
Managing Soils for Improved Pasture
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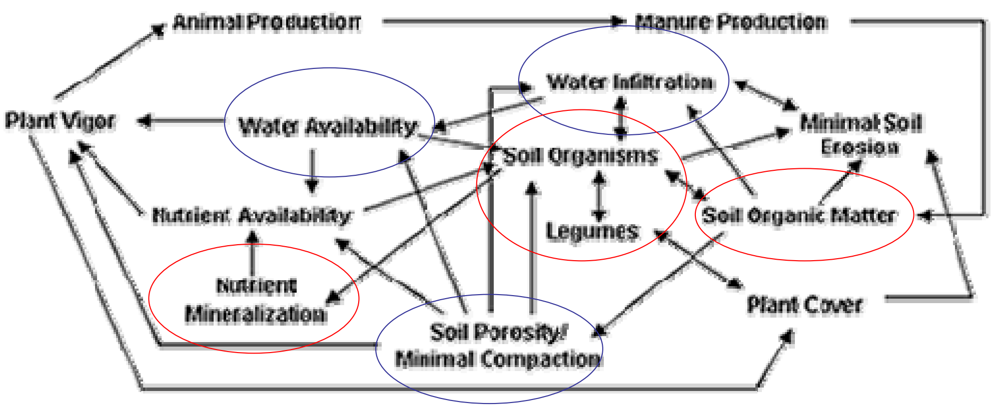
Rota Grazing and Livestock Management Workshop
June 10-12, 2010

Outline



- Water
- Organic matter
- Nitrogen
  - Mineralization
  - Biological nitrogen fixation
  - Fertilization
- Phosphorus

Factors Affecting Pasture Productivity

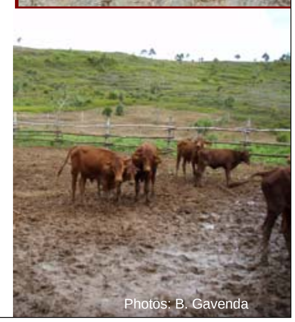


http://attra.ncat.org/attra-pub/nutrientcycling.html

There are numerous interacting factors in determining the productivity of a pasture system. The availability of nutrients is a critical and complex component in pasture productivity. Nutrient availability for plants is governed by soil type, water availability, soil temperature, soil organic matter content, soil microbial community structure and biomass, and the type of forage species in the pasture.

