the South West of Western Australia. The integration of pine timber and livestock production is shown to have a range of economic and environmental benefits available in the long-term. Ways in which the choice of tree density, planting pattern and silvicultural regime can each be directed towards the achievement of various objectives are indicated.

163

Jones, R.K., Dalgliesh, N.P., Dimes, J.P. and McCown, R.L. (1991): Sustaining multiple production systems. 4. Ley pastures in crop-livestock systems in the semi-arid tropics. *Tropical Grasslands* 25:189-196.

Keywords: pastures; tropics; farming systems; Australia; legumes; establishment; nitrogen; crop residues; cattle; grasses; leaching; sustainability; ley farming.

Abstract. The search for economically viable ley pastures in the Australian tropics is an attempt to emulate the successful ley farming systems, based on subclover and wheat, in regions with Mediterranean and temperate climates in southern Australia. The paper examines experimental legume ley pastures in the semi-arid tropics from four points of view, viz., initial establishment and reestablishment of the various ley species after a crop; the contribution of biological nitrogen from the ley to the farming system; the control of pasture species during crop phase; and the feeding value of ley pastures and crop residues to grazing cattle. Management problems highlighted by the research on experimental ley pastures include: grass dominance in the pasture; the extremely rapid decomposition of legume residues and the resultant leaching of mineral nitrogen beyond the root front of the developing crop; and the lack of sufficient crop and pasture residues in some seasons for successful crop establishment using no-till methods. The adequacy of existing genetic resources for ley pastures in this region, the biological and economic sustainability of tropical ley systems, and the prospects for commercial use of the experimental results, are also examined.

164

Dregne, H.E. (1992): Rehabilitating degraded arid lands: options and decisions. *Problems of Desert Development* 3:19-22.

Keywords: degradation; grazing; stocking rate; rangeland; marginal lands; regeneration; improved pastures; economics.

Abstract. Land degradation affects three-quarters of the global grazing land, about half of the rainfed cropland, and about a quarter of the irrigated land. Reclamation of irrigated land is cost-effective for almost all of such land. It is believed to be cost-effective on about two-thirds of the rainfed cropland and no more than half of the grazing land. Since there is no socially or politically acceptable way to reduce stocking rates on marginal rangelands or to prevent cultivation of unfavorable croplands by government edict, ways must be found to bring about voluntary reduction of land pressures. The proposal presented in the paper is to concentrate resources on improved conservation and production on better lands. Little or nothing should be spent on improving marginal lands. In time, the need to exploit marginal lands would decrease, allowing them to recover, albeit slowly.

165

Herrera, M.A., Salamanca, C.P. and Barea, J.M. (1993): Inoculation of woody legumes with selected arbuscular mycorrhizal fungi and rhizobia to recover desertified Mediterranean ecosystems. *Applied and Environmental Microbiology* 59:129-133.

Keywords: legumes; ecosystems; revegetation; shrubs; desertification; degradation; mycorrhiza; rhizobia.

Abstract. Revegetation strategies, either for reclamation or for rehabilitation, are being used to recover desertified ecosystems. Woody legumes are recognized as species that are useful for revegetation of water-deficient, low-nutrient environments because of their ability to form symbiotic associations with rhizobial bacteria and mycorrhizal fungi, which improve nutrient acquisition and help plants to become established and cope with stress situations. A range of woody legumes used in revegetation programs, particularly in Mediterranean regions, were assayed. These legumes included both exotic and native plant species and were used in a test of a desertified semiarid ecosystem in southeast Spain. Screening for the appropriate plant species-microsymbiont combinations was performed previously, and a simple procedure to produce plantlets with optimized mycorrhizal and nodulated status was developed. The results of a 4-year trial showed that (i) only the native shrub legumes were able to become established under the local environmental conditions (hence, a reclamation strategy is recommended) and (ii) biotechnological manipulation of seedlings to be used for revegetation (by inoculation with selected rhizobia and mycorrhizal fungi) improved outplanting performance, plant survival, and biomass development.

166

Nepstad, D.C., Uhl, C. and Serrão, E.A.S. (1991): Recuperation of a degraded Amazonian landscape: forest recovery and agricultural restoration. *Ambio* 20:248-255.

Keywords: grasses; trees; agroforestry; Brazil; deforestation; reforestation; *Anacardium occidentale*; *Bixa orellana*; *Byrsonima crassifolia*; *Bertholletia excelsa*; *Spondias mombin*; *Swietenia macrophylla*; *Cedrela odorata*; *Stryphnodendron pulcherrimum*; fruit trees; tropical forest; pastures; degradation; sustainability; Amazon region.

Abstract. Ranching and logging operations are transforming the moist tropical forests of the eastern Amazonian landscape into a mosaic of pastures and regrowth forests. The process is illustrated by reference to the Paragominas region of Pará state, an area which has been ranched and logged for >20 yr. The new ecosystems of this region are agriculturally unproductive, biologically impoverished, and far more inflammable than the mature forests they replace; hydrological differences between the new and old systems are unknown and potentially large. In the absence of fire, the forest regrows on abandoned sites, accumulating biomass and species at a rate that is inversely related to the intensity of use prior to abandonment. Forest regrows slowest on those rare abandoned pastures that were once scraped with bulldozers. The grass- and shrub-dominated old fields that form on some of these sites resist forest regrowth because of numerous barriers to tree establishment and growth. These barriers have been studied in detail in an old field at Fazenda Vitoria (Vitoria Ranch), 6.5 km NW of Paragominas town, and include low propagule availability, seed and seedling predation, seasonal drought, and root competition with old field vegetation. Knowledge of these barriers provides a basis for developing inexpensive techniques (1) to restore agricultural productivity in old fields by planting tree-based agricultural systems or (2) to restore forest regenerative capacity in old fields by establishing trees that attract seed-carrying animals and ameliorate harsh environmental conditions. The first technique (an agroforestry option) has been used by Brazilian farmers of Japanese descent and involves planting fruit, nut and timber tree seedlings, whose growth may be enhanced by establishing them in a hole filled with loose soil and decaying organic matter in a weed-free area of 50-cm radius. Using this planting method at Fazenda Vitoria promoted fruiting of several species within 1 yr of planting (e.g. *Anacardium occidentalis* [*A. occidentale*], *Bixa orellana* and *Byrsonima crassifolia*). Slower growing fruit and nut trees were robust 2 yr after planting (e.g.

Bertholletia excelsa and *Spondias mombim* [*S. mombin*]) and even some timber species exceeded 4 m in height (e.g. *Swietenia macrophylla* and *Cedrela odorata*). The second technique involves planting 'island-forming' tree species that grow rapidly in full sun and produce fleshy fruits soon after planting, preferably establishing them at short intervals from the forest edge to the centre of the old field, so that seed carrying animals penetrate far into the old field. An example of such a species is *Stryphnodendron pulcherrimum*. These restoration techniques will be needed over large areas of Amazonia if current attempts to reform degraded pastures fail.

167

Uhl, C., Buschbacher, R. and Serrão, E.A.S. (1988): Abandoned pastures in eastern Amazonia. I. Patterns of plant succession. *Journal of Ecology* 76:663-681.

Keywords: pastures; degradation; Amazon region; South America; tropical forest; reforestation.

Abstract. (1) Vegetation composition, structure, and biomass accumulation were studied on thirteen forest sites that had been cut and burned, used as cattle pastures, and then abandoned in the eastern Amazon near Paragominas, Pará, Brazil. (2) The study sites were of two ages (two to four years and seven to eight years) and had received light, medium or heavy use for up to thirteen years. (3) Forest regenerated vigorously on sites of previously light use. Above-ground biomass accumulation averaged 10 t ha^{-1} yr^{-1} or 80 t after eight years (roughly one-quarter of mature forest levels). Tree species richness was also high (about 20 per 100 m^2) and almost all species also occurred in native forest. Moderately grazed pastures also developed forest but biomass accumulation was only 5 t ha^{-1} yr^{-1} . Tree species richness was also lower than on light-use sites and there were fewer forest trees. Abandoned pastures subjected to heavy use had the least distinct patterns of succession. The single eight-year-old site was dominated by grasses and forbs with fewer than one tree per 100 m^2 and an above-ground biomass accumulation of 0.6 t ha^{-1} yr^{-1} , a value only about 6% of that found on light-use sites. (4) The light-use sites had significantly higher biomass and species richness in both age-classes than either moderate- or heavy-use sites. Site age was a good predictor of above-ground biomass accumulation on light- and moderate-use sites, but not on heavy-use sites. (5) These Amazon ecosystems generally can recover after large-scale pasture disturbances. Only where land has been used too intensively for long periods is reforestation uncertain, but probably less than 10% of the pasture land in northern Pará has degraded to this level. Nevertheless, the re-growth forest, regardless of pasture-use history, will not necessarily have the same characteristics of physiognomy or species composition as that originally occupying the site. Moreover, as burning becomes more prevalent in eastern Amazonia, abandoned sites may not develop into forest and the irreversible degradation of the entire regional ecosystem must be contemplated.

168

Pyke, D.A. and Archer, S. (1991): Plant-plant interactions affecting plant establishment and persistence on revegetated rangeland. *Journal of Range Management* 44:550-557.

Keywords: establishment; rangeland; revegetation; ecosystems; plant-plant interactions; species diversity.

Abstract. Restoration and revegetation of rangeland ecosystems is based on knowledge of abiotic and biotic interactions that affect plant establishment. Once plants become autotrophic, interactions within and between plant species may occur and these interactions may range from antagonistic to mutualistic. This full range of potential interactions needs to be considered to ensure successful revegetation. At the intraspecific level, we propose the development and use of density-yield diagrams for rangeland species. These diagrams would be based on the self-thinning principle, that aboveground biomass is related to plant density and to the dynamic process of density-dependent mortality. The proposed approach would be used to determine optimum seeding rates, and to predict future biomass of revegetated rangelands. At the interspecific level, competitive relationships of species used to reseed rangelands need to be identified to enhance the probability that species will coexist and thereby facilitate greater species diversity on the site. A diversity of species and growth forms may provide a more stable cover and productivity than a monoculture on sites characterized by environmental variability while potentially enhancing nutrient status for the site.

169

Mukhammedov, G.M. (1986): Improvement of pastureland in the sand and clay deserts of the Central Kara Kum. (In Russian). *Problemy Osvoeniya Pustyn* 2:11-19.

Keywords: deserts; pastures; sheep; soil chemical properties; soil physical properties; Turkmenistan; shrubs; erosion; desertification; yields; soil salinity; cultivation methods; marginal lands; moisture collection; fertilizers; establishment.

Abstract. The possibilities to create new agrophytocenoses for pasture purposes without irrigation or application of fertilizers in the sand and clay deserts of Kara Kum (Turkmenistan) are outlined. Highly productive plant species of different life-forms adapted to the severe ecological conditions were selected from native vegetation, woody shrubs and semi-shrubs like black saxaul (*Aellenia subaphylla*), white saxaul (*Haloxylon persicum*) and *Calligonum* sp. being of special importance. In order to improve plant establishment, various agronomic techniques for crust breaking, moisture collection and surface stabilization have to be applied. Newly established plantings must be protected from grazing during the first 5 to 6 years. Improved pasturelands of this type can then help to reduce wind erosion and desertification problems as well as improve fodder supply throughout the year and forage yields. (Abstract by bibliography authors)

170

Yadav, I.P.S. and Hazra, C.R. (1989): Research and development linkages for the gainful use of wastelands on forage based farm forestry programme. *Journal of Rural Development (India)* 8:673-680.

Keywords: India; livestock; soil erosion; erosion; agroforestry; trees; shrubs; grasses; legumes; revegetation; marginal lands; acid soil.

Abstract. In India, grazing areas are generally owned by community and are used without any management. Especially marginal and submarginal lands which are usually uneconomical for crop cultivation are often used for grazing by livestock. Due to very high grazing pressure, these lands devoid of valuable forage species and are continuously subjected to soil erosion. The land utilization patterns are, therefore, being focussed for development of grazing resources on marginal, submarginal and wastelands through adoption of silvi-pastoral and

agro-forestry systems. Some suitable trees, shrubs, grasses and legumes for salt affected, acid, alkali and other problematic soils of Central India are presented. The success of any developmental programme depends upon the whole-hearted participation of all the agencies including the farmers.

