Relative Nutrient Requirements of Plants Suitable for Riparian Vegetated Buffer Strips

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I. Abstract

The purpose of this project is to gather, summarize, and present the available information on nitrogen and phosphorus uptake rates by buffer zone vegetation. The literature review was conducted in the disciplines of forestry, agriculture, and horticulture. This undertaking was conducted because of the lack of a well indexed reference guide on this topic. The main purpose of vegetative buffer strips is to reduce the nutrient load entering streams and rivers. Buffer strips can decrease the nutrient load by trapping nutrients bound to the sediments in overland flow. These trapped nutrients become sequestered in the buffer zone and are available for root uptake along with the nutrients in solution in the overland and subsurface flow. Each plant species has different nutrient requirements and therefore has its own distinct nutrient uptake rate. The extensive literature search produced results of direct nutrient uptake and/or related information on optimal fertilizer requirements. The most useful results are summarized, ranked, and presented as tables in Appendix A of this report. The individual findings from the literature are given in Appendix B. Tables are presented for each of the categories of plants which are appropriate for the typical 3-zone design of buffer strips. The highly variable nutrient uptake rates among all the plant species cited in this report supports the need for species specific planting of buffer zones rather than allowing opportunistic colonization of buffer zones.

II. Introduction

The purpose of this project is to review, synthesize, and present the available information on nitrogen and phosphorus uptake rates by plants suitable for riparian vegetated buffer strips. This information would help alleviate the problem of nitrogen and phosphorus uptake information not being readily available to those individuals who are responsible for designing functional buffer zones. This report with nitrogen and phosphorus uptake rates for a wide variety of plant species could facilitate the addition of nutrient removal effectiveness as a factor to consider in addition to the conventional elements of buffer zone management such as slope, soil type, and land use. This work contributes to buffer zone management because it is the first known attempt at summarizing the literature on nitrogen and phosphorus uptake rates.

A goal of this study was to try to identify some plant species which should be included in buffer zones because of their relatively high uptake rates of nitrogen and phosphorus. The managed planting of buffer zones can be supported over random colonization by demonstrating that plant species do exhibit significant differences in their uptake of nitrogen and phosphorous.

III. Literature Search and Professional Contacts

The literature search included holdings of the AGRICOLA database of the National Agricultural Library, the American University, the University of Maryland, the National Library of the Agricultural Research Service, and the LIAS computer data base at The Pennsylvania State University libraries. Knowledgeable professionals were contacted at the Chesapeake Bay

Program Office and in the fields of agronomy, soils, and forest hydrology at The Pennsylvania State University (PSU). Dr. Dick Fox in Agricultural Sciences at PSU gave background information on corn uptake rates. Dr. Douglas Beegle in the Agronomy Department provided tables of information concerning uptake rates by various crops.

Dr. Pamela Edwards at the Northeastern Forest Experiment Station in Fernow, West Virginia supplied background information through multiple personal communications. Mr. Todd, a Forest Service Representative to the Environmental Protection Agency, provided an indexed riparian zone bibliography compiled by David Correll. Several references were obtained from Ms. Karen Sykes, a Watershed Specialist for the USDA Forest Service in Morgantown, WV.

IV. Overall Purpose of Buffer Zone Research

Buffer zone research began as a means of solving the problem of detrimental amounts of nitrogen entering surface waters, caused primarily by agricultural nutrient runoff. High levels of nitrogen in water supplies can have a negative effect on human health. High levels of nutrients in surface waters degrade the habitat for fish and other aquatic organisms. The increased nitrogen levels can cause the rapid growth of algae in rivers, lakes, and estuaries. The presence of large quantities of algae reduces the amount of light which penetrates beneath the water surface potentially causing the death of aquatic plants which are essential to fish communities for breeding habitat, cover, and as a food source. When the algae begin to decompose, dissolved oxygen which is critical for the survival of aquatic fauna is depleted from the water.

Buffer zones have the potential to stop this destructive cycle of events from occurring by preventing the primary nutrients (nitrogen and phosphorus) causing the algal growth from ever entering surface waters. The two main mechanisms of nitrogen retention by buffer zones is vegetative uptake and bacterial denitrification. Vegetative uptake is the focal mechanism of this study.

Buffer zones also prevent nutrients, especially phosphorus, from entering surface waters by trapping of sediment carried by overland flow. Studies of grass filter strips have shown that trapping efficiencies of sediments only exceed 50% when there is shallow (sheet) flow rather than concentrated (channeled) flow. However, the flow most common to field conditions is channeled flow (Dillaha et al. 1989). A combination of grass filter strips with a woody riparian buffer zone may be more useful, because riparian forest buffer zones have the potential to absorb and trap as much or more sediment than grass filter strips alone (Cooper et al. 1987). A three stage strip with mature trees immediately adjacent to the water, then a woody managed strip of trees and shrubs, and finally leaf and stem grasses farthest from the water body is the current preferred strip design. The managed portion of the buffer strip is critical because it affords a means of exporting the nutrients out of the buffer strip in the harvested woody tissue.

The young developing trees in the managed strip also take up more nutrients at that life stage than mature trees.

Phosphorus is normally attached to the soil particles. The trapped phosphorus can be absorbed by the roots of the buffer zone vegetation along with dissolved nitrogen in overland and subsurface flow. Buffer zones not only maintain the chemical quality of a water body, but they also serve to preserve the physical quality by reducing sediment deposition. The roots of the woody vegetation stabilize stream banks and shorelines, and eliminate soil erosion and subsequent nutrient mobilization from those sources.

V. Nitrogen and Phosphorus Retention by Buffer Strips

Most of the buffer strip literature describes the nutrient retention by entire systems and does not distinguish uptake rates on a species specific basis. However, it is useful to cite the nitrogen and phosphorus retention rates of whole buffer zones to gain an appreciation of their retention capacities as composite systems. Cooper at al. (1986) reported that a riparian strip on the coastal plain of North Carolina retained 85% of the nitrate leaving an adjacent field edge. Riparian forests on Maryland's Rhode River watershed retained 80% of the phosphorus and 89% of the nitrogen from adjacent agricultural land (Peterjohn and Correll 1984). Lowrence et al. (1984) calculated that 68% of incoming nitrogen and 30% of incoming phosphorus were retained by a riparian forest in the Little River watershed in the Tifton upland province of the Georgia coastal plain. Cooper et al. (1987) estimated that 84 to 94% of the sediment removed from the cultivated fields remained in the Cypress Creek watershed on the coastal plain of North Carolina. These sediment trapping capabilities are important with respect to nutrient fluxes because phosphorus is normally found bound to soil particles.

Nitrogen retention is well documented during the summer months as evidenced by some of the cited sources, but there is little information on the potential of winter retention. Haycock and Pinay (1993) report that winter retention of nitrate is critical, since 80% of the nitrate leached from agricultural soils is concentrated during this season. This high nitrate leaching in the winter is caused by a combination of bare fields and low evapotranspiration rates. The lower temperatures in winter are less favorable to denitrification, and dormant or dead plants provide less uptake of water and nutrients (Cooper et al. 1986).

On the River Leach in southern England, a poplar (*Populus italics)* vegetated riparian strip retained 99% of the nitrate entering in subsurface groundwater flow during the winter. A grass (*Lolium perenne* L.) vegetated zone on the same river retained 84% of the incoming nitrate (Haycock and Pinay 1993). Although vegetation has no active role in nutrient uptake in the winter, the above ground vegetative biomass contributes carbon to the soil microbiological community that is primarily responsible for nitrate retention in the winter. This explains why the poplar vegetated site, with the greater surface biomass, retained more nitrate than the grass site (Haycock and Pinay 1993).

Few studies focused on the relative nitrogen retention capacities of different vegetation types. Osborne and Kovacic (1993) compared the nitrogen retention capacities of a grass buffer strip and a forest buffer strip and found the grass strip was more variable and less effective in filtering nitrogen than the forest strip.

VI. Discussion of Results (Tables)

The three zone buffer strip

The plant uptake rates for nitrogen and phosphorus were placed into three categories: forest canopy species, forest understory-shrub-forb-fern species, and herbaceous species. These categories account for those plant species which may be included in a 3 zone buffer strip (Welsch 1991). Zone 1 consists of undisturbed forest and contains mostly mature trees which stabilize the water's edge and provide shade to maintain generally beneficial lower water temperatures. There is nutrient uptake occurring in this zone, but not to the extent of zone 2 (the shrub/managed woody species). Zone 2 consists of vigorously growing trees and shrubs which are periodically cut as they approach maturity. This is the zone of maximum nutrient uptake because younger trees require more nutrients for growth than mature trees. Zone 3 consists of a grass filter strip where concentrated flows from adjacent cropland may be converted to dispersed flows by the installation of water bars or spreaders. This grass filter strip may be periodically harvested or grazed upon to facilitate maximum nutrient uptake and removal (Welsch 1991).

The concept of a stream side forest buffer exists as a potential mechanism for decreasing the amount of excess applied nutrients from entering water bodies. If more nutrients were excluded at their source (fertilizer applications), the need for stream side buffers could be reduced.

Fertilizer, plant uptake, and nutrient requirements

Generally, nitrogen and phosphorus are the limiting nutrients for plant survival and growth. Therefore, if the availability of these nutrients is increased, plant uptake will also increase (to a point). Rychnovska (1993) demonstrated this in his fertilizer application experiments with a native grass meadow in the Czech Republic. Corn also increased its uptake of nitrogen as more was applied (Tanji et al. 1981, Barber and Olson 1968). Frissel (1977) reports that wheat increased its nitrogen uptake at higher fertilization levels. Forest species are also nitrogen and phosphorus limited. Increased nitrogen and phosphorus uptake occurs to a certain point and after that point is reached some other nutrient, environmental factor, or the plant's maximum growth rate becomes the agent limiting growth. Once nitrogen and phosphorus are no longer the limiting nutrients any additional fertilizer applications will most likely contribute to nutrient runoff into nearby water bodies. Fertilizer nutrient requirements for maximum growth without excess are unique to each vegetative species. Riparian zones are planned and established to reduce nutrient input to streams, and since the exact nutrient requirements of all forest/shrub/grass species is not known, this study has made the assumption that a good estimate for buffer zone species nutrient requirements exists as the fertilizer requirements of those species, where available. Included in the following tables are vegetative species, some with maximum recommended fertilizer amounts. Fertilizer amounts are indicated as such, and are to be used as approximate surrogates for nutrient uptake rates of those species, or to establish relative ranking of nutrient uptake among species.

Nitrogen and phosphorus uptake in forest canopy species

Deciduous trees have greater nutrient demands than conifers (Cole and Rapp 1981). This is due to the fact that deciduous trees have to compensate for the nutrient losses caused by annual leaf loss. Vegetative uptake is defined as the absorption of nutrients principally by the roots (Duvigneaud and Denaeyer-DeSmet 1970). Certain species may have high uptake rates but may only retain a small proportion of *nutrients*. These are not as useful in a buffer strip as species that may have lower nutrient uptake rates but retain a greater proportion of the absorbed nutrients. A recent publication of the US Department of Agriculture, USDA Forest Service, titled Chesapeake Bay Riparian Handbook: A Guide for Establishing and Maintaining Riparian Forest Buffers (Palone and Todd, 1997) includes a large list of riparian species suggested for planting in Riparian zones of the Mid-Atlantic, Northeastern United States. This study attempted to use this USDA established species list as the basis for the following tables showing the amounts of phosphorus and nitrogen removed from the soil by various species. Table A-1 in Appendix A shows the amounts of nitrogen and phosphorus removed by forest canopy species from soil in pounds per acre per year, as well as the relative uptake of some species as indicated in the literature. When one is planning a buffer strip the local soil moisture conditions must be taken into account, because certain tree species may experience inhibited growth or even expire in wet soils. Slope, plant species-species interactions, soil depth, soil type, and depth of root zone are also important factors when developing plans for riparian buffer strips. The limited research existing for nutrient and fertilizer requirements for riparian species is reflected in Table A-1 in Appendix A as well as other tables in this study. Most values for individual species listed in the tables represent information from one or two studies on nutrient or fertilizer requirements. Therefore, all values should not be viewed as thoroughly representative. In the case of recommended fertilizer values, studies often specify their test fertilizer application rates in large increments (e.g. 0, 50, 100, 200 lbs/acre/yr), therefore, the results may be quite coarse. Thus, the optimal fertilizer requirement may be between, say, 50 and 100 lbs/acre/yr. Table A-1 in Appendix A includes some values which are averages of several unknown species of the same genus.

Sykes et al. (1994), in their publication Crop Tree Management in Riparian Zones, cite that red and white oak, red maple and quakeing aspen accumulate substantial amounts of nitrogen, but only to a point. Once their nitrogen requirements are met, growth and absorption of nitrogen level off. Douglas fir, white ash, basswood, and yellow poplar also increase their nitrogen uptake if increased available nitrogen is present.