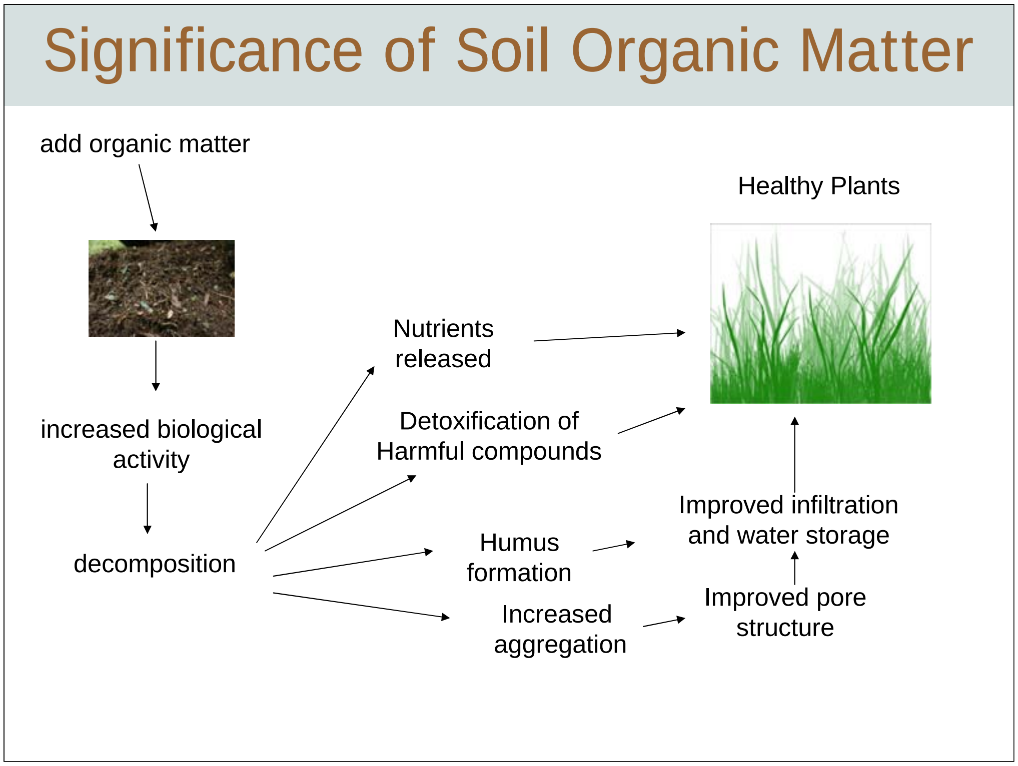
Water

1. Availability
   – Shallow soils have low water holding capacity
   – Sandy soils have low water holding capacity
2. Infiltration
   – Good infiltration minimizes erosion and run-off
   – Maintaining good cover of the ground (plant or residue) increases infiltration
3. Compaction
   – Compacted soils hold less water
   – Compacted soils inhibit water infiltration
   – Compacted soils are prone to erosion and water run-off