171

Johnson, D.E., Borman, M.M. and Ben Ali, M.N. (1992): Evaluation of plant species for land restoration in central Tunisia. *Journal of Arid Environments* 22:305-322.

Keywords: revegetation; land restoration; rangeland; introduced species; grasses; legumes; seeds; establishment; yields.

Abstract. Initial screening of 241 plant species, varieties and accessions for potential use in revegetation was accomplished from 1982 to 1986 throughout Central Tunisia. Plants were rated and ranked on the basis of their survivability, vigor and production. Several promising plant species were further tested for yield at sites representing the major rangeland types in Central Tunisia. Several appear to have potential for revegetating rangelands, but on a site specific basis. Native species and accessions generally out performed introduced species and accessions. Annual species were superior to perennial species. The most promising annual grasses are *Lolium rigidum* and *Bromus mollis*. Legumes that have produced well are *Medicago truncatula, Hedysarum carnosum* and *Hedysarum spinosissimum*. Perennial grasses have survived at only two sites and only three species appear to have potential: *Oryzopsis miliacea* (Syn. *Piptatherum miliaceum*), *Eragrostis curvula* and *Dactylis glomerata*. These perennial grasses do not readily establish from seed. Establishment and productivity of all plants were highly variable from year to year and by location.

172

Serrão, E.A.S. (1981): Pasture research results in the Brazilian Amazon. *Proceedings of the XIV International Grassland Congress, Lexington (USA)*, p. 746-750.

Keywords: Amazon region; tropical savanna; tropical forest; *Panicum maximum*; *Brachiaria humidicola*; *Pueraria phaseoloides*; *Hyparrhenia rufa*; phosphorus; fertilization; pasture management; sustainability; degradation.

Abstract. Natural upland savanna grasslands are represented mainly by well drained savannas, with the cerrado type predominant, and by poorly drained savannas with the campo alto-type being the most common. The main limitations are low forage production potential and, especially, low forage quality. About 3 million ha of rain forest has been replaced by improved pastures of guineagrass (*Panicum maximum*, 80%), jaraguagrass (*Hyparrhenia rufa*, 10%), and *Brachiaria* spp. and other grasses (10%). During the first few years after establishment, pastures are productive. However, with time, a gradual decline of productivity occurs, especially in *P. maximum* pastures. About 0.5 million ha is already in advanced stages of degradation. Limiting factors include climate and plant and soil factors, besides man's influence. Research was conducted on 14 private ranches representing the most important improved- and native-pasture ecosystems of the Amazon region, with the objective of developing technology for (1) reclaiming sown pastures at varying degrees of degradation, (2) increasing the longevity of still-productive sown pastures in forest areas, and (3) increasing productivity of low-producing native pastures. Similar trials at all sites include the following: (1) introduction and evaluation of commercial forage species; (2) evaluation of grass-legume

mixtures; (3) forage fertilization; (4) pasture reclamation, improvement and management (grazing trials); and (5) adaptation of new forage germplasm. Results indicate that (1) maintenance of pasture productivity requires careful management of the soil-animal-plant system; (2) even though guineagrass has been planted on 2.5 million ha, other grasses can be more successful; (3) longevity of still-productive guineagrass pastures can be increased considerably by using appropriate grazing-management systems in combination with strategic use of phosphorus fertilization and legume introduction; (4) reclamation of guineagrass pastures in advanced stages of degradation can be achieved successfully by phosphorus fertilization and by introduction of low-demand grasses such as *Brachiaria humidicola* in combination with legumes, such as *Pueraria phaseoloides*.

173

Hall, T.J. (1988): Pasture species are suitable for revegetating degraded granitic soils of Hervey Range military training area in North Queensland. *Tropical Grasslands* 22:68-72.

Keywords: ground cover; legumes; erosion control; grasses; degradation; revegetation.

Abstract. Twelve pasture species were evaluated for their ability to regenerate eroded shallow granitic soil supporting a *Eucalyptus* woodland in the Hervey range military training area, with grazing excluded. *Bothriochloa insculpta* (Hatch creeping bluegrass) and *Melinis minutiflora* (molasses grass) were the most successful colonizing grasses; they maintained a dense sward for 3 seasons following rough cultivation and fertilization. *Bothriochloa pertusa* (Indian bluegrass) showed potential to give a low ground cover for camp sites. The legumes, *Stylosanthes hamata* (Verano) and *Macroptilium atropurpureum* (Siratro), persisted but their foliage covers were too low to control erosion. Hatch creeping bluegrass was the most promising grass for erosion control.

174

Howeler, R.H., Sieverding, E. and Saif, S. (1987): Practical aspects of mycorrhizal technology in some tropical crops and pastures. *Plant and Soil* 100:249-283.

Keywords: pastures; cassava; grasses; legumes; beans; soil pH; yields; establishment; fertilization; crop rotation; intercropping; VAM; mycorrhiza; acid soil; phosphorus.

Abstract. Greenhouse and field experiments were conducted on the effect of VA mycorrhiza (VAM) on the growth of cassava, various tropical grass and legume species, as well as beans, coffee and tea. A large number of VAM fungal species were evaluated for effectivity in increasing cassava growth and P uptake in acid low-P soils. The effectivity of VAM species and isolates was highly variable and dependent on soil pH and fertilizer applications, as well as on soil temperature and humidity. Two species, *Glomus manihotis* and *Entrophospora colombiana* were found to be most effective for a range of crops and pastures, at low pH and at a wide range of N, P and K levels. At very low P levels nearly all crops and pasture species were highly mycorrhizal dependent, but at higher soil P levels cassava and several pasture legumes were more dependent than grass species. Mycorrhizal inoculation significantly increased cassava and bean yields in those soils with low or ineffective indigenous mycorrhizal populations. In these soils cassava root yields increased on the average 20-25% by VAM inoculation, both at the experiment station and in farmers' fields. VAM inoculation of various pasture legumes and grasses, in combination with rock phosphate applications, increased their early growth and establishment. Agronomic practices such as fertilization, crop

rotations, intercropping and pesticide applications were found to affect both the total VAM population as well as its species composition. While there is no doubt about the importance of VA mycorrhiza in enhancing P uptake and growth of many tropical crops and pastures grown on low-P soils, much more research is required to elucidate the complicated soil-plant-VAM interactions and to increase yields through improved mycorrhizal efficiency.

175

Osonubi, O., Mulongoy, K., Awotoye, O.O., Atayese, M.O. and Okali, D.U.U. (1991): Effects of ectomycorrhizal and vesicular-arbuscular mycorrhizal fungi on drought tolerance of four leguminous woody seedlings. *Plant and Soil* 136:131-143.

Keywords: *Gliricidia sepium*; *Leucaena leucocephala*; VAM; mycorrhiza; legumes; *Albizia lebbeck*; phosphorus.

Abstract. Seedlings of *Acacia auriculiformis* A. Cunn. ex Benth., *Albizia lebbeck* (L.) Benth., *Gliricidia sepium* (Jacq.) Walp and *Leucaena leucocephala* (Lam.) de Wit. were inoculated with an ectomycorrhizal (*Boletus suillus* L. ex Fr.) or indigenous vesicular-arbuscular mycorrhizal (VAM) fungi in a low P soil. The plants were subjected to unstressed (well-watered) and drought-stressed (water-stressed) conditions. In *Gliricidia* and *Leucaena*, both mycorrhizal inoculations stimulated greater plant growth, P and N uptake compared to their non-mycorrhizal (NM) plants under both watering regimes. However, in *Acacia* and *Albizia*, these parameters were only stimulated by either ectomycorrhiza (*Acacia*) or VA mycorrhiza (*Albizia*). Growth reduction occurred as a result of inoculation with other type of mycorrhiza. This was attributed to competition for carbon between *Acacia* and VA mycorrhizas and parasitic association between *Albizia* and ectomycorrhiza. Drought-stressed mycorrhizal and NM *Leucaena*, and drought-stressed mycorrhizal *Acacia* tolerated lower xylem pressure potentials and larger water losses than the drought-stressed mycorrhizal and NM *Albizia* and *Gliricidia*. These latter plants avoided drought by maintaining higher xylem pressure potentials and leaf relative water content (RWC). All four leguminous plants were mycorrhizal dependent. The higher the mycorrhizal dependency (MD), the lower the drought tolerance expressed in terms of drought response index (DRI). The DRI may be a useful determinant of MD, as they are inversely related.

176

Allen, E.B. (1989): The restoration of disturbed arid landscapes with special reference to mycorrhizal fungi. *Journal of Arid Environments* 17:279-286.

Keywords: restoration; revegetation; establishment; succession; grasses; mycorrhiza; grassland; plant competition.

Abstract. The loss of mycorrhizal fungi in arid lands through man-caused and natural disturbances, including drought, erosion, tillage, and grazing, is a particular problem because a large proportion of the initial colonizing plant species are non-mycotrophic and their continued presence may preclude mycorrhizal establishment. As mycorrhizae are supposed to improve the growth of several species which are useful for land restoration and to increase their ability to compete with colonizing non-mycotrophic annuals, it was tested if the addition of mycorrhizal inoculum and removal of non-mycotrophic annuals would increase the rate of mycotrophic plant establishment and succession on disturbed sites in SW Wyoming. After three years of growing surprising results were obtained: (1) On high-nutrient soils coupled

with relatively high precipitations, mycorrhizae may act as a carbon drain, thereby decreasing the growth of planted grass (*Agropyron* species). (2) On poor soils where wind was an important factor, non-mycotrophic annuals were facilitating grass establishment, rather than competing with the grasses. (3) In soils of high inoculum, mycorrhizal fungi seemed to exert some kind of 'pathogenic' effect on non-mycotrophic species by directly reducing their growth and density. Thus, a high initial density of mycorrhizal inoculum may either hinder or promote the early stages of succession and an understanding of the heterogeneity of the landscape is critical before making decisions such as whether to inoculate, or whether to rely on natural dispersal of mycorrhizal fungi. (Abstract by bibliography authors)

177

Archer, S. and Pyke, D.A. (1991): Plant-animal interactions affecting plant establishment and persistence on revegetated rangeland. *Journal of Range Management* 44:558-565.

Keywords: establishment; rangeland; ecosystems; seeds; revegetation; mycorrhiza; invertebrates; rhizobia; succession; pollination; animal-plant interaction.

Abstract. The role of ungulate grazing in shaping rangeland ecosystems is well known relative to other important plant-animal interactions such as pollination, seed dispersal, granivory, and belowground herbivory. Successful rangeland revegetation may be enhanced by strategies that favor certain groups of animals and discourage others. Many perennial forbs and shrubs require animals for successful pollination, reproduction, and subsequent maintenance of species on a site; however, pollination biology of many rangeland plants and pollinator abundances at potential revegetation sites are largely unknown. Granivory may be significant in some locations and planning and design of revegetation areas may be improved by implementing principles of seed escape mechanisms, such as predator satiation, seed escape in space (low perimeter-to-area ratio for revegetation site), and seed escape in time (synchronous or staggered timing for nearby revegetation sites). Seedling establishment may be associated with invertebrate population levels which need to be considered in future revegetation projects. Timing and site preparation are important in limiting belowground herbivory. Animals can serve as dispersal agents of seeds. Livestock dosed with desirable seeds can disperse them in their dung across the landscape, thereby creating patches of desirable plants. If revegetation sites will be grazed by livestock, then managers should choose plant species that tolerate rather than avoid grazing and should apply adequate management to establish and maintain plant populations. Seed inoculated with mutualistic species such as mycorrhizae, nitrogen-fixing bacteria, or actinomycetes may enhance establishemnt, productivity, and nutrient quality of rangeland species while increasing rates of succession.

178

Sundararaju, R. and Chinnathurai, A.K. (1992): Technology packages for reclamation and development of wastelands. *Indian Forester* 118:609-615.

Keywords: reforestation; *Cassia siamea*; *Eucalyptus*; reclamation.