Forest understory-shrub-forb-fern species

Table A-2 in Appendix A indicates the possibility that small understory species and shrubs may have the capacity to remove large amounts of nitrogen. The high growth rate of some young understory species may contribute to their high nutrient uptake. It is apparent, however, that there exists very little literature on nutrient or fertilizer requirements for these types of species.

Herbaceous species

Table A-3a in Appendix A shows the nitrogen, and Table A-3b in Appendix A shows the phosphorus uptake of herbaceous species ranked by decreasing nutrient uptake levels. Species with recommended fertilizer values are indicated by the sub-letter "a." Many species are listed as pounds per ton, since values for individual units planted per acre are unknown, and therefore cannot be converted to pounds per acre per year. Clover, Alfalfa, Gamagrass and Tall Fescue appear to have some of the highest rates of nutrient uptake. It is interesting to note that in order to maximize some plant-species ratios for maximal productivity, some planted species such as Tall Fescue/White Clover require little if any fertilizer. This seems to indicate that this crop has maximal productivity at low nutrient levels, or that the legume partner is fixing atmospheric nitrogen, thus indicating that this species/species combination may not be suitable for riparian buffer zone 3. Legumes and some non-legumes possess the property of increasing soil and plant nitrogen by the action of associated root zone bacteria which fix atmospheric nitrogen; therefore, these species, although perhaps high in nitrogen content, may not be deriving that nutrient from either overland or shallow groung water flow. Thus, these species may not deserve their rank as interceptors of nitrogen in water destined for nearby water bodies. Tables A-4a and A-4b also show nitrogen and phosphorus uptake of herbaceous species, but are ranked alphabetically by species common name.

VII. Summary and Conclusions

This presentation of nitrogen and phosphorus uptake rates by various plant species will hopefully serve as a reference guide for those individuals who are interested in the efficient performance of buffer strips. The importance of including the vegetative uptake of nutrients in the design of functional buffer strips seems apparent. Various researchers (i.e. Lowrance et al. 1984, Peterjohn and Correll 1984, Cooper et al. 1986) have shown that buffer zones can retain up to 89% of the nitrogen and 80% of the phosphorus from adjacent agricultural land. The differences in nitrogen and phosphorus uptake among species expressed in this report are substantial enough to warrant species-specific planting and management of buffer strips. Given that a number of buffer species are equally available, the selection of plants characterized by higher nutrient uptake is likely to provide greater efficiency than strips occupied by randomly selected or naturally colonizing plants.

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Appendix A. Summary of Findings

Table A-1. Riparian canopy tree species and nitrogen/phosphorus amounts removed (uptake).

Table A-2. Riparian understory, shrub, & fern species and nitrogen/phosphorus amounts removed (uptake).

Table A-3a. Herbaceous species ranked by amounts of nitrogen removed (uptake).

Table A-3b. Herbaceous species ranked by amounts of phosphorus removed (uptake).

Table A-4a. Herbaceous species and amounts of nitrogen removed (uptake).

Table A-4b. Herbaceous species and amounts of phosphorus removed (uptake).

Table A-1. Riparian canopy tree species and nitrogen/phosphorus amounts removed (uptake).

				Amount Nutrient Removed (uptake)	
Common Name	Species Name		Relative uptake**	Nitrogen (lbs/acre/yr)	Phosphorus (lbs/acre/yr)
American Beech	*Fagus grandifolia*	*	low P		
Bald Cypress	*Taxodium distichum*	*		24	
Basswood	*Tilia americana*	*	high N,P		
Birch spp.	*Betula spp.*			8a	0.5a
Douglas fir	*Pseudotsuga menziesii*			25b	4.7b
Eastern Cottonwood	*Populus deltoides*	*		149c	
European beech				15a	2a
Hemlock	*Tsuga sieboldii*			39b	
Maple spp.	*Acer spp.*			51b	5.3b
Oak spp.	*Quercus spp.*		high N	26a	2.3a
Pine spp.	*Pinus spp.*			8a	0.7a
Quaking Aspen			high N		
Red Alder	*Alnus rubra*			86b	9b
Red Maple	*Acer rubrum*	*	high N		
Red oak	*Quercus rubra*	*	high N		
Spruce spp.	*Picea spp.*			10a	1a
White ash	*Fraxinus americana*	*	high N		
White oak	*Quercus alba*	*	high N		
Yellow poplar	*Liriodendron tulipifera*	*	high N, P	20a	0.8a
Red Maple, Blueberry, Sweet pepperbush, Swamp azalea, Inkberry	*Acer rubrum, Vaccinium corymbosum, Clethora alnifolia, Rhododendron viscosum, Ilex glabra*	*		107b	

Table A-2. Riparian understory, shrub, & fern species and nitrogen/phosphorus amounts removed (uptake).

				Amount Nutrient Removed (uptake)	
Common Name	Species Name		Relative uptake	Nitrogen (lbs/acre/yr)	Phosphorus (lbs/acre/yr)
Flowering Dogwood	*Cornus florida*	*	high P	100-200c	
Highbush blueberry	*Vaccinium crymbosum*	*		62c	
Smartweed	*Persicaria polygonum*	*		100c	

a value is average net uptake after litterfall losses are excluded
b value is average uptake before litterfall loss
c pounds of nutrient fertilizer recommended per acre per year
** from Sykes, et. al. 1994, whereas quantitative amounts are combined from several studies
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-3a. Herbaceous species ranked by amounts of nitrogen removed (uptake).

			Amount Nitrogen Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Clover, white (15m)	*Trifolium spp.*		49-66	
Alfalfa (15m)	*Medicago sativa*		34-65	
Bromegrass (15m)	*Bromus spp.*	*	14-60	
Tall Fescue (15m)	*Festuca arundinacea*	*	14-54	
Bermudagrass (15m)			14-53	
Timothy (15m)	*Phleum pratense*		14-44	
Clover, white (75m)	*Trifolium spp.*		18-23	
Bluestem	*Andropogen gerardi/scoparius*	*	10-27	
Soybean, straw (10m)	*Glycine spp.*		13-18	
Alfalfa (75m)	*Medicago sativa*		10-20	
Barley, straw (10m)			10-16	
Oat, straw (10m)	*Avena spp.*		9-15	
Tall Fescue (75m)	*Festuca arundinacea*	*	5-18	
Bromegrass (75m)	*Bromus spp.*	*	4-19	
Bermudagrass (75m)			5-17	
Wheat, straw (10m)	*Triticum aestivum*		7-15	
Rye, straw (10m)	*Hordeum spp.*		6-12	
Timothy (75m)	*Phleum pratense*		4-13	
Corn, silage (70m)	*Zea mays*		6-9	
Lucerne				281b
Switchgrass	*Panicum virgatum*	*		200a
Tall Fescue	*Festuca arundinacea*	*		174-179a
Eastern gamagrass 3s	*Tripsacum dactyloides*	*		78-138b
Tall Fescue	*Festuca arundinacea*	*		89b
Eastern gamagrass 6s	*Tripsacum dactyloides*	*		36-122b
Big Bluestem, little Bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	*		40a
Grass-clover	*Festuca pratensis, Phleum pratensis*			32b
Grass	*Nardus stricta, sanquisarba*			23b
Tall Fescue & White Clover	*Festuca arundinacea, Trifolium spp.*			0a

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content of species
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-3b. Herbaceous species ranked by amounts of phosphorus removed (uptake).

			Amount Phosphorus Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa	*Medicago sativa*			22-112a
Clover-grass	*Festuca pratensis, Phleum pratensis*			22-85a
Tall Fescue & white clover	*Festuca arundinacea, Trifolium spp.*			46-48a
Tall Fescue	*Festuca arundinacea*	*		13-39a
Grass-clover	*Festuca pratensis, Phleum pratensis*			4.8b

a pounds of nutrient fertilize recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content of species
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-4a. Herbaceous species and amounts of nitrogen removed (uptake).

			Amount Nitrogen Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa (15m)	*Medicago sativa*		34-65	
Alfalfa (75m)	*Medicago sativa*		10-20	
Barley, straw (10m)			10-16	
Bermudagrass (15m)			14-53	
Bermudagrass (75m)			5-17	
Big Bluestem, little Bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	*		40a
Bluestem	*Andropogen gerardi/scoparius*	*	10-27	
Bromegrass (15m)	*Bromus spp.*	*	14-60	
Bromegrass (75m)	*Bromus spp.*	*	4-19	
Clover, white (15m)	*Trifolium spp.*		49-66	
Clover, white (75m)	*Trifolium spp.*		18-23	
Corn, silage (70m)	*Zea mays*		6-9	
Eastern gamagrass (3s)	*Tripsacum dactyloides*	*		78-138
Eastern gamagrass (6s)	*Tripsacum dactyloides*	*		36-122
Grass	*Nardus stricta, sanquisarba*			24b
Grass-clover	*Festuca pratensis, Phleum pratensis*			33b
Lucerne				281b
Oat, straw (10m)	*Avena spp.*		9-15	
Rye, straw (10m)	*Hordeum spp.*		6-12	
Soybean, straw (10m)			13-18	
Switchgrass	*Panicum virgatum*	*		200a
Tall Fescue	*Festuca arundinacea*	*		89b
Tall Fescue	*Festuca arundinacea*	*		174-179a
Tall Fescue (15m)	*Festuca arundinacea*	*	14-54	
Tall Fescue (75m)	*Festuca arundinacea*	*	5-18	
Tall Fescue & white clover	*Glycine spp.*			0a
Timothy (15m)	*Phleum pratense*		14-44	
Timothy (75m)	*Phleum pratense*		4-13	
Wheat, straw (10m)	*Triticum spp.*		7-15	

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-4b. Herbaceous species and amounts of phosphorus removed (uptake)

			Amount Phosphorus Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa	*Medicago sativa*			22-112a
Clover-grass				22-85a
Grass	*Nardus stricta, sanquisarba*			3.8b
Grass-clover	*Festuca pratensis, Phleum pratensis*			4.8b
Tall Fescue	*Festuca arundinacea*	*		13-39a
Tall Fescue & white clover	*Festuca arundinacea, Phleum*			46-48a

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*

Appendix B. Summary of Literature Search

Table B-1. Forest canopy species.

Table B-2. Riparian understory, shrub, forb, fern species.

Table B-3. Herbaceous species.

Table B-1. Forest Canopy Species

Stand no.	Species common name	Species scientific name	Stand age (yrs.)	Nitrogen (lbs/acre/yr) Uptake	Retention	Return	Phosphorus (lbs/acre/yr) Uptake	Retention	Return	Source
Coniferous										
1	Scots pine	*Pinus sylvestris*	mature	40	9	31	4	<1	2.6	Duvigneaud et al. 1970
2	Scots pine	*Pinus sylvestris*	100	30	11	20	3	<1	1.7	Ehwald 1957
3	Loblolly pine	*Pinus taeda*	20	37	4	33	2	_	_	Switzer and Nelson 1972
4	Loblolly pine	*Pinus taeda*	23	31	_	_	_	_	_	Johnson and Lindberg 1992
5	Loblolly pine	*Pinus taeda*	35	17	_	_	_	_	_	Johnson and Lindberg 1992
6	Loblolly pine	*Pinus taeda*	40	18	_	_	1	_	_	Frissel 1977
7	Black pine	*Pinus nigra*	10	49	_	_	_	_	_	Miller 1984a
8	Black pine	*Pinus nigra*		62	_	_	5	_	_	Miller 1986
9	White pine	*Pinusstrobus*	15	45	_	_	_	_	_	Cole and Rapp 1981
10	White pine	*Pinusstrobus*	30	35	_	_	_	_	_	Johnson and Lindberg 1992
11	Monterey pine	*Pinus radiata*	_	11 to 15	_	_	<2	_	_	Hingston and Raison 1982
12	_	*Pinus pinaster*	14	14	_	_	1	_	_	Hingston and Raison 1982
13	Slash pine	*Pinus elliottii*	22	26	_	_	_	_	_	Johnson and Lindberg 1992
14	Short leaf pine	*Pinus echinata*	30	43	_	_	3	_	_	Cole and Rapp 1981
15	Spruce	*Picea*	_	31	11	20	3	0.8	1.8	Ehwald 1957
16	Spruce	*Picea*	120	55	7	48	2	<0.3	2.1	Parshevnikov 1962
17	Spruce	*Picea*	48	74	_		_	_	_	Bonneau 1992
18	Norway spruce	*Picea abies*	66	44	10	34	_	_	_	Gundersen 1992
19	Norway spruce	*Picea abies*	45	34	9	26	_	_	_	Gundersen 1992
20	Norway spruce	*Picea abies*	40	41	5	36	_	_	_	Gundersen 1992
21	Norway spruce	*Picea abies*	100	54	18	36	5	1.6	3	Ehwald 1957
22	Norway spruce	*Picea abies*	50	45	_	_	_	_	_	Feger 1992
23	Norway spruce	*Picea abies*	100	30	_	_	_	_	_	Feger 1992
24	Norway spruce	*Picea abies*	45	31	_	_	3	_	_	Cole and Rapp 1981
25	Norway spruce	*Picea abies*	60	79	_	_	6	_	_	Cole and Rapp 1981
26	Norway spruce	*Picea abies*	34	48	_	_	4	_	_	Cole and Rapp 1981
27	Norway spruce	*Picea abies*	87	56	_	_	5	_	_	Cole and Rapp 1981
28	Norway spruce	*Picea abies*	115	50	_	_	4	_	_	Cole and Rapp 1981
29	Norway spruce-Scots pine	*Picea abies-Pinus sylvestris*	40	20	_	_	_	_	_	Johnson and Lindberg 1992
30	Red spruce	*Picea rubens*	250	10	_	_	_	_	_	Johnson and Lindberg 1992
31	Red spruce	*Picea rubens*	250	19	_	_	_	_	_	Johnson and Lindberg 1992
32	Red spruce-Balsam fir	*Picea rubens-Abies balsamea*	85	16	_	_	_	_	_	Johnson and Lindberg 1992
33	Bal. fir-Rd spruce-Wt birch	*A. balsamea-P. rubens-B. papyrifera*	virgin	34	_	_	_	_	_	Johnson and Lindberg 1992