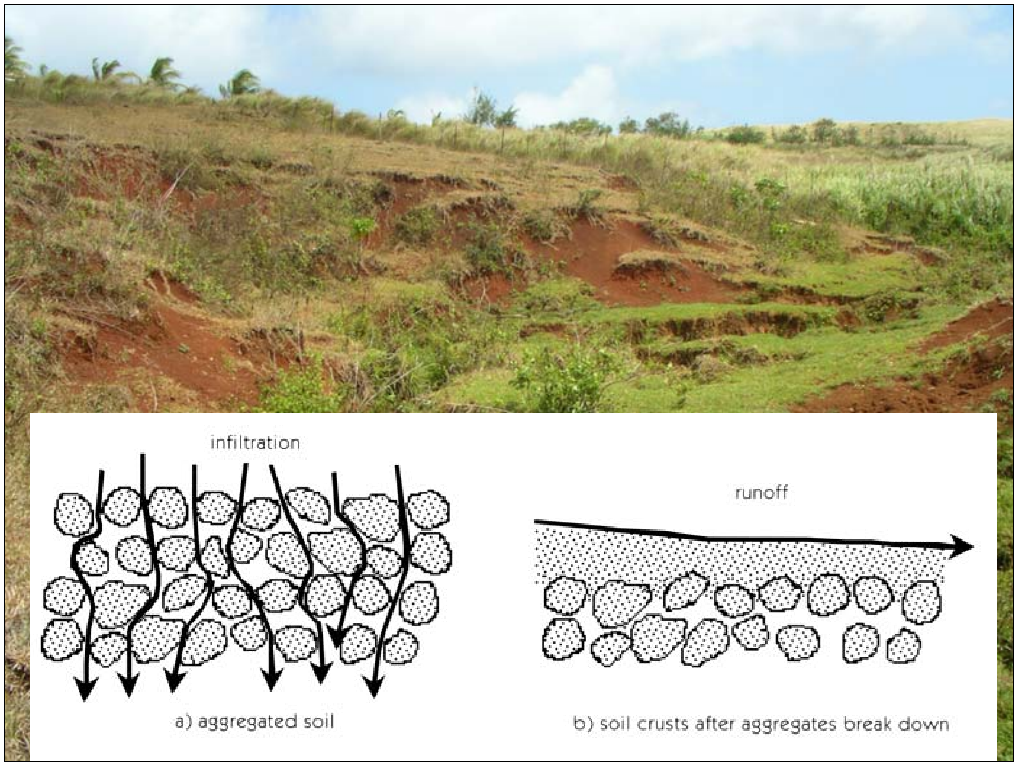


Photos: B. Gavenda

Water is a fundamental growth factor which acts to dissolve and transport plant nutrients. Water also gives life to the myriad soil organisms involved in organic matter decomposition and nutrient cycling. Shallow and sandy soils have a low capacity to hold water during the dry season, and thus pasture productivity is water limited. Maintaining good plant cover throughout the pasture is important to maintain good water relations. Bare soil is susceptible to compaction and low water infiltration. Poor water infiltration leads to erosion and surface run-off, which has a negative impact on coastal water resources. Soils that have been compacted by over stocking and grazing have poor water infiltration and are prone to erosion.

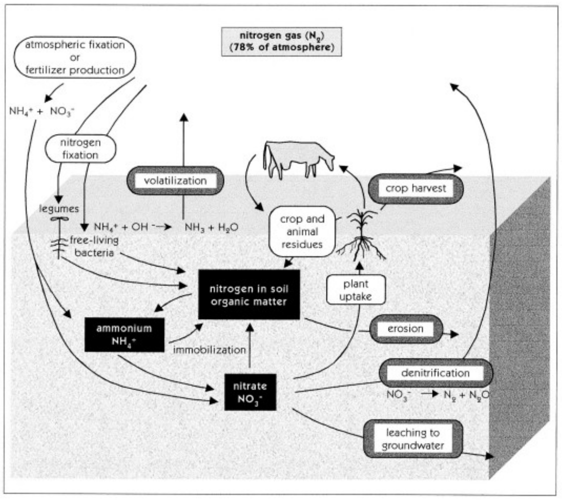


Soil organic matter is the foundation for a healthy and healthy pastures. Organic inputs from animal excretia and plant litter serve as the food feeding the vast population of soil organisms. These organisms are responsible for the decomposition of simple and complex substances in plant and animal tissues into complex substances that make up humus. During the decomposition process, important plant nutrients such as nitrogen, phosphorus and sulfur are converted from their organic form into inorganic forms that are dissolved in soil water and available for plant uptake – process called mineralization. By-products from decomposition help bind soil particles together to improve water infiltration and the growth of roots. Organic matter also plays a key role in detoxifying toxic elements like aluminum, which can inhibit plant growth.



infiltration
runoff
a) aggregated soil
b) soil crusts after aggregates break down

The Nitrogen Cycle

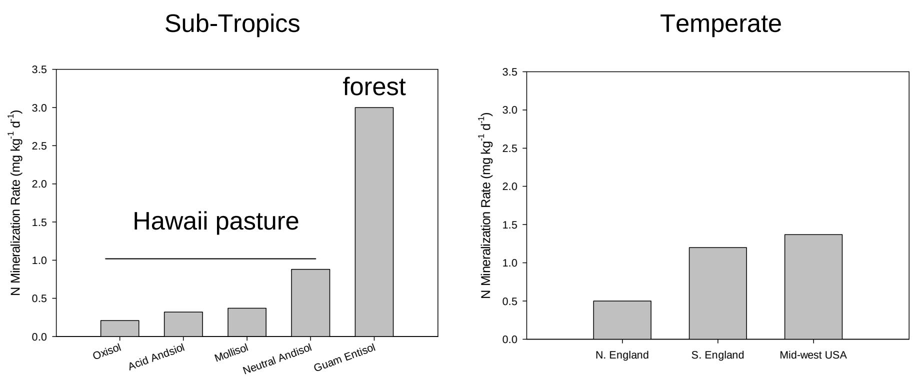


http://attra.ncat.org/attra-pub/nutrientcycling.html

- Inputs
  - Biological N fixation
  - Plant litter
  - Manures
- Transformations
  - Mineralization& immobilization
  - Denitrification
- Losses
  - NO_3^- leaching
  - NH_4^+ volatiloization