Abstract. In wasteland afforestations utmost care should be taken for selection of proper species. In areas of poor depth of soil and poor moisture retention application of fertilizers and tank silt/organic manure will increase success. *Wrightia tinctoria, Hardwickia binata, Albizia amara* will suit well. In social forestry, failure in plantation can be brought down by soil testing and selecting suitable species with some reclamation measures. Experiments in Tamil

Nadu indicate that *Casuarina* performs well in mine spoils. *Acacia planifrons, Acacia mellifera* and *Casuarina junghuhniana* could be used in drought prone area. Area under severe saline/alkaline problems could be improved by applying gypsum and fertilizers with drainage facilities. *Cassia siamea, Casuarina, Eucalyptus camaldulensis* and *Azadirachta indica* grow well even in such area.

179

Bellotti, W.D., Bowman, A. and Silcock, R.G. (1991): Sustaining multiple production systems. 5. Sown pastures for marginal cropping lands in the subtropics. *Tropical Grasslands* 25:197-204.

Keywords: pastures; subtropics; Australia; mixed farming; sustainability; semiarid zones; grasses; legumes; mulch; ley farming.

Abstract. Fertility and structure of surface soil is declining throughout the marginal dryland croplands of eastern Australia. The incorporation of a pasture phase in the cropping sequence appears to be the most promising option for developing a sustainable cropping system. However, special problems currently restrict the use of sown pastures in these lands in subtropical Queensland and NSW. For much of the region, productive and persistent pasture species have been identified. These include the native grasses, *Astrebla lappacea* and *Dichanthium sericeum*. Perennial grasses are still needed on the lighter textured infertile soils and there are still no adapted summer growing legumes for frost prone areas. Unreliable establishment is currently the main technical constraint limiting wider use of the available pasture species. Strategies for overcoming this constraint are discussed and include decision support packages using climatic and biological models, improving establishment by means of aerial seeding, mulches and stubbles, and management for improving the supply of soil moisture.

180

Plowright, R.C. and Hartling, L.K. (1981): Red clover pollination by bumble bees: A study of the dynamics of a plant-pollinator relationship. *Journal of Applied Ecology* 18:639-647.

Keywords: insect pollination; bumble bees; *Trifolium pratense*.

Abstract. (1) A 3-parameter probabilistic model provided a good fit to data relating seed set to the number of florets visited on red clover inflorescences by bumble bees. (2) The model, incorporated as a component in a computer simulation of bees foraging on a patch of red clover plants, was used to compare the pollinating efficiency of bees with different behavioural specifications with respect to the number of florets they visit per inflorescence. (3) Insects which visited only a few florets on each inflorescence were found almost always to cause lower seed set than those which based their decision to leave on the reward status of the inflorescence, even though the rate of inter-inflorescence transitions was greater for the former behavioural specification. Since the second type of behaviour is characteristic of real bumble bees and always returns higher profit to the insect, it is concluded that the coevolutionary relationship between *Bombus* and red clover is adapted to maximize the self interest of both partners.

181

Ahmad, A. (1992): Environmental degradation and possible solutions for restoring the land: A case study of magnesite mining in the Indian Central Himalayas. *Desertification Bulletin (UNEP)* 21:15-23.

Keywords: degradation; India; ecosystems; mining; regeneration; revegetation; soil erosion; grasses.

Abstract. In India, the total land area under mining is estimated at about 7,854 km^2. In 1982, there were about 4,052 working mines, excluding those producing oil, gas, atomic energy, minerals and minor minerals. Of these, 2,854 were mining non-metallic minerals, 720 were mining metallic minerals and the remaining 478 were mining coal and lignite. Among the non-metallic minerals, magnesite mining plays an important role because of its major use in India's steel industry. Mining must be one of the most destructive of all of man's activities on the environment. It destroys the original ecosystem and replaces it with only an empty pit, a sterile wasteland, or both. Consequently, mined land represents a fascinating challenge to scientists who are attempting to find ways of restoring the original ecosystem. This present study was undertaken to rehabilitate a damaged, mined ecosystem using an ecological approach for sustainable development. (Abstract by bibliography authors)

182

West, N.E. (1993): Biodiversity of rangelands. *Journal of Range Management* 46:2-13.

Keywords: rangeland; genetics; ecosystems; invertebrates; livestock; biodiversity; species diversity; sustainability.

Abstract. Biodiversity is a multifaceted phenomenon involving the variety of organisms present, the genetic differences among them, and the communities, ecosystems, and landscape patterns in which they occur. Society will increasingly value biodiversity and influence the passage of laws and writing of regulations involving biodiversity which rangeland managers will have to abide by over the coming decades. While taxonomic knowledge of vertebrates and vascular plants and their abundance, rarity, and distribution, in the developed nations is generally adequate, the same cannot be said of the developing world. Furthermore, adequate knowledge of invertebrates, nonvascular plants, and microbes is deficient everywhere. Although the basis of variation at all higher levels, genetic variation within rangeland species, even the major ones, has barely been assessed. Obtaining statistically adequate data on populations of rare species that are small and secretive is well nigh impossible. We have many means of measuring community diversity, but all of them are value laden. That is, choice of variables to measure and how they are indexed betrays what we consider are important. We should be more forthright in stating to the users the biases of these methods. There are many other, more useful ways to describe community-level diversity besides the traditional focus on species. Ungulate grazing is an important process in many ecosystems. Thus, removal of grazing destabilizes some systems. Livestock grazing will actually increase the chances of survival of some species. Moderate livestock grazing can also enhance community and landscape-level diversity in many instances. Attention is now shifting from "charismatic" species to defensively managing larger tracts of land with habitat or ecosystems holding suites of sensitive species. Since some accelerated extinction of isolated populations and species is inevitable, we need to know which species and ecotypes are most valuable. Understanding of modular, guild, and functional group structure would also help us identify keystone or critical link species and better focus our attention on truly important tracts of land where they live. It

is probably more important to sustain soils and ecosystem processes than any randomly selected species, especially if functionally redundant species can be identified. Similarly, not all introduced, alien, or exotic species are equal threats; it depends on how they fit into ecosystems. Sustainable development will depend on finding balance between use and protection, from range sites to landscapes, and even on a global basis.

183

Miranda, E.E.de and Mattos, C. (1992): Brazilian rain forest colonisation and biodiversity. *Agriculture, Ecosystems and Environment* 40:275-296.

Keywords: biodiversity; ecosystems; deforestation; economics; tropical forest; species diversity; degradation; Brazil; Amazon region.

Abstract. This work explains the tropical rain forest's main characteristics, and the reasons why this ecosystem plays an important role in determining global biodiversity. The occupation process of the two Brazilian tropical rain forests (Atlantic and Amazon) are briefly described, with quantitative information on deforestation and its consequences. Human presence in these areas is millenary, and its role as a source of increase, decrease and maintenance of biodiversity are exemplified. Different kinds of man/forest interactions (such as those characterizing indigenous people, riverside communities, caboclos, rubber tappers and agriculturists) and their relation to biodiversity, are described. The future occupation of the Brazilian tropical rain forest supplanting past mistakes, especially in the Amazon, is proposed as a triple challenge. The first challenge is to stop the destruction of the still-intact forest, and to plan its rational occupation. An example of how this has been done by rubber tappers in the state of Acre, and how it affects wildlife and vegetation communities is given. The second challenge is to reduce the migration flow towards the economic frontier areas, and to propose to the thousands of agriculturists already installed there alternatives to reconcile economic development and environmental preservation. In this case, the situation of a colonization project in the state of Rondônia is described. The third challenge is to restore the biodiversity in the almost 400 000 km^2 of land that have been occupied and degraded for a long time, as in the state of Tocantins. An example of how scientific research contributes to meeting this challenge is described.

184

Pimm, S.L. and Gittleman, J.L. (1992): Biological diversity: Where is it? *Science* 255:940.

Keywords: biodiversity; tropics; species diversity.

Abstract. Some knowledge gaps and facts concerning the distribution of species across the planet (e.g., temperate and tropical diversity), their number in a specific habitat, and the turnover of species across space are discussed in this short paper. (Abstract by bibliography authors)

185

Huston, M. (1979): A general hypothesis of species diversity. *American Naturalist* 113:81-101.

Keywords: species diversity; models; ecosystems; biodiversity.

Abstract. A new hypothesis, based on differences in the rates at which populations of competing species approach competitive equilibrium (reduction or exclusion of some species), is proposed to explain patterns of species diversity. The hypothesis assumes that most communities exist in a state of nonequilibrium where competitive equilibrium is prevented by periodic population reductions and environmental fluctuations. When competitive equilibrium is prevented, a dynamic balance may be established between the rate of competitive displacement and the frequency of population reduction, which results in a stable level of diversity. Under conditions of infrequent reductions, an increase in the population growth rates of competitors generally results in decreased diversity. This model clarifies an underlying pattern of variation in diversity and points out the common elements of previous hypotheses. Rather than arguing that either competition, predation, or productivity control diversity, it demonstrates that all of these may contribute to the same basic mechanism. In doing so, it not only explains the correlations of the other hypotheses with patterns of diversity, but also explains the exceptions that these hypotheses could not explain. This hypothesis may be applied to variations of diversity both on a latitudinal gradient and within specific regions.

186

Walker, B.H. (1992): Biodiversity and ecological redundancy. *Conservation Biology* 6:18-23.

Keywords: biodiversity; species diversity; ecosystems.

Abstract. This paper addresses the problem of which biota to choose to best satisfy the conservation goals for a particular region in the face of inadequate resources. Biodiversity is taken to be the integration of biological variability across all scales, from the genetic, through species and ecosystems, to landscapes. Conserving biodiversity is a daunting task, and the paper asserts that focusing on species is not the best approach. The best way to minimize species loss is to maintain the integrity of ecosystem function. The important questions therefore concern the kinds of biodiversity that are significant to ecosystem functioning. To best focus our efforts we need to establish how much (or how little) redundancy there is in the biological composition of ecosystems. An approach is suggested, based on the use of functional groups of organisms defined according to ecosystem processes. Functional groups with little or no redundancy warrant priority conservation effort. Complementary species-based approaches for maximizing the inclusion of biodiversity within a set of conservation areas are compared to the functional-group approach.

187

McNaughton, S.J. (1993): Biodiversity and function of grazing ecosystems. In: Schulze, E.D. and Mooney, H.A. (eds.), *Biodiversity and Ecosystem Function*. Berlin: Springer-Verlag, p. 361-383.

Keywords: biodiversity; grazing; ecosystems; grassland; species diversity; USA; savanna; Tanzania; California.

Abstract. Fundamental ideas about biodiversity and function of grazing ecosystems are amplified throughout this report. The author looks at the general nature of diversity in grasslands and the relationships between productivity, stability and species diversity. Data are presented from studies of (a) abandoned agricultural fields in Central New York State, USA, (b) the savanna grasslands of Serengeti National Park, Tanzania, and (c) the grasslands of

Yellowstone National Park, USA. There is evidence that primary productivity, as measured by the change in total community standing crop, is inversely related to diversity. The successional studies, however, indicated that species' productivities are spaced more evenly through the growing season in more diverse vegetation. (Abstract by bibliography authors)

188

Ehrlich, P.R. and Wilson, E.O. (1991): Biodiversity studies: Science and policy. *Science* 253:758-762.

Keywords: biodiversity; economics; ecosystems; deforestation; tropical forest.

Abstract. Biodiversity studies comprise the systematic examination of the full array of different kinds of organisms together with the technology by which the diversity can be maintained and used for benefit of humanity. Current basic research at the species level focuses on the process of species formation, the standing levels of species numbers in various higher taxonomic categories, and the phenomena of hyperdiversity and extinction proneness. The major practical concern is the massive extinction rate now caused by human activity, which threatens losses in the esthetic quality of the world, in economic opportunity, and in vital ecosystem services.

189

Burton, P.J., Balisky, A.C., Coward, L.P., Cumming, S.G. and Kneeshaw, D.D. (1992): The value of managing for biodiversity. *The Forestry Chronicle* 68:225-237.

Keywords: biodiversity; ecosystems; sustainability; genetics; species diversity; silvopastoral systems.

Abstract. The concept of biological diversity (biodiversity) is reviewed, with special attention to its measurement and natural trends. While generalizations regarding the necessity of biodiversity need to be interpreted with caution, it is argued that biodiversity should be protected in more ecosystem and landscape reserves, and that biodiversity is a reasonable management objective on timber lands as well. Maintaining biodiversity is important because we cannot always identify which individual species are critical to ecosystem sustainability, nor which species may be useful to mankind in future. Many wild species can provide useful natural products and genetic material, and can serve as ecological indicators. Diversity reduces pest and disease problems, and encourages recovery from disturbance. Uncertainty exists with regard to climate change and future socioeconomic values. It is therefore prudent to maximize flexibility by promoting a wide array of species and potential products. Suggestions are offered on how to promote biodiversity in multiple-use forests.