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
Coniferous			
1	_	_	_
2	Germany	_	_
3	_	_	_
4	Duke Forest, North Carolina, USA	Typic hapludul	Felsic igneous
5	Oak Ridge, Tennessee, USA	Fluventic dystrochrep	shale
6	Mississippi, USA	_	_
7	_	_	_
8	_	_	_
9	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schists, and gneisses
10	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schists, and gneisses
11	Australia	_	_
12	Australia	_	_
13	Gainesville, Florida, USA	Ultic haplaquod - sandy, low nutrient	Marine deposits
14	Walker Branch Site 2, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
15	Germany	_	_
16	USSR	Gley	_
17	Ardennes, France	(Area with high nitrogen pollution	_
18	Klosterhede, Denmark	Podzol, former heathland	Outwashed plain
19	Tange, Denmark	Slightly podzolized (course sand	Fluvial plain with some limeston
20	Strodam, Denmark	Grey-brown forest soil	Sandy moraine
21	Germany	Gley	_
22	Schluchsee Watershed, Black Forest, SW Germany	Iron-humus-podzols	Barhalde granite
23	Schluchsee Watershed, Black Forest, SW Germany	Dystric cambisols	Quartz-sandstone
24	Karelia, USSR	Humus iron podso	Sand moraine
25	Kongalund, Sweden	Brown forest soil (acid)	Cambria shales and sandstone
26	Solling Project, Site F3, Germany	Brown forest soil (acid)	Buntsandstein
27	Solling Project, Site F1, Germany	Brown forest soil (acid)	Buntsandstein
28	Solling Project, Site F2, Germany	Brown forest soil (acid)	Buntsandstein
29	Nordmoen Field Station, Norway	Typic udipsammen	Precambrian and Permian crystalline bedrock
30	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Thunderhead sandstone
31	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Thunderhead sandstone
32	Howland, Maine, USA	Typic haplorthod, Aeric haplaquod	Waterville and Vassalboro formations
33	Whiteface Mountain, Adirondacks, New York, USA	Typic cryohumods or Typic cryorthod	Precambrian anorthosite

Table B-1 (Cont'd). Forest Canopy Species

			Stand age	Nitrogen (lbs/acre/yr)			Phosphorus (kg/ha/yr)			
Stand no.	Species common name	*Species scientific name*	(yrs.)	Uptake	Retention	Return	Uptake	Retention	Return	Source
34	True fir	*Abies firma*	97-145	39	_	_	_	_	_	Cole and Rapp 1981
35	Pacific silver fir	*Tsuga mertensiana*	180	8	_	_	_	_	_	Johnson and Lindberg 1992
36	Hemlock	*Tsuga sieboldii*	120-443	25	_	_	_	_	_	Cole and Rapp 1981
37	Western hemlock	*Tsuga heterophylla*	121	52	_	_	9	_	_	Cole and Rapp 1981
38	Douglas-fir	*Pseudotsuga menziesii*	37	35	21	13	6	5	0.8	Gessel et al. 1973
39	Douglas-fir	*Pseudotsuga menzieesii*	9	3	_	_	_	_	_	Cole and Rapp 1981
40	Douglas-fir	*Pseudotsuga menzieesii*	22	30	_	_	6	_	_	Cole and Rapp 1981
41	Douglas-fir	*Pseudotsuga menzieesii*	30	29	_	_	_	_	_	Cole and Rapp 1981
42	Douglas-fir	*Pseudotsuga menzieesii*	37	31	_	_	6	_	_	Frissel 1977
43	Douglas-fir	*Pseudotsuga menzieesii*	42	29	_	_	_	_	_	Cole and Rapp 1981
44	Douglas-fir	*Pseudotsuga menzieesii*	42	32	_	_	4	_	_	Cole and Rapp 1981
45	Douglas-fir	*Pseudotsuga menzieesii*	55	11	_	_	_	_	_	Johnson and Lindberg 1992
46	Douglas-fir	*Pseudotsuga menzieesii*	73	29	_	_	_	_	_	Cole and Rapp 1981
47	Douglas-fir	*Pseudotsuga menzieesii*	95	33	_	_	_	_	_	Cole and Rapp 1981
48	Douglas-fir	*Pseudotsuga menzieesii*	450	21	_	_	5	_	_	Cole and Rapp 1981
49	Douglas-fir	*Pseudotsuga menzieesii*	_	19	_	_	1	_	_	Ballard and Cole 1974
Boreal										
50	Black spruce	*Picea mariana*	51	2	_	_	1	_	_	Cole and Rapp 1981
51	Black spruce	*Picea mariana*	55	6	_	_	1	_	_	Cole and Rapp 1981
52	Black spruce	*Picea mariana*	130	6	_	_	1	_	_	Cole and Rapp 1981
53	Paper birch	*Betula papyifera*	50	22	_	_	5	_	_	Cole and Rapp 1981
Deciduous										
54	European beech	*Fagus sylvatica*	mature	45	9	36	11	2	9	Duvigneaud et al. 1970
55	European beech	*Fagus sylvatica*	_	52	_	_	5	_	_	Frissel 1977
56	European beech	*Fagus sylvatica*	59	82	_	_	6	_	_	Cole and Rapp 1981
57	European beech	*Fagus sylvatica*	122	67	_	_	6	_	_	Cole and Rapp 1981
58	European beech	*Fagus sylvatica*	_	64	_	_	4	_	_	Ulrich and Mayer 1972
59	European beech	*Fagus sylvatica*	_	40	14	26	4	1	3.1	Ehwald 1957
60	European beech	*Fagus sylvatica*	115	0	_	_	8	5	3	Klausing 1956
61	European beech	*Fagus sylvatica*	125	0	_	_	5	2	2.5	Klausing 1956
62	European beech	*Fagus sylvatica*	10	40	9	31	3	1	2.4	Forgeard et al. 1992
63	European beech	*Fagus sylvatica*	25	44	15	28	4	2	2.1	Forgeard et al. 1992
64	European beech	*Fagus sylvatica*	100	37	9	28	3	1	2.5	Forgeard et al. 1992

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
34	JPTF-71 Yusuhara Takatoriyama, Japar	Brown forest soil (moderately wet	Cretaceous/Mudstone
35	Findley Lake, Washington, USA	Spodosol	Andesite
36	JPTF-70 Yusuhara Kubotaniyama, Japar	Brown forest soil (moderately wet	Cretaceous/Sandstone
37	Cascade Head, Oregon, USA	Utisol	Tyee formation marine siltston
38	Pacific Northwest, USA	_	_
39	Pacific Northwest, USA	_	_
40	Thompson Research Center, Wash., USA	Everett gravelly sandy loam	Glacial outwash
41	Pacific Northwest, USA	_	_
42	Washington, USA	_	_
43	Pacific Northwest, USA	_	_
44	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loar	Glacial outwash
45	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loar	Glacial outwash
46	Pacific Northwest, USA	_	_
47	Pacific Northwest, USA	_	_
48	Andrews Experimental Forest, Oregon, USA	Inceptosol	Miocene tuffs and breccias
49	_	_	_
Boreal			
50	Alaska	Pergelic cryaqupt	_
51	Alaska	Pergelic cryaqupt	_
52	Alaska	Pergelic cryaqupt	_
53	Alaska	Pergelic cryaqupt	_
Deciduous			
54	_	_	_
55	_	_	_
56	Solling Project, Site B4, Germany	Brown forest soil (acid)	Buntsandstein
57	Solling Project, Site B2, Germany	Brown forest soil (acid)	Buntsandstein
58	_	_	_
59	Germany	_	_
60	Germany	_	Diorite
61	Germany	_	Granite
62	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite
63	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite
64	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite

Table B-1 (Cont'd). Forest Canopy Species

			Stand age	Nitrogen (lbs/acre/yr)			Phosphorus (kg/ha/yr)			
Stand no.	Species common name	*Species scientific name*	(yrs.)	Uptake	Retention	Return	Uptake	Retention	Return	Source
65	European beech	*Fagus sylvatica*	80	78	_	_	5	_	_	Cole and Rapp 1981
66	European beech	*Fagus sylvatica*	45-130	70	_	_	8	_	_	Cole and Rapp 1981
67	American beech	*Fagus grandifolia*	_	20	_	_	_	_	_	Johnson & Lindberg 1992
68	English oak-Euro. beech	*Quercus robur-Fagus sylvatica*	70-75	82	27	55	6	2	4.2	Duvigneaud et al. 1970
69	English oak- European ash	*Quercus robur-Fraxinus excelsior*	115-160	110	39	71	8	4	4.8	Duvigneaud et al. 1970
70	Red oak-European ash	*Quercus rubra-Fraxinus excelsior*	140	110	39	71	8	4	4	Duvigneaud et al. 1970
71	_	*Querecto-aegopodietum*	48	93	50	43	13	3	10.7	Remezov et al. 1959
72	_	*Querecto-aegopodietum*	55	82	29	53	6	4	2.6	Mina 1955
73	Oak-Hickory	*Quercus-Carya*	30-80	62	_	_	3	_	_	Cole and Rapp 1981
74	Oak-Hickory	*Quercus-Carya*	60-200	38	_	_	_	_	_	Cole and Rapp 1981
75	Chestnut oak	*Quercus prinus*	30-80	61	_	_	3	_	_	Cole and Rapp 1981
76	Chestnut oak	*Quercus prinus*	_	101	_	_	_	_	_	Binkley 1986
77	Holm-oak	*Quercus ilex*	_	42	_	_	5	_	_	Bellot et al. 1992
78	Holm-oak	*Quercus ilex*	_	49	_	_	5	_	_	Bellot et al. 1992
79	Mediterr. evergreen oak	*Quercus ilex*	150	43	_	_	7	_	_	Cole and Rapp 1981
80	Oak	*Quercus conferts*	35	62	_	_	2	_	_	Alifragis & Papamichos 1992
81	Mixed oak	*Quercus-mixed*	80	71	_	_	4	_	_	Cole and Rapp 1981
82	_	*Quercetum frainetto-Cerris macedonia*	45	78	_	_	11	_	_	Melovski et al. 1992
83	Oak-Ash-Birch-Sycamore	*Quercus-Fraxinus-Betula-Platanus*	_	87	_	_	7	_	_	Frissel 1977
84	Oak-Sourwood-Red maple	*Q.-Oxydendrum arboreum-A. rubrum*	uneven	33	_	_	_	_	_	Johnson & Lindberg 1992
85	Northern hardwoods	*A.saccharum-F.grandifolia-A.rubrum*	100	44	_	_	_	_	_	Johnson & Lindberg 1992
86	Oak-Birch	*Quercus-Betula*	80	70	_	_	3	_	_	Cole and Rapp 1981
87	Yellow poplar-mixed oak	*Liriodendron tulipifera-Quercus*	30-80	52	_	_	3	_	_	Cole and Rapp 1981
88	Yellow poplar-Blackgum	*Lirioden. tulipifera-Nyssa sylvatica*	_	28	13	15	2	<0.7	1.8	Fail et al. 1986
89	Yellow poplar	*Liriodendron tulipifera*	50	43	_	_	4	_	_	Cole and Rapp 1981
90	Birch	*Betula spp.*	_	38	_	_	4	_	_	Miller 1984b
91	European white birch	*Betula verrucosa*	_	50	7	43	4	<0.5	3.2	Ovington & Madgewick 1959
92	Red alder	*Alnus rubra*	30	103	_	_	9	_	_	Cole and Rapp 1981
93	Red alder	*Alnus rubra*	55	69	_	_	_	_	_	Johnson and Lindberg 1992
94	Sugar maple-Yellow birch	*A. saccharum-B. alleghaniensis*	135	33	_	_	_	_	_	Johnson and Lindberg 1992
95	Red maple-Yellow poplar	*A. rubrum-L. tulipifera*	_	57	26	31	5	1	4	Fail et al. 1986
96	Maple-Birch-Beech	*Acer-Betula-Fagus*	60	66	_	_	6	_	_	Cole and Rapp 1981
97		*Eucalyptus grandis*	27	89	_	_	4	_	_	Turner and Lambert 1983
98	_	*Eucalyptus spp.*	_	5 to 10	_	_	<1	_	_	Hingston and Raison 1982
99	Red Maple, Blueberry, Swamp azalea, Inkberry, Sweet pepperbush	*Acer rubrum, Vaccinium corymbosum, Clethora alnifolia, Rhododendron viscosum, Ilex glabra*	_	107	_	_	_	_	_	Nelson et al. 1995
100	Bald Cypress	*Taxodium distichum*	_	24	_	_	_	_	_	Follett et al. 1991
101	Eastern Cottonwood	*Populus deltoides*	_	149	_	_	_	_	_	Blackmon 1977
102	Eastern Cottonwood	*Populus deltoides*	_	45*	_	_	_	_	_	Brar and Katoch 1984