Nitrogen (N) is an essential plant nutrient that is central to protein formation, photosynthesis, and other key plant functions. Nitrogen is required in relatively large quantities and it is often a growth limiting nutrient in pastures. Primary inputs of N into pasture systems are from animal manure, plant litter, biological nitrogen fixation (BNF), and fertilizers. Nitrogen undergoes several transformations in the soil. Nitrogen in organic matter is in organic form that is not available for plant uptake and must be converted into inorganic forms (NH4+ and NO3-) before it can be taken up by plant roots. This conversion is called N mineralization and it is mediated by soil fungi and bacteria. Inorganic N can also be assimilated by soil organisms and rendered unavailable for plant uptake – this process is called N immobilization. In saturated or very wet soils, soil NO3- can be converted into N2 gas (denitrification) by soil bacteria representing a loss of plant available N. In areas that receive plentiful rainfall, soil NO3- can be lost due to leaching (vertical movement of dissolved NO3- with percolating water). Ammonium at the soil surface can also be lost by volatilization where NH4+ is converted to NH3 gas when the pH is alkaline.

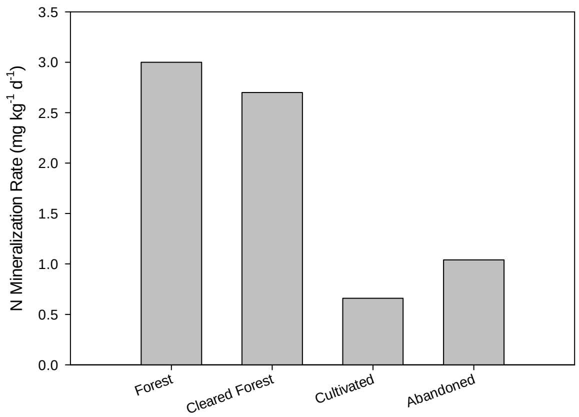
Nitrogen Mineralization



Sources: Deenik (2007), Motavalli et al. (1998), Umkovich et al. (1998)

Nitrogen mineralization rates tend to be higher in the tropics where temperature is high and rainfall plentiful. However, N mineralization is also affected by soil type, clay content, and quality of litter inputs. Acid soils tend to show lower mineralization rates and soils high in clay have lower mineralization than sandy soils. Litter input with high C:N ratios (i.e., >30) result in N immobilization rather N mineralization. In the fertile grassland soils of the temperate zones where soil organic matter is high, native N mineralization rates can supply enough N for good pasture growth. In the acid soils of the tropics, N and P deficiencies severely limit forage growth.

Landuse & Nitrogen Mineralization



Sources: Deenik (2007), Motavalli et al. (1998)

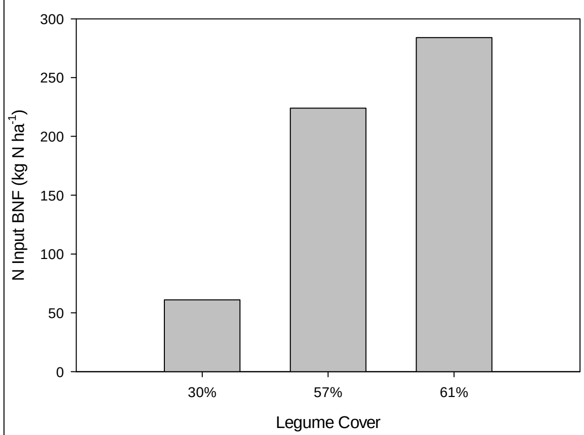
Landuse has a strong influence on N mineralization. Grasslands tend to show high mineralization rates especially when moisture is not limiting. Converting tropical forests to pasture tends to increase N mineralization, but forage type can affect mineralization rates especially if forage litter is rich in C. Motavalli et al. (1998) measured the affect of landuse on N mineralization and found that mineralization rates were highest under forest and recently cleared forest and declined significantly in soils under intensive cultivation. N mineralization potential did not improve in intensively cultivated land that had been abandoned for 11 years.