190

Chalmers, N. (1992): Saving the ark. *Science and Public Affairs London* 7(4):14-19.

Keywords: biodiversity; deforestation; ecosystems; sustainability; species diversity.

Abstract. Biodiversity is being lost due to deforestation, draining of wetlands and release of toxic waste, amongst other activities. It is estimated that a quarter of the world's biodiversity may be under serious threat of extinction over the next 20-30 years (15 000 to 50 000 species/year). Three long-term benefits of biodiversity conservation, namely, socioeconomic,

ecosystem service and cultural are described. The importance of scientists in the study of the world's biodiversity, provision of politicians with priorities for conservation, monitoring the effects of sustainable use of biodiversity and education of the public on the importance of biodiversity are discussed using examples of work currently being undertaken by the Natural History Museum in collaboration with other institutes.

191

Clement, J. (1991): Que penser de la déforestation des pays tropicaux? *ONF - Bulletin Technique* 21:259-267.

Keywords: deforestation; genetics; biodiversity; tropical forest.

Abstract. Deforestation in tropical countries has dramatically accelerated during the last decade, jumping from some 11 million hectares per year to nearly 20 million. This primarily affects the local populations, who are deprived of essential commodities provided by forests such as fuelwood, fruits, medicines, game, etc., as well as the economics of tropical countries, whose timber resources go up in smoke, and deforested soils are inexorably degraded. Moreover, international public opinions are concerned about impact of forest destruction on global climatic equilibria and the preservation of genetic biodiversity. Remedies for deforestation lie for the most part outside the forest sector: food and energy security, harmonious land-use management, etc. On the other hand, the Tropical Forest Action Plan launched in 1985 has as an objective to promote development of new policies aimed at restoring equilibrium between man and his environment within the framework of a sustainable utilization of natural resources.

192

Lugo, A.E., Parrotta, J.A. and Brown, S. (1993): Loss in species caused by tropical deforestation and their recovery through management. *Ambio* 22:106-109.

Keywords: deforestation; degradation; tropical forest; models; trees; biodiversity; species diversity.

Abstract. The loss of species as a result of deforestation and degradation of tropical forest lands is widely discussed. Models based on island biogeography theory are used to evaluate the relationship between extinctions of species and deforestation. The analysis shows that natural resiliency causes the models to overestimate the rates of species extinctions for given intensities of deforestation. There is an opportunity to couple natural processes with management activities to reduce species extinctions and restore species richness to degraded lands. As an example we show how tropical monoculture tree plantations can foster diverse native forests in areas previously deforested. The central point is that well-directed human actions provide us with the means to conserve biodiversity and restore it in locations previously degraded.

193

Murgueitio, E. (1990): Intensive sustainable livestock production: An alternative to tropical deforestation. *Ambio* 19:397-400.

Keywords: deforestation; sustainability; tropical forest; Colombia; forage trees; sugarcane; sheep; yields; swine; pastures; degradation.

Abstract. To solve the problem of tropical forest destruction demands a strategy which is of necessity complex, and yet must also be aggressive, if the remaining tropical forest areas with their ecological riches and biological diversity are to be preserved. Intensive livestock production models, based on true tropical resources, appear to offer real alternatives to the pressures exerted by the major enemy of the forest - the extensively grazed beef animal. The model developed in Colombia employs perennial crops with high biomass production potential (sugarcane and forage trees) and complementary livestock species (pigs and sheep) managed in confinement. Productivity is a function of sugarcane yield which depends on soil fertility, water availability and variety. For the world average yield of 50 t/ha per year, total liveweight production per year from pigs and sheep can be 1500 kg/ha per year. However, with appropriate management, sugarcane can yield up to 180 t/ha per year, which will give 8000 kg liveweight pr hectare per year. Implementing these models on a massive scale will result in a substantial reduction of the area required to support resource-poor farmers, committed to colonizing the forest. At the same time, existing grazing areas can be transformed into more productive units with obvious advantages in terms of job creation and economic stimulus to rural development. More research and development is needed, and especially the validation of the technologies in areas where the rate of forest destruction is most acute.

194

Westoby, M., Walker, B. and Noy-Meir, I. (1989): Opportunistic management for rangelands not at equilibrium. *Journal of Range Management* 42:266-274.

Keywords: rangeland; animal-plant interaction; grassland; livestock; pasture management; succession; models.

Abstract. We discuss what concepts or models should be used to organize research and management on rangelands. The traditional range succession model is associated with the management objective of achieving an equilibrium condition under an equilibrium grazing policy. In contrast, the state-and-transition model would describe rangelands by means of catalogues of alternative states and catalogues of possible transitions between states. Transitions often require a combination of climatic circumstances and management action (e.g., fire, grazing, or removal of grazing) to bring them about. The catalogue of transitions would describe these combinations as fully as possible. Circumstances which allow favorable transitions represent opportunities. Circumstances which threaten unfavorable transitions represent hazards. Under the state-and-transition model, range management would not see itself as establishing a permanent equilibrium. Rather, it would see itself as engaged in a continuing game, the object of which is to seize opportunities and to evade hazards, so far as possible. The emphasis would be on timing and flexibility rather than on establishing a fixed policy. Research under the state-and-transition model would aim to improve the catalogues. Frequencies of relevant climatic circumstances would be estimated. Hypotheses about transitions would be tested experimentally. Often such experiments would need to be planned so that they could be implemented at short notice, at an unknown future time when the relevant circumstances arise.

195

McIvor, J.G. and Orr, D.M. (1991): Sustaining productive pastures in the tropics. 2. Managing native grasslands. *Tropical Grasslands* 25:91-97.

Keywords: pastures; tropics; grassland; natural pastures; Australia; sustainability; animal production.

Abstract. The grasslands of tropical Australia include the naturally treeless, grass dominated communities and the grassy understories of the widespread woodlands and shrublands. Information from the monsoon tallgrass, tropical and subtropical tallgrass, tussock grasslands (Mitchell grass) and *Acacia* (mulga) shrublands is used to show how management can influence grassland performance. Emphasis is placed on vegetation responses but effects on soil characteristics and animal production are also considered. The major management options considered are control of stock (numbers, species, breeds, when and where they graze), fire, feed supplements and timber treatment. Changes in land condition in the Burdekin catchment in response to management and seasonal conditions are outlined. The various options must be integrated and the role of decision support packages is considered. Major changes are occurring in the northern grasslands and future management research should include studies of the ecology of the main grass species, the biology and management of woody plants, other pasture types (e.g., *Bothriochloa/Aristida* lands), stocking rate/animal production relationships, the costs and benefits of management practices, e.g. temporary overgrazing, and grazing systems for changing pasture composition and animal production.

196

Belsky, A.J. (1986): Does herbivory benefit plants? A review of the evidence. *American Naturalist* 127:870-892.

Keywords: grazing; animal-plant interaction; evolution; herbivory.

Abstract. The potential benefits of herbivory to plants have been debated over the last decade. Several investigators claim that removal of or damage to the productive, absorptive, or reproductive tissue of plants by herbivores benefits some plant species by increasing their net primary productivity, seed production, or longevity, and that these changes increase plant fitness and result in the evolution of herbivore-plant mutualisms. Although more than 40 papers have been cited as presenting experimental evidence in support of these benefits and mutualisms, strong evidence is lacking. Increased plant biomass as a result of tissue removal has been found only under growth-chamber conditions and in cultivated crops. Although herbivores may benefit certain plants by reducing competition or removing senescent tissue, no convincing evidence supports the theory that herbivory benefits grazed plants.

197

Eng, P.K., Kerridge, P.C. and Mannetje, L.'t (1978): Effects of phosphorus and stocking rate on pasture and animal production from a guinea grass-legume pasture in Johore, Malaysia. 1. Dry matter yields, botanical and chemical composition. *Tropical Grasslands* 12:188-197.

Keywords: phosphorus; stocking rate; pastures; animal production; grass-legume pastures; yields; chemical composition; grasses; nitrogen; succession; species diversity.

Abstract. Changes in yield on offer, botanical composition, species frequency and chemical composition were measured from a continuously grazed guinea grass-legume (stylo, centro, puero) pasture over three years. The treatments were a factorial combination of three stocking rates and four annual maintenance rates of phosphorus comprising three rates of rock phosphate and one of superphosphate. Pasture availability remained relatively constant at the low stocking rate, after the first year at the medium stocking rate, but declined markedly over the three years at the high stocking rate. The proportion of guinea grass, which was dominant, decreased with stocking rate in the third year. That of centro and stylo increased after the first year and was not affected by stocking rate except that of centro at the high stocking rate in in the third year. Puero disappeared from the pasture at all stocking rates after two years. The phosphorus treatments had no effect on presentation yields. There was a significant increase in phosphorus concentration of all species and calcium concentration of guinea grass with increasing rates of rock phosphate during the second and third year. Phosphorus treatments had no effect on the nitrogen concentration of species except for stylo in the third year.

198

Ryder, R.A. (1980): Effects of grazing on bird habitats. In: DeGraff, R.M. and Tilghmann, N.G. (eds.), *Management of Western forests and grasslands for nongame birds*. Ogden: US Forest Service, Gen. Tech. Rep. INT-86 Intermount. Res. Sta., p. 51-66.

Keywords: grazing; grassland; livestock; rodents; birds; grasses; biodiversity; insects; species diversity.

Abstract. Feeding on plants by various herbivores, especially livestock and big game but also by rodents, lagomorphs, insects and even some birds and reptiles, can alter vegetative communities as habitat for birds. Species composition of plants, density of stands, vigor, seed and insect production, and growth form of plants often change due to grazing. Removal of vegetative cover as well as trampling may expose soils to increased wind and water erosion. In shortgrass, for example, resultant gullies may provide new nesting habitat for rock wrens, rough-winged swallows, Say's phoebes, and barn owls while reducing nesting, escape and young-rearing habitat for species requiring denser stands of taller grasses such as meadowlarks and lark buntings. Just as some plants such as buffalo grass and blue grama can be considered "increasers" with grazing of shortgrass prairie so can horned larks, McCown's longspurs, and mountain plovers. Likewise, western meadowlarks, lark buntings and Brewer's sparrows tend to be "decreasers" similar in response to that of western wheatgrass, needle-and-thread and fourwing saltbush to increased summer grazing by cattle on shortgrass ranges in northcentral Colorado. Differences in effects of grazing on vegetation and soils by various classes of livestock, species of big game, different levels of intensity and seasons of use will be discussed with stress on examples from western forest and grassland types.

199

Paige, K.N. and Whitham, T.G. (1987): Overcompensation in response to mammalian herbivory: The advantage of being eaten. *American Naturalist* 129:407-416.

Keywords: animal-plant interaction; seed production.

Abstract. Plants of scarlet gilia, *Ipomopsis aggregata*, are exposed to high levels of mammalian herbivory (by mule deer, *Odocoileus hemionus*, and elk, *Cervus elaphus*) early in the season, before flowering. During this period of our study, up to 56% of all individuals

experienced a 95% reduction in aboveground biomass. Browsed plants rapidly responded by producing new inflorescences and flowering within 3 wk. Unbrowsed plants produced only single inflorescences, whereas browsed plants produced multiple inflorescences. Field observations and experimental manipulations showed that plants with multiple inflorescences produced significantly greater numbers of flowers and fruits than unbrowsed individuals. Because there were no differences between browsed an unbrowsed individuals in the number of seeds produced per fruit, seed weight, subsequent germination success, and survival, browsed plants enjoyed a 2.4-fold increase in relative fitness. Consequently, there is an immediate reproductive advantage to being eaten. Under the natural field conditions of this study, mammalian herbivores played a beneficial role in the survival and reproductive success of scarlet gilia.

200

Waser, N.M. and Price, M.V. (1981): Effects of grazing on diversity of annual plants in the Sonoran desert. *Oecologia* 50:407-411.