* lbs of fertilizer per acre per year

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
65	Solling Project, Site B3, Germany	Brown forest soil (acid)	Buntsandstein
66	Kongalund Beech site, Sweden	Brown forest soil (acid)	Cambrian shales and sandstone, stony-sandy morain
67	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Anakeesta formation
68	Virelles, Belgium	_	_
69	Wavreille, Belgium	Calcareous brown soil	Devon chalk
70	Belgium	_	_
71	USSR	_	_
72	USSR	_	_
73	Walker Branch Site 1, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
74	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schist, and gneisses
75	Walker Branch Site 3, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
76	Tennessee	_	_
77	Prades Catchments, Spain	xerochrept	Paleozoic slates
78	_	_	_
79	Rouquet, France	Brunified Mediterranean red soil	Portlandien-Kimmeridgien limeston
80	Chalkidiki, North Greece	Well drained loam (acid)	Mica schists
81	Virelles, Belgium	Calcareous brown soil	_
82	Galicica National Park, Yugoslavia	Deep brown soil	Calcareous bedrock
83	Meathop Wood, United Kingdom	Podsolized	Carboniferous limestone
84	Watershed 2, Coweeta, North Carolina, USA	Umbric Dystrocrepts	Granite, mica schist, and gneisses
85	Huntington Forest, Adirondacks, New York, USA	Typic haplorthod - bouldery, fine sandy, loam	Hornblende-granitic gneiss
86	Meathop Wood, United Kingdom	Glacial drift and brown earths	Carboniferous limestone
87	Walker Branch Site 4, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
88	Tifton, Georgia, USA	Underlain by an impermeable clay layer	Hawthorne Formation
89	Liriodendron Site, Oak Ridge, Tenn., USA	Deep alluvial emory silt loam	Knox dolomite limestone
90	_	_	_
91	United Kingdom	Fen	_
92	Thompson Research Center, Washington, USA	Typic haplorthod, alderwood gravelly sandy loam	Glacial till
93	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loam	Glacial outwash
94	Turkey Lakes Watershed, Ontario, Canada	Orthic Humo-Ferric and Ferro-Humic Podzol	Basalt and granite
95	Tifton, Georgia, USA	Underlain by an impermeable clay layer	Hawthorne Formation
96	Hubbard Brook, New Hampshire, USA	Boulders, glacial till, podzolic-haplorthod	Littleton gneiss
97	New South Wales	_	_
98	Australia	_	_
99	Rhode Island	sandy mixed mesic Haplaquept	_
100	Wisconsin	_	_
101	Mississippi	_	_
102	India	_	_

Table B-2. Riparian understory, shrub, forb, fern species

No.	Species/System description	Dominant species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
1	Riparian mosses	*Pleuroziopsis ruthenica, Plagiomnium insigne*	1	0.1	_	_
2	Riparian ferns	*Athyrium filix-femina,Blechnum spicant*	1	0.5	_	_
3	Riparian herbs	*Bromus sitchensis,Carex, Circaea, Viola, Heracleum*	9	0.9	_	_
4	Riparian shrubs	*Oplopanax, Ribes, Vaccinium parvifolium*	4	0.3	_	_
5	Citrus, apple, pear, peach, grape and persimmon		73	8.9	182	43
6	Tea plants	_	122	9.8	144	28
7	Irrigated beans	_	112	13.4	45	71
8	Palustrine reed marsh	*Scirpus fluvatilis*	156	_	_	_
9	Palustrine sedge fen	*Carex lacustris*	142	_	_	_
10	Palustrine sedge fen	*Carex rosata*	89	_	_	_
11	Blanket bog	*Caluneto-Eriophoretum, Sphagnum spp.*	54	_	_	_
12	Basin bog	*Sphagnum spp.*	27	_	_	_
13	Rich fen	*Chamaedaphne calyculata, Betula pimula*	27	_	_	_
14	Subarctic mire	*Rubus chamaemorus, Eriophorum vaginatum*	5.9	_	_	_
15	Bog forests and fens	_	45	_	_	_
16	Cypress swamp	*Taxodium distichum*	50	_	_	_
17	Cypress domes	*Taxodium distichum, Nyssa sylvatica*	9.2	_	_	_
18	Riverine tidal marsh	*Typha, Carex calamagrostis*	199	_	_	_
19	Riverine marsh	*Typha latfolia*	281.4	37.9	_	_
20	Riverine marsh	*Typha latfolia-Sparganium eurycarpum*	146	27.6	_	_
21	Riverine marsh	*Scirpus fluviatilis*	154.1	30.3	_	_
22	Riverine marsh	*Carex lacustris*	78.4	19.7	_	_
23	Riverine marsh	*Phalaris arundinacea*	111.1	19.1	_	_
24	Riverine marsh	*Polygoniumspp. mix*	84.1	14.6	_	_
25	Riverine marsh	*Salix interior*	163.5	113.3	_	_
26	Leatherleaf-Bog birch wetland	_	27	1.5	_	_
27	Highbush blueberry	*Vaccinium crymbosum*	62	_	_	_
28	Smartweed	*Persicaria polygonum*	100	_	_	_
29	Flowering Dogwooc	*Cornus florida*	_	_	100-200	_

Table B-2 (Cont'd). Riparian understory, shrub, forb, fern species

No.	Source	Site	Soil type	Geology
1	Alaback and Sidle 1986	Chichagof Island, Southeast Alask	_	_
2	Alaback and Sidle 1986	Chichagof Island, Southeast Alask	_	_
3	Alaback and Sidle 1986	Chichagof Island, Southeast Alask	_	_
4	Alaback and Sidle 1986	Chichagof Island, Southeast Alask	_	_
5	Frissel 1977	Japan	_	_
6	Frissel 1977	Japan	_	_
7	Frissel 1977	France	_	_
8	Bowden 1987	Theresa Marsh, Wisconsir	_	_
9	Bowden 1987	Michigan Hollow, New Yorl	_	_
10	Bowden 1987	Inlet Valley, New Yorl	_	_
11	Bowden 1987	Pennine, UK	_	_
12	Bowden 1987	Thoreau's Bog, Massachusett	_	_
13	Bowden 1987	Houghton Lake, Michigai	_	_
14	Bowden 1987	Stordalen, Sweder	_	_
15	Bowden 1987	_	_	_
16	Bowden 1987	Okefenokee Swamp, Georgi	_	_
17	Bowden 1987	Florida	_	_
18	Bowden 1987	North River, Massachusett	_	_
19	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
20	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
21	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
22	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
23	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
24	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
25	Klopatek 1978	Theresa Marsh, Wisconsir	_	_
26	Richardson et al. 1978	Central Michigar	_	_
27	Hanson and Hancock 1996	Michigan	_	_
28	Toth et al. 1972	New Jersey	_	_
29	Walker & Beacher 1963	Appalachian Mtns	_	_

Table B-3. Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
1	Blanket bog vegetation	*Calluna vulgaris, Eriophorum vaginatum*	37	3	–	–
		Sphagnum, Juncetum, Nardetum				
2	Heath, Shrub heath	*Nardus stricta, Molinia caerulea*	39	3	–	–
		Calluna vulgaris				
3	Grass	–	179	27	268	45
4	Grass	–	80	17	0	0
5	–	*Lolium rigidum*	22	–	–	–
6	Grass	*Cynodon plectostachyus*	80	–	–	–
7	Grass	–	40	–	–	–
8	Grass	–	196	28	179	67
9	Grass	–	321	43	357	71
10	Grass	–	357	47	714	143
11	Grass	–	357	47	714	143
12	Grass	*Nardus stricta, Sanquisorba, Polygonum*	24	4	0	0
13	Grass	*Nardus stricta, Sanquisorba, Polygonum*	86	16	89	20
14	Grass	*Nardus stricta, Sanquisorba, Polygonum*	129	23	179	39
15	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	33	5	0	0
16	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	104	19	89	20
17	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	158	29	179	39
18	Grass, White clover	*Trifolium repens*	143	21	89	45
19	Grass, Clover	–	164	18	107	27
20	Forage, Clover	–	49	9	34	9.2
21	Clover	–	34	3	–	5.6
22	Red Clover	*Trifolium pratense*		5	–	–
23	Red Clover	*Trifolium pratense*		6	–	–
24	Lucerne	–	281	12	0	89
25	Native grass (some legumes)	–	30	–	–	–
26	Bluegrass	*Poa pratensis*	135	18	150	21
27	Bluegrass	*Poa pratensis*	102	–	–	–
28	Kentucky bluegrass, native		15	–	–	–
	grasses and weeds (no legumes)				89	40.8
29	Graminae-legume mixture	–	156	13		
30	Grass, Wheat, Clover	–	48	9	31	4
31	Wheat	*Triticum aestivum*	136	30	128	89.5
32	Wheat	*Triticum aestivum*	50	9	30	12