Biological Nitrogen Fixation

- Conversion of atmospheric N_2 gas into ammonia by soil bacteria and legume symbiosis

Biological nitrogen fixation (BNF) is the conversion of inert (non-reactive) N2 gas into reactive ammonia that is incorporated into living cells and used to build proteins. The conversion involves the symbiotic relationship between soil bacteria (rhizobium) and legumes. This process can contribute significant amounts of plant available N when legumes are planted in conjunction with other grasses. BNF is limited by Ca and P deficiency in acid soils.

BNF & Nitrogen Inputs



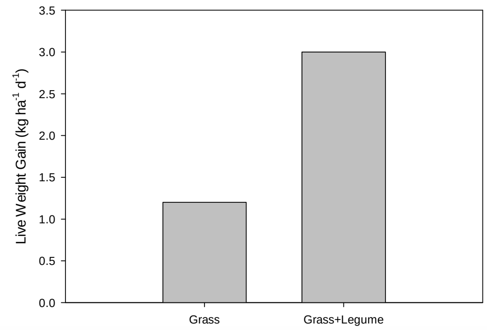
Source: White et al. (2000)

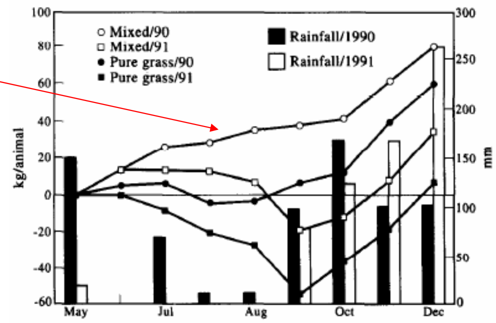
- Legume provides sufficient N for good forage growth
- In acid soils of tropics liming and P fertilizer inputs are needed to establish legume

Planting a legume along with a grass in a pasture system is an excellent way to make sure that the pasture is not N deficient. In the tropics studies have shown that the legume supplies that companion grass with as much 50 kg N per ha per year acting as a sustainable alternative to N fertilization (Miranda and Bodey, 1987). In acid soils, however, where soil P and K can be limiting annual applications of P and K fertilizers are required to maintain legume growth

Mixed Pastures & Animal Growth

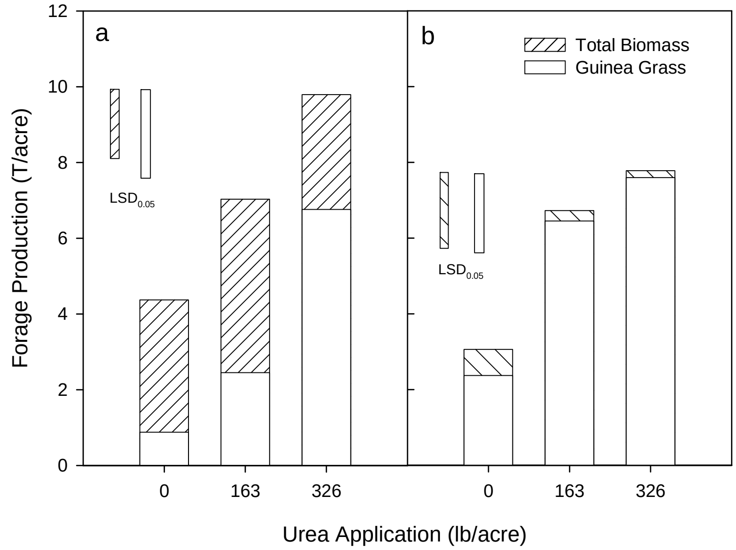
- Pastures containing grass/legume mix increase animal growth rate
- Gains are attained during dry season