Keywords: deserts; species diversity; cattle; models; animal-plant interaction.

Abstract. A two-year survey of winter-germinating annual plants in southern Arizona indicates that species diversity declines consistently as a function of increasingly recent grazing by cattle. This finding conflicts with reports that predators enhance prey species diversity in some marine and terrestrial systems. Consideration of equilibrium and nonequilibrium models suggests, however, that enhanced diversity should occur only for open, multi-celled prey populations experiencing intermittant predation. These general conditions appear not to hold for the cattle-annual plant system.

201

Caldwell, M.M., Richards, J.H., Johnson, D.A., Nowak, R.S. and Dzurec, R.S. (1981): Coping with herbivory: Photosynthetic capacity and resource allocation in two semiarid *Agropyron* bunchgrasses. *Oecologia* 50:14-24.

Keywords: grasses; animal-plant interaction.

Abstract. *Agropyron desertorum*, a grazing-tolerant bunchgrass introduced to the western U.S. from Eurasia, and *Agropyron spicatum*, a grazing-sensitive bunchgrass native to North America, were examined in the field for photosynthetic capacity, growth, resource allocation, and tiller dynamics. These observations allowed identification of physiological characteristics that may contribute to grazing tolerance in semiarid environments. Following defoliation, *A. desertorum* plants rapidly reestablished a canopy with 3 to 5 times the photosynthetic surface of *A. spicatum* plants. This difference was primarily due to the greater number of quickly growing new tillers produced following defoliation. *Agropyron spicatum* produced few new tillers following defoliation despite adequate moisture, and carbohydrate pools that were equivalent to those in *A. desertorum*. Leaf blades of regrowing tillers had higher photosynthetic capacity than blades of unclipped plants of both species, but the relative increase, considered on a unit mass, area, or nitrogen basis, was greater for *A. desertorum* than for *A. spicatum*. *Agropyron desertorum* also had lower investment of nitrogen and biomass per unit area of photosynthetic tissues, more tillers and leaves per bunch, and shorter lived stems, all of which can contribute to greater tolerance of partial defoliation.

202

Owen, D.F. (1980): How plants may benefit from the animals that eat them. *Oikos* 35:230-235.

Keywords: grasses; animal-plant interaction; insect-plant interaction; nutrient cycle; nitrogen fixation.

Abstract. It is suggested that the mutually beneficial relationships between flowers and their pollinators and between fruits and fruit-eaters can be extended to cover a much wider range of plant-consumer interactions. The ability to photosynthesize is by itself of limited value to a plant if growth and reproduction are restricted by the availability of nutrients. Hence natural selection should favour adaptations that increase the rate of supply of a scarce resource. By enlisting the "help" of a consumer a plant may facilitate cycling and increase the supply of a nutrient in short supply; in particular the deposition of sugary honeydew by aphids may increase the rate of nitrogen fixation beneath the plant by providing an energy source to free-living nitrogen-fixing bacteria. Consumers may also affect the growth form of a plant in a beneficial way; grasses, for example, survive best when cropped and are probably totally co-evolved with grazers: one would not be possible without the other. A speculative paper as this almost certainly contains errors of interpretation, but even if only some of the suggestions are correct the common viewpoint that plants defend themselves against consumers will have to be radically changed.

203

Maschinsky, J. and Whitham, T.G. (1989): The continuum of plant responses to herbivory: The influence of plant association, nutrient availability, and timing. *American Naturalist* 134:1-19.

Keywords: animal-plant interaction.

Abstract. In a single population of *Ipomopsis arizonica* (Polemoniaceae), we show a continuum of compensatory responses to vertebrate herbivory. We demonstrate experimentally that the degree of herbivore impact depends on plant association, nutrient availability, and timing of grazing. From 1985 to 1987, the most common response to vertebrate herbivory was equal compensation, whereby grazed plants set numbers of fruit and seeds equal to controls within the same growing season. However, we also observed cases of significant overcompensation and undercompensation. In 1985 and 1987, overcompensation occurred in vertebrate-grazed plants that were supplemented with nutrients and growing free of competition. These plants produced 33% to 120% more fruit than control, ungrazed plants. Cases of undercompensation occurred in groups where *I. arizonica* grew in association with grasses or where nutrients were not supplemented. Grazed and clipped plants in these groups produced from 28% to 82% as many fruits as did ungrazed controls. Our studies indicate that the compensatory response of plants to grazing is probabilistic when three external factors are considered. The probability of compensation for herbivory decreases as competition with other plants increases, as nutrient levels decrease, and as the time of herbivory comes later in the growing season.

204

Milchunas, D.G., Sala, O.E. and Lauenroth, W.K. (1988): A generalized model of the effects of grazing by large herbivores on grassland community structure. *American Naturalist* 132:87-106.

Keywords: models; grassland; animal-plant interaction; plant competition; plant succession; succession; evolution.

Abstract. Current disturbance models do not adequately account for the wide range of responses by grassland plant communities to grazing by large generalist herbivores. The evolutionary history of grazing, an important factor in the response of grasslands to grazing, has not been explicitly addressed. Grazing history alone, however, is not a good predictor of plant-herbivore interactions. Interactions occur along gradients of convergent to divergent selection pressures with increasing environmental moisture and of intolerance to tolerance of grazing with increasingly long evolutionary histories of grazing. We suggest that feedback mechanisms between plants and grazing animals are well developed in grasslands with long evolutionary histories of grazing. Feedback mechanisms are manifest in the rapid switching capabilities (of plant species and modes of competition) of subhumid grasslands with long evolutionary histories of grazing and divergent selection pressures. Switching capabilities do not exist in semiarid grasslands with long evolutionary histories of grazing and convergent selection pressures. Rather, for heavily grazed dominant species dominance increases. Feedback mechanisms are not well developed in systems with short evolutionary histories of grazing. In these cases, the differences in response to grazing by semiarid and subhumid situations arise primarily from differences in the grazing tolerance of plants adapted to semiaridity or of plants adapted to competition for light and from the different effects of grazing on canopy structure.

205

Walker, B. (1991): Sustaining tropical pastures - summative address. *Tropical Grasslands* 25:219-223.

Keywords: natural pastures; animal production; sustainability; Australia; farming systems; pastures; weeds.

Abstract. By the year 2000 over 95% of the pastoral areas of northern Australia will still consist of native pastures. Previous studies show that in Queensland, about 50-60% of native pastures are in good condition; 30% require low key-management inputs to improve them and the remainder will need a major capital outlay to restore them. Research inputs into native pastures fall well below those required. In addition to current work described at this conference, an assessment of the present condition and health of the grazing lands, together with an ongoing program to monitor trends, particularly in high risk areas, is urgently needed. Management packages directed at specific needs for local areas are required. An optimistic scenario for development of introduced pasture over the next decade is that sown and naturalized pastures will increase from the present 9.8 to 13.4 m ha. Areas of fodder crops will increase from 500 000 to 1.0 m ha and clearing of woodlands and control of woody weeds will continue at least at the present level of 500 000 ha per year. Most of this development will be on the more fertile soils in the above 600 mm mean annual rainfall areas south of Townsville. Research emphasis should now move away from species development to developing management systems for optimal productivity and stability. Scientists and advisors have not been successful in developing sound guidelines on the development and management

of pastoral systems sustainable on a whole property basis up to the present time. Producers are more advanced in their thoughts and actions on sustainable systems and their knowledge and experience should be accessed before any new work is undertaken. An over riding influence on long term work on sustainable pastoral systems is the shortage of funds and resources. Administrators and research leaders will need to make some tough decisions on research priorities.

206

Lonsdale, W.M. (1994): Inviting trouble: Introduced pasture species in northern Australia. *Australian Journal of Ecology* 19:345-354.

Keywords: pastures; Australia; weeds; grasses; legumes; seeds; introduced species.

Abstract. I surveyed the history of exotic pasture introductions in northern Australia to compare the rate of introduction of useful species with that of weeds. Between 1947 and 1985, 463 exotic grasses and legumes in at least 2033 accessions were intentionally introduced into the region, the grasses predominantly from Africa, and the legumes from Central and South America. Of these, only 21 (5%) came to be recommended as useful, while 60 (13%) became listed as weeds. Seventeen of the useful plants were in fact also weeds, leaving only 4 species (<1%) that were useful without causing weed problems. They were far outnumbered by the 43 species (9%) that were weeds but had no recorded use. Of the 60 weeds, 21 were weeds of cropping, 20 were weeds of conservation and 19 were weeds of both sectors. Thirteen were listed as major crop weeds. Growth rate, maximum height, seed size, and continent of origin were unrelated to weediness. Good predictors of weediness were whether a plant was useful, a good performer in trials, or persisted at a field site. In addition, grasses were more likely, and legumes less likely, to be weedy than expected. It is argued that a new form of assessment is required before an exotic plant species is released into Australian environment as a pasture plant. This would recognize that a successful introduction is almost certain to become a weed in some situations, and would attempt to assesss the net national benefit of the proposed introduction.

207

Johnson, H.B. and Mayeux, H.S. (1992): Viewpoint: A view on species additions and deletions and the balance of nature. *Journal of Range Management* 45:322-333.

Keywords: ecosystems; deserts; establishment; tropics; species diversity; rangeland; vegetation change; introduced species; evolution.

Abstract. Popular assumptions about ecosystem stability and the delicate balance of nature are found lacking when examined in terms of paleoecological, historical and current biochronological, and biogeographical sequences in a wide variety of environments. Species composition of vegetation varies continuously in time as well as space in the absence of acute perturbations. Species have been added or removed from ecosystems without greatly affecting ecosystem function. Natural ecosystems exhibit greater stability (inertia) in physiognomic structure and funtional processes than in species composition. For instance, creosotebush became dominant over many million of hectares of the Chihuahuan, Sonoran, and Mojave Deserts over a short period of 11,000 years, but a limited number of generations precludes establishment of highly integrated and biologically regulated communities by co-evolution. Dramatic shifts in species composition of eastern deciduous forests of North America occured

in prehistory and continue into the present. Similar changes are noted in the constant assembling and reassembling of species in the purportedly ancient and stable forests of the tropics. Numerous introductions with few extinctions in the flora of California have increased species richness and probably diversity, and many recent additions are primary contributors to ecosystem productivity. Recognition that rangeland ecosystems persist in unstable rather than stable compositions provides both a challenge and an opportunity for natural resource management. The challenge is to develop new management principles that incorporate nonequilibrium theory. The opportunity is the promotion of policies and regulations that more closely reflect reality.

208

Kaushal, B.R. and Vats, L.K. (1983): Population dynamics and biomass production of aboveground insects in a tropical grassland. *Proceedings of the Indian Academy of Science (Animal Science)* 92:447-452.

Keywords: insects; grassland; India; ecosystems.

Abstract. Population dynamics and aboveground insects were studied in a tropical grassland. A total of 30 species belonging to five insect orders viz., *Odonata, Mantoidea, Blattoidea, Neuroptera* and *Diptera* were collected. Maximum population density and biomass values on stands I and II were determined.

209

Mellink, E. (1991): Bird communities associated with three traditional agroecosystems in the San Luis Potosí Plateau, Mexico. *Agriculture, Ecosystems and Environment* 36:37-50.

Keywords: tropical savanna; wild birds; agroecosystems; pests; crop residues; Mexico; grassland; animal-plant interaction; farming systems.

Abstract. The bird communities associated with three traditional dry farming systems, their borders and their unfarmed surroundings on the San Luis Potosí Plateau, Mexico, were studied throughout the year. The systems studied were (1) a purely rain-fed field in a grassland with shrubs, (2) a field on a bajada irrigated with runoff water in a complex and dense community of cacti and shrubs, and (3) a bajío field irrigated with spring moisture and an ephemeral wash in a savanna. The results are in agreement with the hypothesis that complex agroecosystems are less susceptible to pest outbreaks than simple ones. There was no typical cropland avifauna; communities depended on the particular type of agroecosystem and on the original habitat. The foliage height diversity index did not always parallel bird richness, since there are factors affecting the latter which do not affect the index. Edge effect was not evident in this study. Although two agroecosystems had lower richness than their surroundings, the presence of isolated fields increased regional bird richness.

210

Olsson, G.A., Liljelund, L.-E. and Hedlund, L. (1991): A strategy for the conservation of biodiversity. *Ambio* 20:269-270.