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
1	High elevation moorland, sheep	Frissel 1977	Northern Pennines, England	Peaty	_
2	Traditional hill sheep farming	Frissel 1977	United Kingdom	Peaty podsols, peaty gleys	_
3	Intensive sheep farming	Frissel 1977	United Kingdom	_	_
4	Permanent pasture land, no fertilizers	Frissel 1977	France	_	_
5	_	Dahlman et al. 1967	Merredin, W. Australia	Solonized	_
6	_	Dahlman et al. 1967	Ibadan, W. Nigeria	Latosolic	_
7	Grass cut periodically & allowed to lie	Dahlman et al. 1967	New York	_	_
8	Leys in rotation w/ crop, 50% grazed	Frissel 1977	France	_	_
9	Leys in rotation w/ crop, 25% grazed	Frissel 1977	France	_	_
10	Leys in rotation w/ crop, zero grazed	Frissel 1977	France	_	_
11	Forage production w/out animals	Frissel 1977	France	_	_
12	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
13	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
14	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
15	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
16	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
17	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
18	Leys in rotation w/ crop, 75% grazed	Frissel 1977	France	_	_
19	Intensive sheep farming	Frissel 1977	United Kingdom	_	_
20	Mountainous farm, grassland w/ livestock	Frissel 1977	JRD Brusno, Czech Republic	Brown, acid	_
21	Extensive livestock, subterranean pasture	Frissel 1977	Australia	_	_
22	Altaswede Cultivar	Fageria et al. 1991	Canada	_	_
23	Kenstar Cultivar	Fageria et al. 1991	United States	_	_
24	Lucerne in rotation w/ crop, 50% grazed	Frissel 1977	France	_	_
25	_	Dahlman et al. 1967	Texas	Desurfaced Blackland	_
26	Grazing	Frissel 1977	Western North Carolina	_	_
27	Bluegrass on previous cultivated land	Dahlman et al. 1967	Bethany, Missouri	_	_
28	_	Dahlman et al. 1967	Pennsylvania	_	_
29	Forage crop	Frissel 1977	Japan	_	_
30	Mixed arable farm	Frissel 1977	Southwestern clay district, Netherlands	Young clay soils	Young marine clay deposits
31	Lowland farm w/ livestock, no grazing	Frissel 1977	JRD Tesedikovo, Czech Republic	Chernozem on loess	_
32	_	Frissel 1977	Central Kansas	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
33	Wheat	*Triticum aestivum*	22	_	0	_
34	Wheat	*Triticum aestivum*	15	_	0	_
35	Wheat	*Triticum aestivum*	148	_	80	_
36	Wheat	*Triticum aestivum*	121	_	80	_
37	Wheat-grain	*Triticum aestivum*	67	13	_	_
38	Wheat-straw	*Triticum aestivum*	45	6	_	_
39	Winter wheat	_	85	19	87	22
40	Barley-grain	*Hordeum vulgare*	110	18	_	_
41	Barley-straw	*Hordeum vulgare*	40	6	_	_
42	Corn	*Zea mays*	73	_	_	_
43	Corn	*Zea mays*	98	_	_	_
44	Corn	*Zea mays*	115	_	_	_
45	Corn	*Zea mays*	127	_	_	_
46	Corn	*Zea mays*	112	20	100	27
47	Corn	*Zea mays*	70	_	0	_
48	Corn	*Zea mays*	113	_	75	_
49	Corn	*Zea mays*	163	_	151	_
50	Corn	*Zea mays*	179	_	226	_
51	Corn-total shoot	*Zea mays*	345	62	_	_
52	Corn-lower leaves (below the ear)	*Zea mays*	109	12	_	_
53	Corn-upper leaves(above the ear)	*Zea mays*	72	9	_	_
54	Corn-stem and tassel	*Zea mays*	50	8	_	_
55	Corn-ear and shank	*Zea mays*	228	53	_	_
56	Corn	*Zea mays*	69	_	0	_
57	Corn	*Zea mays*	138	_	80	_
58	Corn	*Zea mays*	191	_	161	_
59	Corn	*Zea mays*	253	_	321	_
60	Corn	*Zea mays*	159	_	223	_
61	Corn	*Zea mays*	143	_	223	_
62	Corn	*Zea mays*	137	_	223	_
63	Rice-grain	*Oryza sativa*	128	23	_	_
64	Rice-straw	*Oryza sativa*	67	4	_	_
65	Upland Rice-grain	_	37	5	_	_
66	Upland Rice-straw	_	28	2	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
33	Semi-arid, grain harvested-straw returned	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
34	Semi-arid, grain + straw harvested	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
35	Semi-arid, grain harvested-straw returned	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
36	Semi-arid, grain + straw harvested	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
37	_	Fageria et al. 1991	Tropics and subtropics	_	_
38	_	Fageria et al. 1991	Tropics and subtropics	_	_
39	Continuous winter wheat	Frissel 1977	Eastern England	_	_
40	_	Fageria et al. 1991	Tropics and subtropics	_	_
41	_	Fageria et al. 1991	Tropics and subtropics	_	_
42	0% Crop residue rate	Power et al. 1986	_	_	_
43	50% Crop residue rate	Power et al. 1986	_	_	_
44	100% Crop residue rate	Power et al. 1986	_	_	_
45	150% Crop residue rate	Power et al. 1986	_	_	_
46	_	Frissel 1977	Northern Indiana	_	_
47	_	Barber and Olson 1968	_	_	_
48	_	Barber and Olson 1968	_	_	_
49	_	Barber and Olson 1968	_	_	_
50	_	Barber and Olson 1968	_	_	_
51	_	Fageria et al. 1991	South Carolina	_	_
52	_	Fageria et al. 1991	South Carolina	_	_
53	_	Fageria et al. 1991	South Carolina	_	_
54	_	Fageria et al. 1991	South Carolina	_	_
55	_	Fageria et al. 1991	South Carolina	_	_
56	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
57	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
58	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
59	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
60	0.8 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
61	1.15 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
62	1.5 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
63	1983 Dry Season	Fageria et al. 1991	Calauan, Laguna Province, Phillipines	_	_
64	1983 Dry Season	Fageria et al. 1991	Calauan, Laguna Province, Phillipines	_	_
65	IAC 25 Cultivar	Fageria et al. 1991	Brazil	_	_
66	IAC 25 Cultivar	Fageria et al. 1991	Brazil	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	(lbs/acre/yr) Phosphorus
67	Upland Rice-grain	_	41	6	_	_
68	Upland Rice-straw	_	29	1	_	_
69	Upland Rice-grain	_	29	4	_	_
70	Upland Rice-straw	_	36	3	_	_
71	Upland Rice-grain	_	33	5	_	_
72	Upland Rice-straw	_	18	1	_	_
73	Upland Rice-grain	_	25	4	_	_
74	Upland Rice-straw	_	45	3	_	_
75	Upland rice, wheat, barley, sweet potatoe		79	11	58	33.6
76	Paddy rice	_	86	20	86	40
77	Cowpea-grain	_	36	7	_	_
78	Peanut	*Arachis hypogaea*	158	_	0	_
79	Peanut	*Arachis hypogaea*	128	_	179	_
80	Peanut	*Arachis hypogaea*	21	_	0	_
81	Peanut	*Arachis hypogaea*	46	_	179	_
82	Russet Burbank Potatoes-tops	*Salanum tuberosum*	125	6	_	_
83	Russet Burbank Potatoes-tubers	*Salanum tuberosum*	252	36	_	_
84	Irish potatoes	*Salanum tuberosum*	129	14	150	90
85	Potatoes, Wheat, Beets, Wheat	_	174	31	272	21
86	Potatoes, Wheat, Beets, Wheat	_	174	31	296	27
87	Cotton	*Gossypium hirsutum*	113	17	160	12
88	Cotton	*Gossypium hirsutum*	36	6	_	_
89	Cotton	*Gossypium hirsutum*	55	10	_	_
90	Cotton	*Gossypium hirsutum*	112	20	_	_
91	Soybean	*Glycine max*	107	12	_	17
92	Soybean	*Glycine max*	89	_	_	_
93	Soybean	*Glycine max*	132	_	_	_
94	Soybean	*Glycine max*	158	_	_	_
95	Soybean	*Glycine max*	174	_	_	_
96	_	*Stylosanthes humilis*	9 to 95	_	_	_
97	_	*Stylosanthes humilis*	26	_	_	_
98	_	*Stylosanthes humilis*	47	_	_	_
99	_	*Stylosanthes humilis*	102	_	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
67	EEPG 369 Cultivar	Fageria et al. 1991	Brazil	_	_
68	EEPG 369 Cultivar	Fageria et al. 1991	Brazil	_	_
69	Jaguary Cultivar	Fageria et al. 1991	Brazil	_	_
70	Jaguary Cultivar	Fageria et al. 1991	Brazil	_	_
71	Batatais Cultivar	Fageria et al. 1991	Brazil	_	_
72	Batatais Cultivar	Fageria et al. 1991	Brazil	_	_
73	IAC 47 Cultivar	Fageria et al. 1991	Brazil	_	_
74	IAC 47 Cultivar	Fageria et al. 1991	Brazil	_	_
75	Intensive arable	Frissel 1977	Japan	_	_
76	Intensive arable	Frissel 1977	Japan	_	_
77	_	Fageria et al. 1991	Tropics	_	_
78	Robut 33-1 Genotype	Fageria et al. 1991	_	_	_
79	Robut 33-1 Genotype	Fageria et al. 1991	_	_	_
80	Non-nod Genotype	Fageria et al. 1991	_	_	_
81	Non-nod Genotype	Fageria et al. 1991	_	_	_
82	79 tons/ha yield	Fageria et al. 1991	Central Washington	_	_
83	79 tons/ha yield	Fageria et al. 1991	Central Washington	_	_
84	_	Frissel 1977	Maine	_	_
85	Crop rotation, beet tops ploughed in	Frissel 1977	Netherlands	Clay	_
86	Crop rotation, beet tops removed	Frissel 1977	Netherlands	Clay	_
87	_	Frissel 1977	Kern County, California	_	_
88	2.5 bales/ha yield	Fageria et al. 1991	_	_	_
89	3.75 bales/ha yield	Fageria et al. 1991	_	_	_
90	7.5 bales/ha yield	Fageria et al. 1991	_	_	_
91	_	Frissel 1977	Northeast Arkansas	_	_
92	0% Crop residue rate	Power et al. 1986	_	_	_
93	50% Crop residue rate	Power et al. 1986	_	_	_
94	100% Crop residue rate	Power et al. 1986	_	_	_
95	150% Crop residue rate	Power et al. 1986	_	_	_
96	_	Probert 1982	Katherine, N.T., Australia	_	_
97	_	Probert 1982	Rodd's Bay, Queensland, Australia	Solodic	_
98	No phosphorus	Probert 1982	Lansdown, N. Queensland, Australia	_	_
99	With phosphorus	Probert 1982	Lansdown, N. Queensland, Australia	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus	Nitrogen Uptake (lbs/ton)
100	_	*Phaseolus atropurpureus*	115	_	_	_	
101	_	*Centrosema pubescens*	92 to 109	_	_	_	
102	_	*Pueraria phaseoloides*	116	_	_	_	
103	Siratro	_	39	_	_	_	
104	Mixed legumes	_	72	_	_	_	
105	_	*Desmodium uncinatum*	30 to 77	_	_	_	
106	_	*Stylosanthes guianensis*	48	_	_	_	
107	Tall Fescue	*Festuca arundinacea*	_	_	174-179	13-39	
108	Big bluestem, Little bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	_	_	40		
109	Alfalfa	*Medicago sativa*	_	_		22-112	
110	Eastern gamagrass	*Tripsacum dactyloides*	79-138	_	_	_	
111	Eastern gamagrass	*Tripsacum dactyloides*	36-122	_	_	_	
112	Switchgrass	*Panicum virgatum*	_	_	200	_	
113	Clover-grass	_	_	_	_	22-85	
114	Tall Fescue	*Festuca arundinacea*	_	_		71	
115	Clover, White		_	_	_	_	49-66
116	Alfalfa	*Medicago sativa*	_	_	_	_	34-65
117	Bromegrass	*Bromus spp.*	_	_	_	_	14-60
118	Tall Fescue	*Festuca arundinacea*	_	_	_	_	14-54
119	Bermudagrass		_	_	_	_	14-53
120	Timothy	*Phleum pratense*	_	_	_	_	14-44
121	Clover, White		_	_	_	_	18-23
122	Bluestem	*Andropogen gerardi/scoparius*	_	_	_	_	10-27
123	Soybean, straw		_	_	_	_	13-18
124	Alfalfa	*Medicago sativa*	_	_	_	_	10-20
125	Barley, straw		_	_	_	_	10-16
126	Oat, straw	*Avena spp.*	_	_	_	_	9-15
127	Tall Fescue	*Festuca arundinacea*	_	_	_	_	5-18
128	Bromegrass	*Bromus spp.*	_	_	_	_	4-19
129	Bermudagrass		_	_	_	_	5-17
130	Wheat, straw	*Triticum aestivum*	_	_	_	_	7-15
131	Rye, straw		_	_	_	_	6-12
132	Timothy	*Phleum pratense*	_	_	_	_	4-13
133	Corn, silage	*Zea mays*	_	_	_	_	6-9
134	Tall Fescue & White Clover	*Festuca arundinacea, Trifolium spp.*	_	_	0	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
100	_	Probert 1982	Samford, Queensland, Australia	_	_
101	_	Probert 1982	Wet Coast, Queensland, Australia	_	_
102	_	Probert 1982	Wet Coast, Queensland, Australia	_	_
103	_	Probert 1982	Samford, Queensland, Australia	Red podzolic	_
104	_	Probert 1982	Beerwah, Queensland, Australia	Lateritic podzolic	_
105	_	Probert 1982	Beerwah, Queensland, Australia	Lateritic podzolic	_
106	_	Probert 1982	McDonnell, N. Queensland, Australia	Yellow earth	_
107	_	Burmester & Adams 1983	Alabama	Fine sandy loam	_
108	_	Owensby and Smith 1979	Kansas	transitional udic ustolls	_
109	_	Peaslee 1978	Kentucky	_	_
110	3 year old stand	Brejda et. al. 1996	Missouri	Chequest silty clay loam	_
111	6 year old stand	Brejda et. al. 1996	Missouri	Piopolis silty clay loam	_
112	_	Sladden et. al. 1995	Alabama	thermic typic Kandiudult	_
113	_	Peaslee 1978	Kentucky	_	_
114	_	Miles & Manson 1995	South Africa	_	_
115	15% moisture content	Follett et al. 1991	North America	_	_
116	15% moisture content	Follett et al. 1991	North America	_	_
117	15% moisture content	Follett et al. 1991	North America	_	_
118	15% moisture content	Follett et al. 1991	North America	_	_
119	15% moisture content	Follett et al. 1991	North America	_	_
120	15% moisture content	Follett et al. 1991	North America	_	_
121	75 % moisture content	Follett et al. 1991	North America	_	_
122		Follett et al. 1991	North America	_	_
123	10% moisture content	Follett et al. 1991	North America	_	_
124	75 % moisture content	Follett et al. 1991	North America	_	_
125	10% moisture content	Follett et al. 1991	North America	_	_
126	10% moisture content	Follett et al. 1991	North America	_	_
127	75 % moisture content	Follett et al. 1991	North America	_	_
128	75 % moisture content	Follett et al. 1991	North America	_	_
129	75 % moisture content	Follett et al. 1991	North America	_	_
130	10% moisture content	Follett et al. 1991	North America	_	_
131		Follett et al. 1991	North America	_	_
132	75 % moisture content	Follett et al. 1991	North America	_	_
133	70 % moisture content	Follett et al. 1991	North America	_	_
134	_	Burmester and Adams 1983	Alabama	Fine sandy loam	_

Table A-1. Riparian canopy tree species and nitrogen/phosphorus amounts removed (uptake).