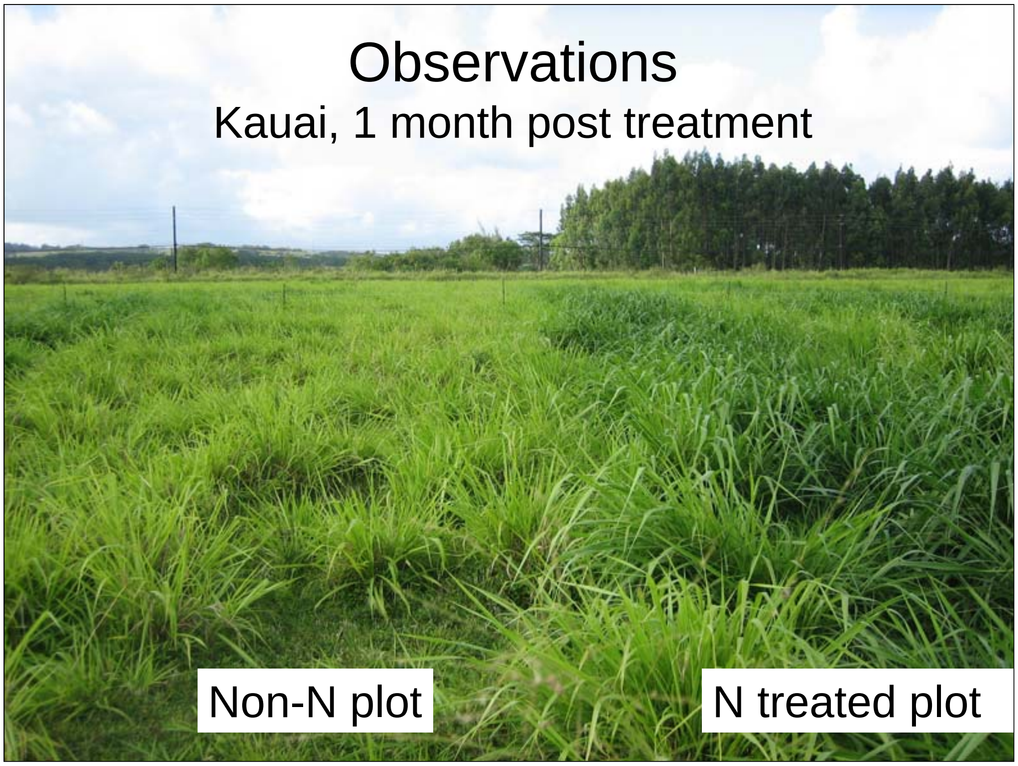




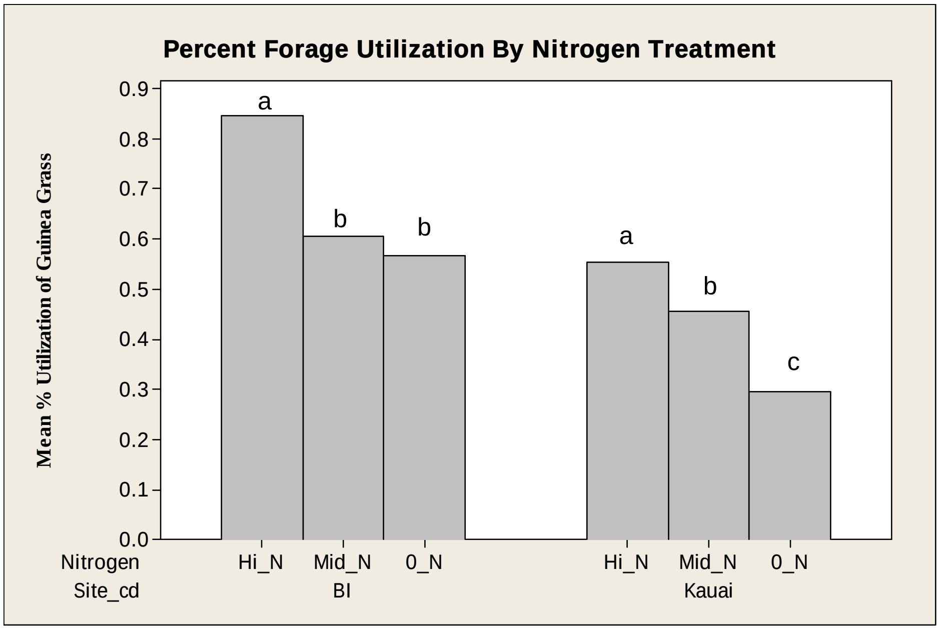
Sources: Santana and Pereira (1995) and Spain et al. (1994)