Keywords: biodiversity; ecosystems; sustainability; species diversity.

Abstract. Conservation of biological diversity is the most important issue for nature conservation. The importance of biological diversity for humankind, and its ecological, social, economical and cultural values are well recognized within societies. One expression of this recognition is the negotiations on a new global convention on conservation of biodiversity. Almost 100 developing and developed countries are currently involved in this effort. However, there are diverging views about how to achieve maintenance and conservation of biological diversity on the different levels of ecosystems; habitats, species and genes. Generally, two approaches can be recognized. The traditional strategy emphasizes conservation of ecologically sensitive areas by protecting them and by excluding or minimizing human impact. The rationale behind this strategy is that human impact is a negative and disturbing factor that must be minimized. Protection of sensitive areas is highly important and in some specific cases the only possible way to conserve certain species or ecosystems. However, the protection of limited areas, especially against the background of increasing human population pressures, and thus the increasing demand on land utilization, will never encompass more than a very limited part of the world's biological diversity. Thus, protected areas should only be viewed as refuge sites, and as a complement to other measures.

211

Brose, M. (1988):*)* Vielfalt als Grundkonzept standortgerechten Landbaus in Zentralbrasilien. *Entwicklungsperspektiven Bd. 32*. Kassel (Germany): Lateinamerika-Dokumentationsstelle FB6, Gesamthochschule Kassel, p. 1-136.

Keywords: agroforestry; Amazon region; farming systems; shifting cultivation; tropical forest; sustainability; ethnobiology.

Abstract. Data available about ethnobiology in Central Brazil are summarized in this book. The author presents indigenous knowledge and traditional land use systems of Indian tribes in order to enrich the discussion on sustainable and situation-specific farming systems. Descriptions are given of agriculture in the 16th century (chapter 2); ecological knowledge of the Kayapó tribe (chapter 3); land use systems in different ecological zones (chapter 4); specific knowledge concerning the use of trees, medicinal plants, soil fertility etc. (chapter 5); and cultural aspects (chapter 6). In the last chapter, the relevance of ethnobiological information for the development of sustainable farming systems is discussed. (Abstract by bibliography authors)

212

Chapin III, F.S., Schulze, E.D. and Mooney, H.A. (1992): Biodiversity and ecosystem processes. *Trends in Ecology and Evolution* 7:107-108.

Keywords: biodiversity; ecosystems; species diversity.

Abstract. Results of a workshop on 'Biodiversity and Ecosystem Function', held in Bayreuth, Germany in October 1991, are briefly summarized: A major question was whether diversity that is important to ecosystem processes is best characterized at the level of species or at some broader level of functional group. The general consensus was that functional groups (= species that have 'similar' effects on ecosystem processes) are useful in organizing our ecological understanding of diversity, but that the details of functional groups will depend on the ecosystem and question under study. A major research challenge is to predict which species in

a community are keystone species or could become so under reasonable scenarios of environmental changes. The workshop provided substantial evidence that biotic diversity at levels ranging from genetic diversity among populations to landscape diversity is critical to the maintenance of natural and agricultural ecosystems.

213

Burger, D. (1994): Der Treibhauseffekt: Ursachen, Folgen und Gegenstrategien. *entwicklung + ländlicher raum* 28 (1):3-5.

Keywords: atmosphere; carbon cycle; biomass burning.

Abstract. CO_2 and other trace gases relevant for the climate contribute to the heating up of the atmosphere. The natural greenhouse effect raised the earth air temperature to an average of 18°C and permitted the evolution of life. The additional greenhouse effect caused by man is threatening today mankind (life on earth) through rising sea levels, shifting of vegetation zones, loss of biodiversity, changing rainfall patterns and stronger and more frequent storms. Counter-strategies must englobe the reducing of energy consumption in industrialized countries, enhancing the efficient use of energy and promoting alternative energies. Also within agriculture and forestry, there is a potential for developing strategies to counter-act the process of CO_2-enrichment in the atmosphere.

214

Keller, M., Jacob, D.J., Wofsy, S.C. and Harriss, R.C. (1991): Effects of tropical deforestation on global and regional atmospheric chemistry. *Climatic Change* 19:139-158.

Keywords: deforestation; Amazon region; tropical forest; atmosphere; cattle; biomass burning.

Abstract. A major portion of tropospheric chemistry occurs in the tropics. Deforestation, colonization, and development of tropical rain forest areas could provoke significant changes in emission of radiatively and photochemically active trace gases. A brief review of studies on trace gas emissions in pristine and disturbed tropical habitats is followed by an effort to model regional tropospheric chemistry under undisturbed and polluted conditions. Model results suggest that changing emissions could stimulate photochemistry leading to enhanced ozone production and greater mineral acidity in rainfall in colonized agricultural regions. Model results agree with measurements made during the NASA ABLE missions. Under agricultural pastoral development scenarios, tropical rain forest regions could export greater levels of N_2O, CH_4, CO, and photochemical precursors of NO_x and O_3 to the global atmosphere with implications for climatic warming.

215

Fan, Song-Miao, Wofsy, S.C., Bakwin, P.S. and Jacob, D.J. (1990): Atmosphere-biosphere exchange of CO_2 and O_3 in the central Amazon forest. *Journal of Geophysical Research* 95(D10):16851-16864.

Keywords: tropical forest; Amazon region; atmosphere.

Abstract. Measurements of vertical fluxes for CO_2 and O_3 were made at a level 10 m above the canopy of the Amazon forest during the wet season, using eddy correlation techniques. Vertical profiles of CO_2 and O_3 were recorded continuously from above the canopy to the soil

surface, and forest floor respiration was measured using soil enclosures. Nocturnal respiration of CO_2 by the forest ecosystem averaged 2.57 kg C/ha/h, with about 85% from the forest floor. During the daytime, CO_2 was taken up at a mean rate of 4.4 kg C/ha/h. Net ecosystem uptake of carbon dioxide increased with solar flux by 0.015 (kg C/ha/h)/(W/m^2), corresponding to fixation of 0.0076 moles CO_2 per mole photons. The relationship between net ecosystem exchange and solar flux was virtually the same in the Amazon forest as in forests in Canada and Tennessee. The relatively high efficiency for utilization of light (about 30% of the theoretical maximum) and the strong dependance of net CO_2 uptake on solar flux suggest that light may significantly regulate net ecosystem exchange and carbon storage in the tropical forest. Changes in the distribution of cloud cover, associated for example with climatic shifts, might induce globally significant changes in carbon storage. Rates for uptake of O_3 averaged $2.3*10^{11}$ molecules/cm^2/s in the daytime (10 hours, 700-1700 hours), dropping by roughly a factor of 10 during the 14 hours from dusk to dawn. The mean O_3 deposition velocity at 40 m was 0.26 cm/s in the night and 1.8 cm/s in the day. Diurnal variation of O_3 deposition was regulated both by stratification of the atmospheric boundary layer and by stomatal response to light and water deficit. The total flux of O_3 to the forest was limited largely by supply from the free troposphere above. Deposition of O_3 to the forest canopy appears to be a regionally, and perhaps globally, important sink for tropospheric O_3.

216

Nobre, C.A., Sellers, P.J. and Shukla, J. (1991): Amazonian deforestation and regional climate change. *Journal of Climate* 4:957-988.

Keywords: deforestation; tropical forest; pastures; atmosphere; grasses; Amazon region; annual field crops.

Abstract. Large-scale conversion of tropical forests into pastures or annual crops could lead to changes in the climate. We have used a coupled numerical model of the global atmosphere and biosphere (Center for Ocean-Land-Atmosphere Atmosphere GCM) to assess the effects of Amazonian deforestation on the regional and global climate. We found that when the Amazonian tropical forests were replaced by degraded grass (pasture) in the model, there was a significant increase in the mean surface temperature (about 2.5 degrees C) and a decrease in the annual evapotranspiration (30% reduction), precipitation (25% reduction), and runoff (20% reduction) in the region. The differences between the two simulations were greatest during the dry season. The deforested case was associated with larger diurnal fluctuations of surface temperature and vapor pressure deficit; such effects have been observed in existing deforested areas in Amazonia. The calculated reduction in precipitation was larger than the calculated decrease in evapotranspiration, indicating a reduction in the regional moisture convergence. There was also an increase in the length of the dry season in the southern half of the Amazon Basin, which could have serious implications for the reestablishment of the tropical forests following massive deforestation since rainforests only occur where the dry season is very short or nonexistent. An empirical bioclimatic scheme based on an integrated soil moisture stress index was used to derive the movement of the savanna-forest boundary in response to the simulated climate change produced by large-scale deforestation. The implications of possible climate changes in adjacent regions are discussed.

217

Luizao, F., Matson, P., Livingston, G., Luizao, R. and Vitousek, P. (1989): Nitrous oxide flux following tropical land clearing. *Global Biogeochemical Cycles* 3:281-285.

Keywords: nitrous oxide; deforestation; tropical forest; pastures; Amazon region; atmosphere; South America; ecosystems.

Abstract. The importance of seasonal cycles of N_2O flux from tropical ecosystems and the possibility that tropical deforestation could contribute to a global increase in N_2O concentrations were assessed by measuring N_2O flux from forest, cleared land, and pasture over an annual cycle in the central Amazon. A pasture that had been converted from tropical forest had three-fold greater annual N_2O flux than a paired forest site; similar results were obtained in other pastures. If these results are general, such tropical pastures represent a globally significant source of increased N_2O.

218

Houghton, R.A., Skole, D.L. and Lefkowitz, D.S. (1991): Changes in the landscape of Latin America between 1850 and 1985. II. Net release of CO_2 to the atmosphere. *Forest Ecology and Management* 38:173-199.

Keywords: atmosphere; deforestation; shifting cultivation; Amazon region; carbon cycle; South America; pastures; degradation; ecosystems; establishment.

Abstract. Net release of carbon to the atmosphere from deforestation in Latin America was calculated for the period 1850-1985. Stocks of carbon in vegetation and soils of major ecosystems, and changes in these stocks of carbon as a result of disturbance, were used to calculate the net annual flux of carbon. Total net release of carbon between 1850 and 1985 was about $30x10^{15}$ g (range 17-$35x10^{15}$ g). Land uses responsible for emissions of carbon were increased areas of pastures (42% of total emissions), croplands (34%), degraded lands (19%), and shifting cultivation (5%). Logging and the establishment of plantations contributed or accumulated negligible amounts of C over this 135-year period. Annual releases of C to the atmosphere increased over the period 1850-1985; half of the total release occurred after 1960. By 1985 net annual release was $0.67x10^{15}$ g C (range 0.39 - $0.82x10^{15}$ g C). Relative contributions of different land uses to this flux were different from those over the long-term. The greatest single source of C in 1985 resulted from increases in area of degraded lands (37% of net flux), and the importance of shifting cultivation increased to almost 20%. The range of estimates calculated here for the current net flux of C is lower than earlier estimates. The range results from uncertainties in rates of land-use change, in types of ecosystems cleared and stocks of C in these ecosystems, and in rates of decay and regrowth of organic matter associated with land-use change.

219

Burger, D. (1994): Aufforstung und andere forstliche CO_2-Strategien. *entwicklung + ländlicher raum* 28(1):11-15.

Keywords: atmosphere; carbon cycle; reforestation; deforestation; agroforestry.

Abstract. Forestry CO_2-soak pits are formed not only by the vegetation cover and the relatively high amount of biomass in the soil but also by the carbon stored in the products. Their effect increases when these products substitute the fossil sources of energy. The

limitations for the translation into action of forestry CO_2-soak pits strategies lie not as much in the availability of suitable land or of the production techniques, as in the field of organization, management, funding and processing techniques as well as in the continuous existence of the same general conditions that have lead to the present destruction of forests. The forestry CO_2 strategies should contribute not only to the CO_2 absorption but also to the regional development. They should be sustainable and socio-culturally acceptable. According to these criteria, various strategies of forest protection and rehabilitation of degraded forest areas should become the first priority, while the development of timber plantations ranks last in the same priority list.

220

Goldammer, J.G. (1994): Vegetationsbrände und globales Klima: Wechselwirkungen. *entwicklung + ländlicher raum* 28(1):6-10.