				Amount Nutrient Removed (uptake)	
Common Name	Species Name		Relative uptake**	Nitrogen (lbs/acre/yr)	Phosphorus (lbs/acre/yr)
American Beech	*Fagus grandifolia*	*	low P		
Bald Cypress	*Taxodium distichum*	*		24	
Basswood	*Tilia americana*	*	high N,P		
Birch spp.	*Betula spp.*			8a	0.5a
Douglas fir	*Pseudotsuga menziesii*			25b	4.7b
Eastern Cottonwood	*Populus deltoides*	*		149c	
European beech				15a	2a
Hemlock	*Tsuga sieboldii*			39b	
Maple spp.	*Acer spp.*			51b	5.3b
Oak spp.	*Quercus spp.*		high N	26a	2.3a
Pine spp.	*Pinus spp.*			8a	0.7a
Quaking Aspen			high N		
Red Alder	*Alnus rubra*			86b	9b
Red Maple	*Acer rubrum*	*	high N		
Red oak	*Quercus rubra*	*	high N		
Spruce spp.	*Picea spp.*			10a	1a
White ash	*Fraxinus americana*	*	high N		
White oak	*Quercus alba*	*	high N		
Yellow poplar	*Liriodendron tulipifera*	*	high N, P	20a	0.8a
Red Maple, Blueberry, Sweet pepperbush, Swamp azalea, Inkberry	*Acer rubrum, Vaccinium corymbosum, Clethora alnifolia, Rhododendron viscosum, Ilex glabra*	*		107b	

Table A-2. Riparian understory, shrub, & fern species and nitrogen/phosphorus amounts removed (uptake).

				Amount Nutrient Removed (uptake)	
Common Name	Species Name		Relative uptake	Nitrogen (lbs/acre/yr)	Phosphorus (lbs/acre/yr)
Flowering Dogwood	*Cornus florida*	*	high P	100-200c	
Highbush blueberry	*Vaccinium crymbosum*	*		62c	
Smartweed	*Persicaria polygonum*	*		100c	

a value is average net uptake after litterfall losses are excluded
b value is average uptake before litterfall loss
c pounds of nutrient fertilizer recommended per acre per year
** from Sykes, et. al. 1994, whereas quantitative amounts are combined from several studies
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-3a. Herbaceous species ranked by amounts of nitrogen removed (uptake).

			Amount Nitrogen Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Clover, white (15m)	*Trifolium spp.*		49-66	
Alfalfa (15m)	*Medicago sativa*		34-65	
Bromegrass (15m)	*Bromus spp.*	*	14-60	
Tall Fescue (15m)	*Festuca arundinacea*	*	14-54	
Bermudagrass (15m)			14-53	
Timothy (15m)	*Phleum pratense*		14-44	
Clover, white (75m)	*Trifolium spp.*		18-23	
Bluestem	*Andropogen gerardi/scoparius*	*	10-27	
Soybean, straw (10m)	*Glycine spp.*		13-18	
Alfalfa (75m)	*Medicago sativa*		10-20	
Barley, straw (10m)			10-16	
Oat, straw (10m)	*Avena spp.*		9-15	
Tall Fescue (75m)	*Festuca arundinacea*	*	5-18	
Bromegrass (75m)	*Bromus spp.*	*	4-19	
Bermudagrass (75m)			5-17	
Wheat, straw (10m)	*Triticum aestivum*		7-15	
Rye, straw (10m)	*Hordeum spp.*		6-12	
Timothy (75m)	*Phleum pratense*		4-13	
Corn, silage (70m)	*Zea mays*		6-9	
Lucerne				281b
Switchgrass	*Panicum virgatum*	*		200a
Tall Fescue	*Festuca arundinacea*	*		174-179a
Eastern gamagrass 3s	*Tripsacum dactyloides*	*		78-138b
Tall Fescue	*Festuca arundinacea*	*		89b
Eastern gamagrass 6s	*Tripsacum dactyloides*	*		36-122b
Big Bluestem, little Bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	*		40a
Grass-clover	*Festuca pratensis, Phleum pratensis*			32b
Grass	*Nardus stricta, sanquisarba*			23b
Tall Fescue & White Clover	*Festuca arundinacea, Trifolium spp.*			0a

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content of species
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-3b. Herbaceous species ranked by amounts of phosphorus removed (uptake).

			Amount Phosphorus Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa	*Medicago sativa*			22-112a
Clover-grass	*Festuca pratensis, Phleum pratensis*			22-85a
Tall Fescue & white clover	*Festuca arundinacea, Trifolium spp.*			46-48a
Tall Fescue	*Festuca arundinacea*	*		13-39a
Grass-clover	*Festuca pratensis, Phleum pratensis*			4.8b

a pounds of nutrient fertilize recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content of species
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-4a. Herbaceous species and amounts of nitrogen removed (uptake).

			Amount Nitrogen Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa (15m)	*Medicago sativa*		34-65	
Alfalfa (75m)	*Medicago sativa*		10-20	
Barley, straw (10m)			10-16	
Bermudagrass (15m)			14-53	
Bermudagrass (75m)			5-17	
Big Bluestem, little Bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	*		40a
Bluestem	*Andropogen gerardi/scoparius*	*	10-27	
Bromegrass (15m)	*Bromus spp.*	*	14-60	
Bromegrass (75m)	*Bromus spp.*	*	4-19	
Clover, white (15m)	*Trifolium spp.*		49-66	
Clover, white (75m)	*Trifolium spp.*		18-23	
Corn, silage (70m)	*Zea mays*		6-9	
Eastern gamagrass (3s)	*Tripsacum dactyloides*	*		78-138
Eastern gamagrass (6s)	*Tripsacum dactyloides*	*		36-122
Grass	*Nardus stricta, sanquisarba*			24b
Grass-clover	*Festuca pratensis, Phleum pratensis*			33b
Lucerne				281b
Oat, straw (10m)	*Avena spp.*		9-15	
Rye, straw (10m)	*Hordeum spp.*		6-12	
Soybean, straw (10m)			13-18	
Switchgrass	*Panicum virgatum*	*		200a
Tall Fescue	*Festuca arundinacea*	*		89b
Tall Fescue	*Festuca arundinacea*	*		174-179a
Tall Fescue (15m)	*Festuca arundinacea*	*	14-54	
Tall Fescue (75m)	*Festuca arundinacea*	*	5-18	
Tall Fescue & white clover	*Glycine spp.*			0a
Timothy (15m)	*Phleum pratense*		14-44	
Timothy (75m)	*Phleum pratense*		4-13	
Wheat, straw (10m)	*Triticum spp.*		7-15	

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*
spp indicates all species of given genus

Table A-4b. Herbaceous species and amounts of phosphorus removed (uptake)

			Amount Phosphorus Removed (uptake)	
Common Name	Species		lbs/ton	lbs/acre/year
Alfalfa	*Medicago sativa*			22-112a
Clover-grass				22-85a
Grass	*Nardus stricta, sanquisarba*			3.8b
Grass-clover	*Festuca pratensis, Phleum pratensis*			4.8b
Tall Fescue	*Festuca arundinacea*	*		13-39a
Tall Fescue & white clover	*Festuca arundinacea, Phleum*			46-48a

a pounds of nutrient fertilizer recommened per acre per year.
b pounds of nutrient uptake per acre per year
m percent moisture content
3s three year old stand
6s six year old stand
* indicates species is recommended for riparian zone establishment in *Palone, R.S. et al. 1997.*

Table B-1. Forest Canopy Species

Stand no.	Species common name	*Species scientific name*	Stand age (yrs.)	Nitrogen (lbs/acre/yr) Uptake	Nitrogen Retention	Nitrogen Return	Phosphorus (lbs/acre/yr) Uptake	Phosphorus Retention	Phosphorus Return	Source
Coniferous										
1	Scots pine	*Pinus sylvestris*	mature	40	9	31	4	<1	2.6	Duvigneaud et al. 1970
2	Scots pine	*Pinus sylvestris*	100	30	11	20	3	<1	1.7	Ehwald 1957
3	Loblolly pine	*Pinus taeda*	20	37	4	33	2	_	_	Switzer and Nelson 1972
4	Loblolly pine	*Pinus taeda*	23	31	_	_		_	_	Johnson and Lindberg 1992
5	Loblolly pine	*Pinus taeda*	35	17	_	_	_	_	_	Johnson and Lindberg 1992
6	Loblolly pine	*Pinus taeda*	40	18	_	_	1	_	_	Frissel 1977
7	Black pine	*Pinus nigra*	10	49	_	_	_	_	_	Miller 1984a
8	Black pine	*Pinus nigra*		62	_	_	5	_	_	Miller 1986
9	White pine	*Pinusstrobus*	15	45	_	_	_	_	_	Cole and Rapp 1981
10	White pine	*Pinusstrobus*	30	35	_	_	_	_	_	Johnson and Lindberg 1992
11	Monterey pine	*Pinus radiata*	_	11 to 15	_	_	<2	_	_	Hingston and Raison 1982
12	_	*Pinus pinaster*	14	14	_	_	1	_	_	Hingston and Raison 1982
13	Slash pine	*Pinus elliottii*	22	26	_	_	_	_	_	Johnson and Lindberg 1992
14	Short leaf pine	*Pinus echinata*	30	43	_	_	3	_	_	Cole and Rapp 1981
15	Spruce	*Picea*	_	31	11	20	3	0.8	1.8	Ehwald 1957
16	Spruce	*Picea*	120	55	7	48	2	<0.3	2.1	Parshevnikov 1962
17	Spruce	*Picea*	48	74	_		_	_	_	Bonneau 1992
18	Norway spruce	*Picea abies*	66	44	10	34	_	_	_	Gundersen 1992
19	Norway spruce	*Picea abies*	45	34	9	26	_	_	_	Gundersen 1992
20	Norway spruce	*Picea abies*	40	41	5	36	_	_	_	Gundersen 1992
21	Norway spruce	*Picea abies*	100	54	18	36	5	1.6	3	Ehwald 1957
22	Norway spruce	*Picea abies*	50	45	_	_	_	_	_	Feger 1992
23	Norway spruce	*Picea abies*	100	30	_	_	_	_	_	Feger 1992
24	Norway spruce	*Picea abies*	45	31	_	_	3	_	_	Cole and Rapp 1981
25	Norway spruce	*Picea abies*	60	79	_	_	6	_	_	Cole and Rapp 1981
26	Norway spruce	*Picea abies*	34	48	_	_	4	_	_	Cole and Rapp 1981
27	Norway spruce	*Picea abies*	87	56	_	_	5	_	_	Cole and Rapp 1981
28	Norway spruce	*Picea abies*	115	50	_	_	4	_	_	Cole and Rapp 1981
29	Norway spruce-Scots pine	*Picea abies-Pinus sylvestris*	40	20	_	_	_	_	_	Johnson and Lindberg 1992
30	Red spruce	*Picea rubens*	250	10	_	_	_	_	_	Johnson and Lindberg 1992
31	Red spruce	*Picea rubens*	250	19	_	_	_	_	_	Johnson and Lindberg 1992
32	Red spruce-Balsam fir	*Picea rubens-Abies balsamea*	85	16	_	_	_	_	_	Johnson and Lindberg 1992
33	Bal. fir-Rd spruce-Wt birch	*A. balsamea-P. rubens-B. papyrifera*	virgin	34	_	_	_	_	_	Johnson and Lindberg 1992