Urea Application & Grass Production




Observations
Kauai, 1 month post treatment
Non-N plot
N treated plot

Observations
Kauai, 3 months post treatment



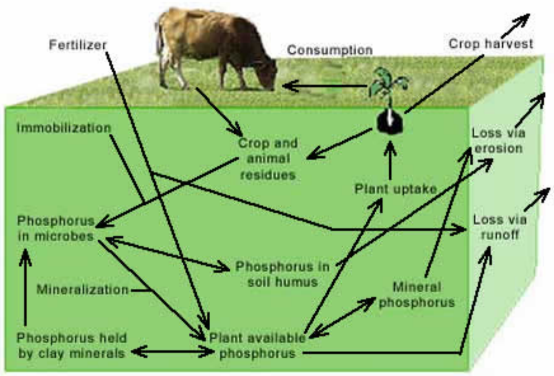
Cattle preferentially grazed high N plots

Evidence for Selective Grazing

Problems with Urea Use

1. Urea must be imported and cost may be prohibitive.
2. Urea applied to surface of alkaline soils developed on limestone parent material susceptible to volatilization (gaseous loss as NH_3). Volatilization can be reduced by applying urea to wet soils
3. Prolonged use can acidify soil

The Phosphorus Cycle



http://attra.ncat.org/attra-pub/nutrientcycling.html#phosphorus_cycle.html

- Inputs
  - plant and animal residues/manure
  - fertilizers
- Transformations
  - mineralization& immobilization
  - P-fixation
- Losses
  - erosion
  - run-off

Phosphorus (P) is an essential plant nutrient that is used in energy transfer and reproduction processes. Phosphorus is required by legumes for effective BNF. Unlike N, which is abundant in the atmosphere, P originates in rocks, minerals, and organic matter in the soil. The mineral forms of phosphorus are apatitite, which may be in a carbonate, hydroxide, fluoride, or chloride form, and iron or aluminum phosphates. Chemical reactions and microbial activity affect the availability of phosphorus for plant uptake. Under acid conditions, phosphorus is held tightly by aluminum and iron in soil minerals. Under alkaline conditions, phosphorus is held tightly by soil calcium. Thus, P reacts with clay minerals such as Al/Fe oxides in acid soils and Ca in alkaline soils making it only sparingly soluble and causing P deficiency. Like N, P in organic matter can be made available for plant uptake through microbially mediated mineralization reactions. Soil organic matter is an important source of plant available P. In most grasslands, the highest concentration of phosphorus is in the surface soils associated with decomposing manure and plant residues.