Keywords: atmosphere; carbon cycle; tropical forest; tropical savanna; subtropics; fire ecology; biomass burning.

Abstract. Throughout all vegetation zones of the globe wildfires in forests and other vegetation types and the use of prescribed fires in forestry and agriculture are a non-uniform phenomenon. In the densely populated and industrialized regions, e.g. in Central Europe, even a small forest fire may cause public concern. Traditional use and the desired effects of fire in modern agriculture has been replaced by mechanical and chemical technologies. In the less populated tropical and subtropical landscapes and in the temperate and boreal zones of North America and Eurasia, large-scale use of fire and wildfires are still a common phenomenon. This contribution describes the most important fire regions and fire regimes of the globe and summarizes the impact of vegetation fires on atmosphere and as well as the possible feedback mechanisms between a globally changed climate and the occurence of fire.

221

Groot, P. de (1990): Are we missing the grass for the trees? *New Scientist* 1698:29-30.

Keywords: atmosphere; overgrazing; carbon cycle; tropical savanna; natural grassland; biomass burning.

Abstract. Amazonian rainforest going up in smoke has become a powerful image of environmental destruction and the growing threat from the greenhouse effect. On the other hand, tropical grasslands have been almost totally ignored, although their capacity to extract carbon dioxide from the atmosphere is equal to that of tropical rainforests and often exceeds that of cropping systems. Natural savanna grassland converted into cropping land or degraded by frequent burning and overgrazing is therefore also an important source of net CO_2 release. This fact has probably been widely ignored because at least half of the dry matter production of grasslands is located in the below-ground parts of the plant, which are generally neglected by common methods of biomass production estimates.

222

Walker, B.H. (1994): Global change strategy options in the extensive agriculture regions of the world. *Climatic Change* 27:39-47.

Keywords: biomass burning; burnings; tropics; methane; cattle; atmosphere; soil erosion; livestock; stocking rate.

Abstract. The extensive agricultural regions contain relatively little of the world's carbon and their main influence on atmospheric composition is via biomass burning in the more humid regions of the tropics, and methane from cattle production. In terms of direct feedback influence on climate their effects are via opaqueness of the atmosphere (dust and aerosols) and the albedo of the surface. Change in these regions is brought about by the separate and (especially) interactive effects of climate, fire and herbivory. Likely changes in productivity, vegetation structure and soil erosion will lead to some changes in stored carbon and feedback effects. Possible increased cultivation of marginal areas is an important unknown. Management options include livestock numbers, type and distribution, fire regimes, woody vegetation clearing, subsistence cropping and rehabilitation measures. Response strategies in line with IPCC goals include reducing stocking rates, halting clearing of woody plants, reducing fire frequencies and (where cropping is practised) use of zero-tillage. A modelling approach is suggested as a basis for examining which responses are appropriate, given that most managers in these regions have very few options and the regions contribute relatively little to the control of the world's climate.

223

Dale, V.H., Houghton, R.A. and Hall, C.A.S. (1991): Estimating the effects of land-use change on global atmospheric CO_2 concentrations. *Canadian Journal of Forest Research* 21:87-90.

Keywords: atmosphere; Asia; land-use changes.

Abstract. Determining how land-use change effects atmospheric CO_2 concentrations requires new approaches to research because of the large area and the long period of time involved. This special issue of the *Canadian Journal of Forest Research* presents a series of papers that demonstrate one approach to the problem. Estimates of the flux of carbon to the atmosphere are based on site-specific information concerning the effects of land-use change on the carbon content of terrestrial vegetation. This spatially explicit approach combines historical and current information on land-use change for a specific area. South and southeast Asia was chosen for the study because the region is undergoing major land-use changes and makes a significant contribution to atmospheric CO_2. The results of the study have assisted in reducing the uncertainty about the magnitude of carbon release while providing new constraints to the analysis.

224

Haas, G., Geier, U., Schulz, D. and Koepke, U. (1994): Die CO_2-Effizienz des Organischen Landbaus - Chancen für die Entwicklung landwirtschaftlicher Produktionssysteme in der Dritten Welt? *entwicklung + ländlicher raum* 28(1):25-29.

Keywords: fertilizers; nitrogen fixation; legumes; tropics; subtropics; farming systems; ecosystems; agroforestry; carbon cycle; energy balance; atmosphere.

Abstract. Comparison between organic and conventional plant production in Germany reveals savings of fossil energy and thus CO_2-emissions of 61 per cent. This is basically due to the fact that mineral nitrogen fertilizers are not used. The method of ensuring nitrogen supply by nitrogen fixation through legume symbiosis can be adapted anywhere in the world. A further

main area of fossil fuel consumption in the agriculture of the industrialized countries is caused by the intensive use of machinery. In countries with large manpower resources in rural areas, savings can be made by developing labour-intensive production systems. To calculate the CO_2-binding capacities when comparing the systems, the sum of all CO_2-sinks in the systems has to be included. As well as the bound carbon contained in crops actually harvested, this also includes catch crops, underseeds, harvest remains and roots. High soil C-contents in organic farming increase not only the soil fertility but also the reduction function of the system. For the respective site-specific conditions in the countries of the tropics and sub-tropics, farming systems are to be developed which imitate natural ecosystems, as here for example "standing C-sinks" can be established on the basis of rain forests, inter alia in the form of agroforestry systems. The agricultural policies pursued by developing countries to date have been based on the guiding principle of conventional farming making intensive use of external inputs, as practised in the industrialized countries. In view of the economic and ecological problems caused by conventional farming, organic farming is currently becoming increasingly widespread in North America and Europe. The productivity of organic farming achieved in these countries through intensive development work is virtually the same the world over, i.e. is sufficient to feed the population. More efficient use of natural resources in organic farming and system-immanent environmentally and climatically sound production are now integral approaches in the development of site-appropriate production systems in developing countries.

225

Escobar, C.J. and Toriatti D., J.L. (1991): Distribución de la materia orgánica y del carbono-13 natural en un Ultisol del piedemonte amazónico. *Pasturas Tropicales* 13(2):27-30.

Keywords: pastures; Colombia; soil chemical properties; soil organic matter; tropical forest; South America; Amazon region.

Abstract. The distribution of natural soil carbon (C-13) and its changes as a result of cutting forest and then planting pasture were studied in two areas of an Ultisol from Caquetá, Colombia. The study site had perudic moisture and isohyperthermic temperature regimes. One site was under forest (P_0) and the other site had been deforested and cultivated with *Paspalum notatum* (P_{15}) for 15 years. Soil physical, chemical and mineralogical characteristics at the two sites were very similar. Morphological differences observed could be related to soil management. Total C content decreased with depth in the two profiles. The quantity of carbon lost was around 57.5 tons/ha of C in the pasture system, after 15 years of use. The $\delta^{13}C$ values are about -29‰ in 0-0.34 m of the profile under forest, and about -19‰ in the 0.14 m layers of the profile under pasture. On layers of 0.14-0.30 m, this value was -25‰. The $\delta^{13}C$ values were used to estimate the quantities of C derived from forest and from pasture. Carbon derived from pasture represented, between 64.6% in surface and 29.5% in depth, of the total carbon at P_{15}.

226

Crutzen, P.J., Aselmann, I. and Seiler, W. (1986): Methane production by domestic animals, wild ruminants, other herbivorous fauna, and humans. *Tellus* 38B:271-284.

Keywords: atmosphere; cattle; methane.

Abstract. A detailed assessment of global methane production through enteric fermentation by domestic animals and humans is presented. Measured relations between feed intake and methane yields for animal species are combined with population statistics to deduce a current yearly input of methane to the atmosphere of 74 Tg (1 Tg = 10^{12} g), with an uncertainty of about 15%. Of this, cattle contribute about 74%. Buffalos and sheep account for 8-9%, and the remainder stems from camels, mules and asses, pigs, and horses. Human CH_4 production is probably less than 1 Tg per year. The mean annual increase in CH_4 emission from domestic animals and humans over the past 20 years has been 0.6 Tg, or 0.75% per year. Population figures on wild ruminants are so uncertain that calculated CH_4 emissions from this source may range between 2 Tg and 6 Tg per year. Current CH_4 emission by domestic and wild animals is estimated to be about 78 Tg, representing about 15-25% of the total CH_4 released to the atmosphere from all sources. The likely CH_4 production from domestic animals in 1890 was about 17 Tg, so that this source has increased by a factor of 4.4. A brief tentative discussion is also given on the potential CH_4 production by other herbivorous fauna, especially insects. Their total CH_4 production probably does not exceed 30 Tg annually.

227

Leng, R.A. (1991): Digestive physiology of ruminants: implications for improving animal production from poor quality forages. In: Leng, R.A. (ed.), *Improving ruminant production and reducing methane emissions from ruminants by strategic supplementation*. Washington, D.C., USA: United States Environmental Protection Agency (EPA), EPA/400/1-91/004. p. 43-52.

Keywords: methane; cattle; forage quality; atmosphere.

Abstract. The information given in this chapter is fundamental to understanding the strategies for limiting methane production from ruminants. Aspects covered include anatomy of the ruminant, the microbiology of the rumen, the requirements of rumen microorganisms for nutrients and the stoichiometry of rumen fermentative digestion of feed and the balances of nutrients available to the animal. Practical implications of the balances of protein to energy in the digestion products that are absorbed are discussed. (Abstract by bibliography authors)

228

Leng, R.A. (1991): Modifying methane production. In: Leng, R.A. (ed.), *Improving ruminant production and reducing methane emissions from ruminants by strategic supplementation*. Washington, D.C., USA: United States Environmental Protection Agency (EPA), EPA/400/1-91/004. p. 53-71.

Keywords: methane; cattle; forage quality; atmosphere.

Abstract. Two factors affect methane production per unit of digestible feed; these are microbial growth efficiency and the formation of propionate in the rumen. Higher production of either cells or propionate reduces methane production per unit of organic matter digested in the rumen. Microbial growth efficiency is inefficient in animals fed on forage based diets, typical of those fed to ruminants in developing countries, and can be stimulated by nutrient supplementation. This reduces methane generation markedly. Factors that limit the efficiency of microbial growth in the rumen are discussed. Ruminants use low-digestibility forages more efficiently when their protein status is improved by supplementation with a bypass protein. Methane production per unit of production, therefore, can be ameliorated in practice by

balancing the nutrient available from rumen fermentation with dietary protein that avoids fermentation. The implications of improving both feed conversion efficiency and growth rate, for the rates of methane production per animal or per unit of product are outlined. (Abstract by bibliography authors)

229

Holter, J.B. and Young, A.J. (1992): Methane prediction in dry and lactating Holstein cows. *Journal of Dairy Science* 75:2165-2175.

Keywords: methane; dairy cows; feed supplements; forage quality; production level; atmosphere.

Abstract. Data from six experiments (two with dry cows) were used to predict partitioning of gross energy to CH_4 in Holstein cows using selected independent variables, some of which were intercorrelated, and a stepwise backward elimination regression procedure. Methane outputs ranged from 3.1 to 8.3% (mean 5.5) of gross energy intake for 134 dry cow balance trials and from 1.7 to 14.9% (mean 5.2) of gross energy intake for 358 lactating cow energy balance trials. This is equivalent to 176 and 300 g/d or 245 and 419 L/d of CH_4 for dry and lactating Holstein cows, respectively. Digestibilities of hemicellulose and neutral detergent solubles were positive predictors, and cellulose digestibility was a negative predictor of CH_4 output in dry cows fed all forage diets, but hemicellulose digestibility was not a significant variable for predicting CH_4 production by lactating cows fed diets with concentrate and forages. Fiber digestibility generally remained in models to predict CH_4 output. Except for one data set, regression equations accounted for 50 to 72% of the variation in percentage of gross energy partitioned to CH_4 by Holstein cows. Results confirm that increased concentrate feeding reduces CH_4 production. Supplementation of lactation diets with fat generally increases fat digestibility, and this trait was associated with reduced CH_4 output. Results enable 1) estimation of CH_4 output for calculation of metabolizable energy and 2) computation of the contribution from dairy cows to global warming.

230

Tamminga, S. (1992): Nutrition management of dairy cows as a contribution to pollution control. *Journal of Dairy Science* 75:345-357.

Keywords: dairy cows; pollution; methane; production level; forage quality; atmosphere; nitrogen.