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
Coniferous			
1	–	–	–
2	Germany	–	–
3	–	–	–
4	Duke Forest, North Carolina, USA	Typic hapludul	Felsic igneous
5	Oak Ridge, Tennessee, USA	Fluventic dystrochrep	shale
6	Mississippi, USA	–	–
7	–	–	–
8	–	–	–
9	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schists, and gneisses
10	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schists, and gneisses
11	Australia	–	–
12	Australia	–	–
13	Gainesville, Florida, USA	Ultic haplaquod - sandy, low nutrient	Marine deposits
14	Walker Branch Site 2, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
15	Germany	–	–
16	USSR	Gley	–
17	Ardennes, France	(Area with high nitrogen pollution	–
18	Klosterhede, Denmark	Podzol, former heathland	Outwashed plain
19	Tange, Denmark	Slightly podzolized (course sand	Fluvial plain with some limeston
20	Strodam, Denmark	Grey-brown forest soil	Sandy moraine
21	Germany	Gley	–
22	Schluchsee Watershed, Black Forest, SW Germany	Iron-humus-podzols	Barhalde granite
23	Schluchsee Watershed, Black Forest, SW Germany	Dystric cambisols	Quartz-sandstone
24	Karelia, USSR	Humus iron podso	Sand moraine
25	Kongalund, Sweden	Brown forest soil (acid)	Cambria shales and sandstone
26	Solling Project, Site F3, Germany	Brown forest soil (acid)	Buntsandstein
27	Solling Project, Site F1, Germany	Brown forest soil (acid)	Buntsandstein
28	Solling Project, Site F2, Germany	Brown forest soil (acid)	Buntsandstein
29	Nordmoen Field Station, Norway	Typic udipsammen	Precambrian and Permian crystalline bedrock
30	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Thunderhead sandstone
31	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Thunderhead sandstone
32	Howland, Maine, USA	Typic haplorthod, Aeric haplaquod	Waterville and Vassalboro formations
33	Whiteface Mountain, Adirondacks, New York, USA	Typic cryohumods or Typic cryorthod	Precambrian anorthosite

Table B-1 (Cont'd). Forest Canopy Species

			Stand age	Nitrogen (lbs/acre/yr)			Phosphorus (kg/ha/yr)			
Stand no.	Species common name	*Species scientific name*	(yrs.)	Uptake	Retention	Return	Uptake	Retention	Return	Source
34	True fir	*Abies firma*	97-145	39	_	_	_	_	_	Cole and Rapp 1981
35	Pacific silver fir	*Tsuga mertensiana*	180	8	_	_	_	_	_	Johnson and Lindberg 1992
36	Hemlock	*Tsuga sieboldii*	120-443	25	_	_	_	_	_	Cole and Rapp 1981
37	Western hemlock	*Tsuga heterophylla*	121	52	_	_	9	_	_	Cole and Rapp 1981
38	Douglas-fir	*Pseudotsuga menziesii*	37	35	21	13	6	5	0.8	Gessel et al. 1973
39	Douglas-fir	*Pseudotsuga menzieesii*	9	3	_	_	_	_	_	Cole and Rapp 1981
40	Douglas-fir	*Pseudotsuga menzieesii*	22	30	_	_	6	_	_	Cole and Rapp 1981
41	Douglas-fir	*Pseudotsuga menzieesii*	30	29	_	_	_	_	_	Cole and Rapp 1981
42	Douglas-fir	*Pseudotsuga menzieesii*	37	31	_	_	6	_	_	Frissel 1977
43	Douglas-fir	*Pseudotsuga menzieesii*	42	29	_	_	_	_	_	Cole and Rapp 1981
44	Douglas-fir	*Pseudotsuga menzieesii*	42	32	_	_	4	_	_	Cole and Rapp 1981
45	Douglas-fir	*Pseudotsuga menzieesii*	55	11	_	_	_	_	_	Johnson and Lindberg 1992
46	Douglas-fir	*Pseudotsuga menzieesii*	73	29	_	_	_	_	_	Cole and Rapp 1981
47	Douglas-fir	*Pseudotsuga menzieesii*	95	33	_	_	_	_	_	Cole and Rapp 1981
48	Douglas-fir	*Pseudotsuga menzieesii*	450	21	_	_	5	_	_	Cole and Rapp 1981
49	Douglas-fir	*Pseudotsuga menzieesii*	_	19	_	_	1	_	_	Ballard and Cole 1974
Boreal										
50	Black spruce	*Picea mariana*	51	2	_	_	1	_	_	Cole and Rapp 1981
51	Black spruce	*Picea mariana*	55	6	_	_	1	_	_	Cole and Rapp 1981
52	Black spruce	*Picea mariana*	130	6	_	_	1	_	_	Cole and Rapp 1981
53	Paper birch	*Betula papyifera*	50	22	_	_	5	_	_	Cole and Rapp 1981
Deciduous										
54	European beech	*Fagus sylvatica*	mature	45	9	36	11	2	9	Duvigneaud et al. 1970
55	European beech	*Fagus sylvatica*	_	52	_	_	5	_	_	Frissel 1977
56	European beech	*Fagus sylvatica*	59	82	_	_	6	_	_	Cole and Rapp 1981
57	European beech	*Fagus sylvatica*	122	67	_	_	6	_	_	Cole and Rapp 1981
58	European beech	*Fagus sylvatica*	_	64	_	_	4	_	_	Ulrich and Mayer 1972
59	European beech	*Fagus sylvatica*	_	40	14	26	4	1	3.1	Ehwald 1957
60	European beech	*Fagus sylvatica*	115	0	_	_	8	5	3	Klausing 1956
61	European beech	*Fagus sylvatica*	125	0	_	_	5	2	2.5	Klausing 1956
62	European beech	*Fagus sylvatica*	10	40	9	31	3	1	2.4	Forgeard et al. 1992
63	European beech	*Fagus sylvatica*	25	44	15	28	4	2	2.1	Forgeard et al. 1992
64	European beech	*Fagus sylvatica*	100	37	9	28	3	1	2.5	Forgeard et al. 1992

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
34	JPTF-71 Yusuhara Takatoriyama, Japar	Brown forest soil (moderately wet	Cretaceous/Mudstone
35	Findley Lake, Washington, USA	Spodosol	Andesite
36	JPTF-70 Yusuhara Kubotaniyama, Japar	Brown forest soil (moderately wet	Cretaceous/Sandstone
37	Cascade Head, Oregon, USA	Utisol	Tyee formation marine siltstone
38	Pacific Northwest, USA	_	_
39	Pacific Northwest, USA	_	_
40	Thompson Research Center, Wash., USA	Everett gravelly sandy loam	Glacial outwash
41	Pacific Northwest, USA	_	_
42	Washington, USA	_	_
43	Pacific Northwest, USA	_	_
44	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loar	Glacial outwash
45	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loar	Glacial outwash
46	Pacific Northwest, USA	_	_
47	Pacific Northwest, USA	_	_
48	Andrews Experimental Forest, Oregon, USA	Inceptosol	Miocene tuffs and breccias
49	_	_	_
Boreal			
50	Alaska	Pergelic cryaqupt	_
51	Alaska	Pergelic cryaqupt	_
52	Alaska	Pergelic cryaqupt	_
53	Alaska	Pergelic cryaqupt	_
Deciduous			
54	_	_	_
55	_	_	_
56	Solling Project, Site B4, Germany	Brown forest soil (acid)	Buntsandstein
57	Solling Project, Site B2, Germany	Brown forest soil (acid)	Buntsandstein
58	_	_	_
59	Germany	_	_
60	Germany	_	Diorite
61	Germany	_	Granite
62	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite
63	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite
64	Villecartier Forest, Brittany, France	Brown forest soil (acid)	Bonnemain Cadomian granite

Table B-1 (Cont'd). Forest Canopy Species

			Stand age	Nitrogen (lbs/acre/yr)			Phosphorus (kg/ha/yr)			
Stand no.	Species common name	*Species scientific name*	(yrs.)	Uptake	Retention	Return	Uptake	Retention	Return	Source
65	European beech	*Fagus sylvatica*	80	78	_	_	5	_	_	Cole and Rapp 1981
66	European beech	*Fagus sylvatica*	45-130	70	_	_	8	_	_	Cole and Rapp 1981
67	American beech	*Fagus grandifolia*	_	20	_	_	_	_	_	Johnson & Lindberg 1992
68	English oak-Euro. beech	*Quercus robur-Fagus sylvatica*	70-75	82	27	55	6	2	4.2	Duvigneaud et al. 1970
69	English oak- European ash	*Quercus robur-Fraxinus excelsior*	115-160	110	39	71	8	4	4.8	Duvigneaud et al. 1970
70	Red oak-European ash	*Quercus rubra-Fraxinus excelsior*	140	110	39	71	8	4	4	Duvigneaud et al. 1970
71	_	*Querecto-aegopodietum*	48	93	50	43	13	3	10.7	Remezov et al. 1959
72	_	*Querecto-aegopodietum*	55	82	29	53	6	4	2.6	Mina 1955
73	Oak-Hickory	*Quercus-Carya*	30-80	62	_	_	3	_	_	Cole and Rapp 1981
74	Oak-Hickory	*Quercus-Carya*	60-200	38	_	_	_	_	_	Cole and Rapp 1981
75	Chestnut oak	*Quercus prinus*	30-80	61	_	_	3	_	_	Cole and Rapp 1981
76	Chestnut oak	*Quercus prinus*	_	101	_	_	_	_	_	Binkley 1986
77	Holm-oak	*Quercus ilex*	_	42	_	_	5	_	_	Bellot et al. 1992
78	Holm-oak	*Quercus ilex*	_	49	_	_	5	_	_	Bellot et al. 1992
79	Mediterr. evergreen oak	*Quercus ilex*	150	43	_	_	7	_	_	Cole and Rapp 1981
80	Oak	*Quercus conferts*	35	62	_	_	2	_	_	Alifragis & Papamichos 1992
81	Mixed oak	*Quercus-mixed*	80	71	_	_	4	_	_	Cole and Rapp 1981
82	_	*Quercetum frainetto-Cerris macedonia*	45	78	_	_	11	_	_	Melovski et al. 1992
83	Oak-Ash-Birch-Sycamore	*Quercus-Fraxinus-Betula-Platanus*	_	87	_	_	7	_	_	Frissel 1977
84	Oak-Sourwood-Red maple	*Q.-Oxydendrum arboreum-A. rubrum*	uneven	33	_	_	_	_	_	Johnson & Lindberg 1992
85	Northern hardwoods	*A.saccharum-F.grandifolia-A.rubrum*	100	44	_	_	_	_	_	Johnson & Lindberg 1992
86	Oak-Birch	*Quercus-Betula*	80	70	_	_	3	_	_	Cole and Rapp 1981
87	Yellow poplar-mixed oak	*Liriodendron tulipifera-Quercus*	30-80	52	_	_	3	_	_	Cole and Rapp 1981
88	Yellow poplar-Blackgum	*Lirioden. tulipifera-Nyssa sylvatica*	_	28	13	15	2	<0.7	1.8	Fail et al. 1986
89	Yellow poplar	*Liriodendron tulipifera*	50	43	_	_	4	_	_	Cole and Rapp 1981
90	Birch	*Betula spp.*	_	38	_	_	4	_	_	Miller 1984b
91	European white birch	*Betula verrucosa*	_	50	7	43	4	<0.5	3.2	Ovington & Madgewick 1959
92	Red alder	*Alnus rubra*	30	103	_	_	9	_	_	Cole and Rapp 1981
93	Red alder	*Alnus rubra*	55	69	_	_	_	_	_	Johnson and Lindberg 1992
94	Sugar maple-Yellow birch	*A. saccharum-B. alleghaniensis*	135	33	_	_	_	_	_	Johnson and Lindberg 1992
95	Red maple-Yellow poplar	*A. rubrum-L. tulipifera*	_	57	26	31	5	1	4	Fail et al. 1986
96	Maple-Birch-Beech	*Acer-Betula-Fagus*	60	66	_	_	6	_	_	Cole and Rapp 1981
97		*Eucalyptus grandis*	27	89	_	_	4	_	_	Turner and Lambert 1983
98	_	*Eucalyptus spp.*	_	5 to 10	_	_	<1	_	_	Hingston and Raison 1982
99	Red Maple, Blueberry, Swamp azalea, Inkberry, Sweet pepperbush	*Acer rubrum, Vaccinium corymbosum, Clethora alnifolia, Rhododendron viscosum, Ilex glabra*	_	107	_	_	_	_	_	Nelson et al. 1995
100	Bald Cypress	*Taxodium distichum*	_	24	_	_	_	_	_	Follett et al. 1991
101	Eastern Cottonwood	*Populus deltoides*	_	149	_	_	_	_	_	Blackmon 1977
102	Eastern Cottonwood	*Populus deltoides*	_	45*	_	_	_	_	_	Brar and Katoch 1984