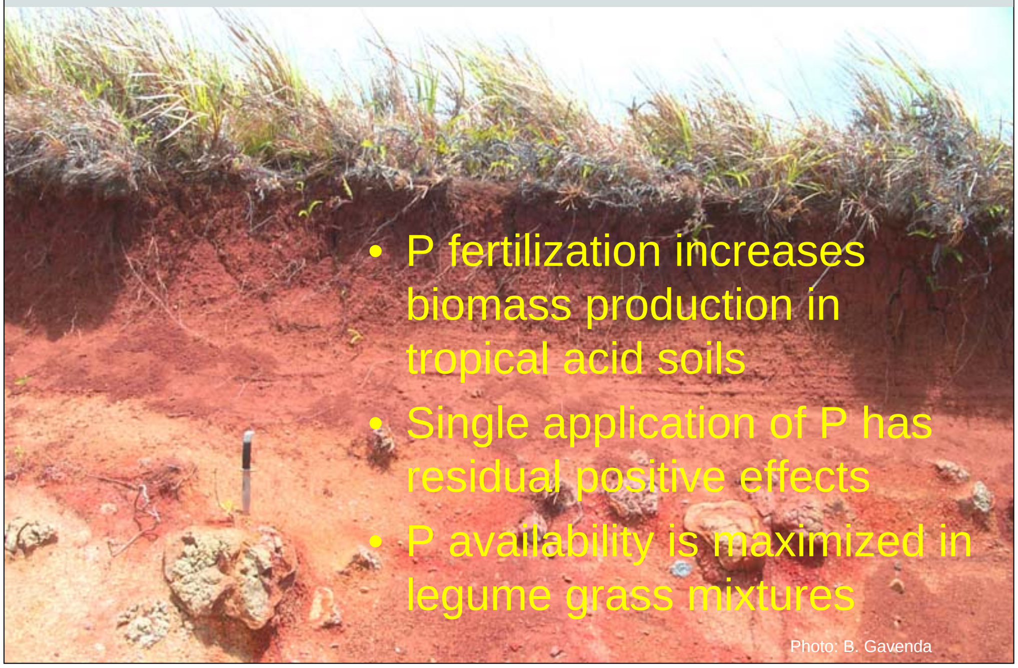
Mycorrhizae and P Availability

- Symbiotic relationship between fungi and plant roots
- Fungal hyphae extend root area
- Increase P uptake, increase tolerance to drought
- Facilitate transfer of N from legumes to grasses

Mycorrhizal fungi attach to plant roots and form thin threads that grow through the soil and wrap around soil particles. These thin threads increase the ability of plants to obtain phosphorus and water from soils. Mycorrhizae are especially important in acid and sandy soils where phosphorus is either chemically bound or has limited availability. Besides transferring phosphorus and water from the soil solution to plant roots, mycorrhizae also facilitate the transfer of nitrogen from legumes to grasses. Well-aerated and porous soils, and soil organic matter, favor mycorrhizal growth.

Source: http://attra.ncat.org/attra-pub/nutrientcycling.html

P Fertilization



- P fertilization increases biomass production in tropical acid soils
- Single application of P has residual positive effects
- P availability is maximized in legume grass mixtures

Photo: B. Gavenda

Soil Test Results

Soil	pH	TN	TC	P	K	Ca	Mg
		%			ppm		
	7.9	1.06	13.44	23	54	9730	434
	7.9	1.01	15.22	71	70	10402	516
	8.0	0.78	13.59	66	64	9134	534
	8.0	0.64	8.06	23	52	7270	198
Luta	7.9	0.71	7.59	16	112	7260	238
	7.3	1.01	9.96	21	106	6376	562
	7.3	0.77	7.67	28	76	5088	482
	7.5	0.75	7.34	52	102	5512	596
	7.5	0.92	9.05	52	102	6846	612

- Soils high in organic matter and total (TN). Difficult to determine N availability
- Soils high in P, Ca and Mg, but show low K
- Need to manage for N and K to boost productivity

Soil Test Results

Soil test results for surface soils from pastures and Forest on Tinian

Landuse	Soil	pH	TN	OC	P	K	Ca	Mg
			%			ppm		
Pasture A	1	7.8	0.50	8.43	39	52	8442	602
	2	7.7	0.45	5.41	17	86	7016	586
	3	7.0	0.44	4.75	15	98	4520	566
	4	7.5	0.56	7.05	20	170	7880	522
Pasture B	1	7.8	0.40	4.86	54	140	7586	428
	2	7.4	0.45	4.58	38	76	5256	624
	3	7.8	0.39	5.85	31	48	8572	386
	4	6.6	0.45	4.56	31	94	3862	664
Forest	1	7.1	0.51	5.00	53	106	5146	680
	2	7.7	0.48	5.17	49	138	7378	548
	3	6.9	0.66	6.95	105	222	6082	718
	4	6.8	0.46	5.10	10	98	4426	684

Summary

- Pasture productivity depends on many factors
- Water and nitrogen availability often limit pasture production
- Legumes can contribute significant N to the pasture system
- Rota soils are likely limited by both N and K
- Introducing legumes into the pasture is likely a sustainable option for increased N availability and pasture production