Abstract. Dairy production causes unavoidable losses in respiration, faeces, and urine, which may become an environmental burden as contributors to the "greenhouse" effect (CO_2, CH_4) or to the pollution of air (NH_3), soil surface, and sub-soil water (NO_3^-, P). Losses in respirations can be reduced by increasing feed quality and level of production. Increased feed quality can reduce losses in methane, whereas an increased level of production decreases the relative losses in maintenance. Faecal and urinary losses can be reduced by minimizing the intake of N and P relative to energy. Further reductions can result from increasing feed quality and level of production, from matching or synchronizing the availability of N and energy in the rumen, and from shifting the site of digestion of protein and starch from the rumen to the small intestine. Improved feed quality will reduce endogenous protein losses. In order to exploit fully the potential of nutritional management in pollution control, computer simulation models describing dairy production in a dynamic way are needed.

231

Pelchen, A. and Peters, K.J. (1994): Schadgase aus der Tierhaltung - Auswirkungen auf den Treibhauseffekt. *entwicklung + ländlicher raum* 28(1):20-24.

Keywords: methane; cattle; atmosphere; forage quality.

Abstract. The importance of animal husbandry for global warming is rather small. The share of 4 per cent is not significant compared to other sources of greenhouse gases. On the other hand the husbandry of ruminants is inseparably linked to methane emissions and they can only be influenced within tight borders. Main factors are quantity, quality and digestibility of feeds as well as the energy supply to the animal: A reduction of crude fibre in the ration reduces the emissions of methane. An increase in digestibility decreases the production of methane per unit of gross energy (GE) at feeding levels of three times maintenance, but increases it for lower levels of feeding. An enlargement of the energy supply from maintenance to multiples of maintenance reduces the energy loss per unit of gross energy via methane. According to these facts the principle "More performance - less methane" comprises the main issue to reduce methane emissions. Anything enhancing the yield of milk and meat from the single animal diminishes the rate of methane emissions per unit of desired product, because it allows a reduction in total animal numbers. Special measures for the developing countries have to be taken, to make sure that necessary future expansions in the production are not achieved by an increase in herd sizes but by a growth of the performance of the single animal. The potential for a reduction of methane emissions in the developing countries is much higher than in the industrialized countries.

232

Matthews, R.B., Kropff, M.J. and Bachelet, D. (1994): Climate change and rice production in Asia. *entwicklung + ländlicher raum* 28(1):16-19.

Keywords: rice; South East Asia; methane; atmosphere.

Abstract. Rice is the second most important crop in the world after wheat, with about 522 million tons being produced from about 148 million hectares in 1990. The largest production of rice is from Asia, which produces about 94 per cent of the total world production. In this region, rice is the main item of the diet, and provides an average of 35 per cent of the total calorific intake compared to only 2 per cent in the US. Rapid population growth is already placing increasing pressure on the rice-growing resources in the region, not only from the increased demand from a higher number of people to feed, but also from the encroachment of residential areas into rice growing areas. The effects of climate change only add to an already complex problem, even more so as rice cultivation itself has a significant effect on global warming through the emission of the greenhouse gas, methane, from decaying plant material in the water-logged paddy fields. There is clearly an urgent need to evaluate the interaction between climate change and rice production in this region to provide a basis for decisions by policy makers, agriculturalists and environmentalists alike.

233

Fisher, M.J., Rao, I.M., Ayarza, M.A., Lascano, C.E., Sanz, J.I., Thomas, R.J. and Vera, R.R. (1994): Carbon storage by introduced deep-rooted grasses in the South American savannas. *Nature* 371:236-238.

Keywords: grasses; savanna; pastures; South America; land-use changes; burnings; atmosphere; carbon cycle; introduced species.

Abstract. Estimates of the global carbon dioxide balance have identified a substantial 'missing sink' of 0.4-4.3 Gt per year. It has been suggested that much of this may reside in the terrestrial biosphere. Here we present an analysis of the carbon stored by pastures based on deep-rooted grasses which have been introduced in the South American savannas. Although the deep-rooted grasses were chosen principally for agricultural reasons, we find that they also sequester significant amounts of organic carbon deep in the soil. If our study sites are representative of similar pastures throughout South America, this process could account for the sequestration of 100-507 Mt carbon per year - a substantial part of the 'missing sink'. Thus, although some land-use changes (such as burning tropical rainforests) contribute to the atmospheric CO_2 burden, we conclude that the introduced pastures studies here help to offset the effect of anthropogenetic CO_2 emissions.

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Haiger, A. (1993): Naturgemäße Milchviehzucht. In: Zerger, U. (ed.), *Forschung im ökologischen Landbau*. Bad Dürkheim/Germany: Stiftung Ökologischer Landbau (SÖL), p. 57-63.

Keywords: sustainability; dairy cows; production level; breeding.

Abstract. Ruminants play an important role for different kinds of land-use systems: They make use of plants like forage legumes and grasses that are essential for the sustainability of many agricultural systems, or of landscapes that are unsuitable for other forms of agricultural exploitation than grazing. In a 5-year average of a cow producing 4500 kg milk/yr, 1 kg of fodder protein yields about 430 g of milk protein. For meat production, this relation is only 1 kg : 120 g in the case of beef cattle and 1 kg : 180 g in the case of swine. Selecting cows for higher individual milk yields per time unit is an efficient measure to save fodder and labour costs, resulting in reduced energy needs per kg milk produced. A cow producing 5000 kg milk/yr needs 38% less energy per kg milk than an animal yielding 2000 kg in the same time period. A further increase of another 3000 kg (to 8000 kg/yr) reduces the energy needs per kg milk produced only by 10%. On the other hand, cows with this production level need increasing amounts of concentrates to meet their energy requirements. Very high individual production levels therefore depend on fossil energy used for cheap production of concentrates. Individual milk yields of more than 7000 kg/yr imply surplus nitrogen in the fodder ration, resulting in a potential danger of groundwater pollution. The author therefore suggests an ecological range of individual milk yields, the optimum being between 5000 and 7000 kg/animal/yr. Furthermore, corresponding criteria for selection and breeding of milk cows are discussed. (Abstract by bibliography authors)

235

Fajer, E.D., Deane Bowers, M. and Bazzaz, F.A. (1989): The effects of enriched carbon dioxide atmospheres on plant-insect herbivore interactions. *Science* 243:1198-1200.

Keywords: atmosphere; insects; insect-plant interaction; pest development.

Abstract. Little is known about the effects of enriched CO_2 atmospheres, which may exist in the next century, on natural plant-insect herbivore interactions. Larvae of a specialist insect herbivore, *Junonia coenia* (Lepidoptera: Nymphalidae), were reared on one of its host plants, *Plantago lanceolata* (Plantaginaceae), grown in either current low (350 ppm) or high (700 ppm) CO_2 environments. Those larvae raised on high-CO_2 foliage grew more slowly and experienced greater mortality, especially in greater instars, than those raised on low-CO_2 foliage. Poor larval performance on high-CO_2 foliage was probably due to the reduced foliar water and nitrogen concentrations of those plants and not to changes in the concentration of the defensive compounds, iridoid glycosides. Adult pupal weight and female fecundity were not affected by the CO_2 environment of the host plant. These results indicate that interactions between plants and herbivorous insects will be modified under the predicted CO_2 conditions of the 21st century.

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Fungameza, D.B. (1991): Agroforestry and ecofarming practices for soil conservation in Kigoma Tanzania. *Göttinger Beiträge zur Land- und Forstwirtschaft in den Tropen und Subtropen,* Vol. 63, Göttingen (Germany): E. Goltze Verlag, 264 p.

Keywords: agroforestry; soil erosion; intercropping; maize; beans; yields; weed control; fertilizers; improved fallow; natural fallow; green manure; *Leucaena leucocephala*; legume trees; shrubs; *Crotalaria* ; *Tephrosia vogelii*; *Calliandra calothyrsus*; *Flemingia macrophylla*; *Albizia lebbeck*; *Cassia siamea*; *Mucuna utilis*; *Cassia spectabilis*; Tanzania; Africa; tropical highlands.

Abstract. This research work focussed on soil erosion in Kigoma, Tanzania and/or prevention or control measures. An interdisciplinary approach was followed. A methodology which combined diagnosis and design and user perspective was used to detect constraints and opportunities existing within the land use systems practiced in the area. The aproach required the analysis of the physical environment, socio-economy, population patterns, land use systems with household supply problems, production and conservation constraints. More focus was put on the needs of different land users. The severity and causes of soil erosion were assessed qualitatively and these were matched to the needs of the people in order to highlight agroforestry and ecofarming practices for soil conservation. The productivity of candidate technologies was tested either on station or direct in collaboration with villagers. The following results were obtained: 1. Intercropping maize with beans on the same ridge in a ridge-furrow ("matuta") system did not affect the yields of the former. The yields of beans were significantly depressed by 68-90%. The best Land Equivalent Ratios and Area Time Equivalent Ratios were obtained when beans and maize were intercropped in parallel rows. 2. Sowing maize on top of the ridges and broadcasting in the furrows the seeds of *Crotalaria juncea* and *C. retusa* at the rate of 50 kg/ha decreased significantly the amount of weeds by 62-74% during the first weeding and had no effect on the yields of maize. 3. Depending on the amount of biomass added in the furrows, *Crotalaria ochroleuca* and *C. retusa* increased the yields of succeeding maize crop by 62-168% and by 79-184% over the control, respectively. Highest maize yields were obtained by combination of this treatment with mineral fertilizer addition. 4. *Tephrosia vogelii* fallow accumulated 195 kg N/ha. Incorporating the biomass into the soil increased significantly the yields of subsequent maize crop by 2.5 time over the natural fallow. 5. *Calliandra calothyrsus* hedgerows yielded 11.12 and 17.97 t/ha dry matter during the first and second year, respectively. The use of *C. calothyrsus* green manure raised

significantly the yields of hedgerow intercropped maize by 74 and 96% over the control and were 71% of the yields obtained in a fertilizer treatment. Combined use of green manure and fertilizer resulted in significantly higher (33-34%) maize yields than the fertilizer check. 6. Three year-old *Albizia lebbek* and *Leucaena leucocephala* tree lines did not affect the yields of maize planted in their vicinity. 7. *Cassia siamea* trees planted scattered on crop land improved topsoil chemical properties under their canopies. There was an increase in soil pH, organic carbon, total N, total P, exchangeable K, Ca and Mg. But yields of maize planted under the fertile canopies of *C. siamea* were depressed by 79%. 8. Whereas trees and shrub species found in the natural Miombo woodland were growing slowly at the rate of 0.75-1.25 cm per year, planted multipurpose species showed mean diameter increments which ranged from 1.39 cm per year for *Syzygum cumini* to 4.99 cm for *Albizia lebbek*. Mean annual height increments were in the range of 0.82 m in the case of *S. cumini* to 4.58 m in the case of *Cassia spectabilis*. The survival of trees planted by different land users was poor (0-21%) on communal lands, fair (25-68%) by individuals and good (60-89%) in schools. (Abstract by bibliography authors)

237

Bourgoing, R. (1990): Choix et méthode d'établissement de la plante de couverture pour la culture du cocotier hybride en milieu villageois. *Oléagineux* 45:23-30.

Keywords: fallow; erosion; fertility; cover crops; weeds; legumes; *Centrosema pubescens; Calopogonium mucunoides; Pueraria javanica*.

Abstract. Hybrid coconut plantations on smallholdings are usually located on land used for growing food crops or on land which was formerly cultivated then abandoned and left fallow. In the former case, the plantations have become highly susceptible to erosion, and in the latter case, they have been invaded by *Imperata*. In both cases, the soils have lost much of their fertility. Recuperation of such land for hybrid coconut growing requires the use of appropriate soil conservation techniques. One of the best known soil conservation techniques - planting a good cover crop before or at the same time as the coconuts are planted - is capable of improving the structure and fertility of the soil within a short time, whilst controlling erosion and perennial weed development. A description of the most widely used legume species (*Centrosema pubescens, Calopogonium mucunoides, C. caeruleum, Pueraria javanica, Psophocarpus palustris, Flemingia macrophylla*), their main characteristics, growing methods, as well as management practices are given in this paper. (Abstract by bibliography authors)

7 List of keywords