* lbs of fertilizer per acre per year

Table B-1 (Cont'd). Forest Canopy Species

Stand no.	Site	Soil type	Geology
65	Solling Project, Site B3, Germany	Brown forest soil (acid)	Buntsandstein
66	Kongalund Beech site, Sweden	Brown forest soil (acid)	Cambrian shales and sandstone, stony-sandy morain
67	Great Smoky Mountains Nat. Park, Tenn.-N. C., USA	Umbric dystrochrepts	Anakeesta formation
68	Virelles, Belgium	_	_
69	Wavreille, Belgium	Calcareous brown soil	Devon chalk
70	Belgium	_	_
71	USSR	_	_
72	USSR	_	_
73	Walker Branch Site 1, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
74	Watershed 1, Coweeta, North Carolina, USA	Saluda stony loam	Granite, mica schist, and gneisses
75	Walker Branch Site 3, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
76	Tennessee	_	_
77	Prades Catchments, Spain	xerochrept	Paleozoic slates
78	_	_	_
79	Rouquet, France	Brunified Mediterranean red soil	Portlandien-Kimmeridgien limestone
80	Chalkidiki, North Greece	Well drained loam (acid)	Mica schists
81	Virelles, Belgium	Calcareous brown soil	_
82	Galicica National Park, Yugoslavia	Deep brown soil	Calcareous bedrock
83	Meathop Wood, United Kingdom	Podsolized	Carboniferous limestone
84	Watershed 2, Coweeta, North Carolina, USA	Umbric Dystrocrepts	Granite, mica schist, and gneisses
85	Huntington Forest, Adirondacks, New York, USA	Typic haplorthod - bouldery, fine sandy, loam	Hornblende-granitic gneiss
86	Meathop Wood, United Kingdom	Glacial drift and brown earths	Carboniferous limestone
87	Walker Branch Site 4, Oak Ridge, Tenn., USA	Typic paleudults	Knox dolomite
88	Tifton, Georgia, USA	Underlain by an impermeable clay layer	Hawthorne Formation
89	Liriodendron Site, Oak Ridge, Tenn., USA	Deep alluvial emory silt loam	Knox dolomite limestone
90	_	_	_
91	United Kingdom	Fen	_
92	Thompson Research Center, Washington, USA	Typic haplorthod, alderwood gravelly sandy loam	Glacial till
93	Thompson Research Center, Wash., USA	Alderwood series, Everett gravelly sandy loam	Glacial outwash
94	Turkey Lakes Watershed, Ontario, Canada	Orthic Humo-Ferric and Ferro-Humic Podzol	Basalt and granite
95	Tifton, Georgia, USA	Underlain by an impermeable clay layer	Hawthorne Formation
96	Hubbard Brook, New Hampshire, USA	Boulders, glacial till, podzolic-haplorthod	Littleton gneiss
97	New South Wales	_	_
98	Australia	_	_
99	Rhode Island	sandy mixed mesic Haplaquepts	_
100	Wisconsin	_	_
101	Mississippi	_	_
102	India	_	_

Table B-2. Riparian understory, shrub, forb, fern species

No.	Species/System description	Dominant species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
1	Riparian mosses	*Pleuroziopsis ruthenica, Plagiomnium insigne*	1	0.1	_	_
2	Riparian ferns	*Athyrium filix-femina,Blechnum spicant*	1	0.5	_	_
3	Riparian herbs	*Bromus sitchensis,Carex, Circaea, Viola, Heracleum*	9	0.9	_	_
4	Riparian shrubs	*Oplopanax, Ribes, Vaccinium parvifolium*	4	0.3	_	_
5	Citrus, apple, pear, peach, grape and persimmon		73	8.9	182	43
6	Tea plants	_	122	9.8	144	28
7	Irrigated beans	_	112	13.4	45	71
8	Palustrine reed marsh	*Scirpus fluvatilis*	156	_	_	_
9	Palustrine sedge fen	*Carex lacustris*	142	_	_	_
10	Palustrine sedge fen	*Carex rosata*	89	_	_	_
11	Blanket bog	*Caluneto-Eriophoretum, Sphagnum spp.*	54	_	_	_
12	Basin bog	*Sphagnum spp.*	27	_	_	_
13	Rich fen	*Chamaedaphne calyculata, Betula pimula*	27	_	_	_
14	Subarctic mire	*Rubus chamaemorus, Eriophorum vaginatum*	5.9	_	_	_
15	Bog forests and fens	_	45	_	_	_
16	Cypress swamp	*Taxodium distichum*	50	_	_	_
17	Cypress domes	*Taxodium distichum, Nyssa sylvatica*	9.2	_	_	_
18	Riverine tidal marsh	*Typha, Carex calamagrostis*	199	_	_	_
19	Riverine marsh	*Typha latfolia*	281.4	37.9	_	_
20	Riverine marsh	*Typha latfolia-Sparganium eurycarpum*	146	27.6	_	_
21	Riverine marsh	*Scirpus fluviatilis*	154.1	30.3	_	_
22	Riverine marsh	*Carex lacustris*	78.4	19.7	_	_
23	Riverine marsh	*Phalaris arundinacea*	111.1	19.1	_	_
24	Riverine marsh	*Polygoniumspp. mix*	84.1	14.6	_	_
25	Riverine marsh	*Salix interior*	163.5	113.3	_	_
26	Leatherleaf-Bog birch wetland	_	27	1.5	_	_
27	Highbush blueberry	*Vaccinium crymbosum*	62	_	_	_
28	Smartweed	*Persicaria polygonum*	100	_	_	_
29	Flowering Dogwooc	*Cornus florida*	_	_	100-200	_

Table B-2 (Cont'd). Riparian understory, shrub, forb, fern species

No.	Source	Site	Soil type	Geology
1	Alaback and Sidle 1986	Chichagof Island, Southeast Alaska	_	_
2	Alaback and Sidle 1986	Chichagof Island, Southeast Alaska	_	_
3	Alaback and Sidle 1986	Chichagof Island, Southeast Alaska	_	_
4	Alaback and Sidle 1986	Chichagof Island, Southeast Alaska	_	_
5	Frissel 1977	Japan	_	_
6	Frissel 1977	Japan	_	_
7	Frissel 1977	France	_	_
8	Bowden 1987	Theresa Marsh, Wisconsin	_	_
9	Bowden 1987	Michigan Hollow, New York	_	_
10	Bowden 1987	Inlet Valley, New York	_	_
11	Bowden 1987	Pennine, UK	_	_
12	Bowden 1987	Thoreau's Bog, Massachusetts	_	_
13	Bowden 1987	Houghton Lake, Michigan	_	_
14	Bowden 1987	Stordalen, Sweden	_	_
15	Bowden 1987	_	_	_
16	Bowden 1987	Okefenokee Swamp, Georgia	_	_
17	Bowden 1987	Florida	_	_
18	Bowden 1987	North River, Massachusetts	_	_
19	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
20	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
21	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
22	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
23	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
24	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
25	Klopatek 1978	Theresa Marsh, Wisconsin	_	_
26	Richardson et al. 1978	Central Michigan	_	_
27	Hanson and Hancock 1996	Michigan	_	_
28	Toth et al. 1972	New Jersey	_	_
29	Walker & Beacher 1963	Appalachian Mtns	_	_

Table B-3. Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
1	Blanket bog vegetation	*Calluna vulgaris, Eriophorum vaginatum*	37	3	_	_
		Sphagnum, Juncetum, Nardetum				
2	Heath, Shrub heath	*Nardus stricta, Molinia caerulea*	39	3	_	_
		Calluna vulgaris				
3	Grass	_	179	27	268	45
4	Grass	_	80	17	0	0
5	_	*Lolium rigidum*	22	_	_	_
6	Grass	*Cynodon plectostachyus*	80	_	_	_
7	Grass	_	40	_	_	_
8	Grass	_	196	28	179	67
9	Grass	_	321	43	357	71
10	Grass	_	357	47	714	143
11	Grass	_	357	47	714	143
12	Grass	*Nardus stricta, Sanquisorba, Polygonum*	24	4	0	0
13	Grass	*Nardus stricta, Sanquisorba, Polygonum*	86	16	89	20
14	Grass	*Nardus stricta, Sanquisorba, Polygonum*	129	23	179	39
15	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	33	5	0	0
16	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	104	19	89	20
17	Grass/Clover	*Festuca pratensis, Phleum pratensis, Dactylis*	158	29	179	39
18	Grass, White clover	*Trifolium repens*	143	21	89	45
19	Grass, Clover	_	164	18	107	27
20	Forage, Clover	_	49	9	34	9.2
21	Clover	_	34	3	_	5.6
22	Red Clover	*Trifolium pratense*		5	_	_
23	Red Clover	*Trifolium pratense*		6	_	_
24	Lucerne	_	281	12	0	89
25	Native grass (some legumes)	_	30	_	_	_
26	Bluegrass	*Poa pratensis*	135	18	150	21
27	Bluegrass	*Poa pratensis*	102	_	_	_
28	Kentucky bluegrass, native		15	_	_	_
	grasses and weeds (no legumes)				89	40.8
29	Graminae-legume mixture	_	156	13		
30	Grass, Wheat, Clover	_	48	9	31	4
31	Wheat	*Triticum aestivum*	136	30	128	89.5
32	Wheat	*Triticum aestivum*	50	9	30	12

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
1	High elevation moorland, sheep	Frissel 1977	Northern Pennines, England	Peaty	_
2	Traditional hill sheep farming	Frissel 1977	United Kingdom	Peaty podsols, peaty gleys	_
3	Intensive sheep farming	Frissel 1977	United Kingdom	_	_
4	Permanent pasture land, no fertilizers	Frissel 1977	France	_	_
5	_	Dahlman et al. 1967	Merredin, W. Australia	Solonized	_
6	_	Dahlman et al. 1967	Ibadan, W. Nigeria	Latosolic	_
7	Grass cut periodically & allowed to lie	Dahlman et al. 1967	New York	_	_
8	Leys in rotation w/ crop, 50% grazed	Frissel 1977	France	_	_
9	Leys in rotation w/ crop, 25% grazed	Frissel 1977	France	_	_
10	Leys in rotation w/ crop, zero grazed	Frissel 1977	France	_	_
11	Forage production w/out animals	Frissel 1977	France	_	_
12	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
13	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
14	Native meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
15	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
16	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
17	Renovated meadow stand	Rychnovska 1993	Vojtechuv Kopec hill, Brno, Czech Republic	_	_
18	Leys in rotation w/ crop, 75% grazed	Frissel 1977	France	_	_
19	Intensive sheep farming	Frissel 1977	United Kingdom	_	_
20	Mountainous farm, grassland w/ livestock	Frissel 1977	JRD Brusno, Czech Republic	Brown, acid	_
21	Extensive livestock, subterranean pasture	Frissel 1977	Australia	_	_
22	Altaswede Cultivar	Fageria et al. 1991	Canada	_	_
23	Kenstar Cultivar	Fageria et al. 1991	United States	_	_
24	Lucerne in rotation w/ crop, 50% grazed	Frissel 1977	France	_	_
25	_	Dahlman et al. 1967	Texas	Desurfaced Blackland	_
26	Grazing	Frissel 1977	Western North Carolina	_	_
27	Bluegrass on previous cultivated land	Dahlman et al. 1967	Bethany, Missouri	_	_
28	_	Dahlman et al. 1967	Pennsylvania	_	_
29	Forage crop	Frissel 1977	Japan	_	_
30	Mixed arable farm	Frissel 1977	Southwestern clay district, Netherlands	Young clay soils	Young marine clay deposits
31	Lowland farm w/ livestock, no grazing	Frissel 1977	JRD Tesedikovo, Czech Republic	Chernozem on loess	_
32	_	Frissel 1977	Central Kansas	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
33	Wheat	*Triticum aestivum*	22	_	0	_
34	Wheat	*Triticum aestivum*	15	_	0	_
35	Wheat	*Triticum aestivum*	148	_	80	_
36	Wheat	*Triticum aestivum*	121	_	80	_
37	Wheat-grain	*Triticum aestivum*	67	13	_	_
38	Wheat-straw	*Triticum aestivum*	45	6	_	_
39	Winter wheat	_	85	19	87	22
40	Barley-grain	*Hordeum vulgare*	110	18	_	_
41	Barley-straw	*Hordeum vulgare*	40	6	_	_
42	Corn	*Zea mays*	73	_	_	_
43	Corn	*Zea mays*	98	_	_	_
44	Corn	*Zea mays*	115	_	_	_
45	Corn	*Zea mays*	127	_	_	_
46	Corn	*Zea mays*	112	20	100	27
47	Corn	*Zea mays*	70	_	0	_
48	Corn	*Zea mays*	113	_	75	_
49	Corn	*Zea mays*	163	_	151	_
50	Corn	*Zea mays*	179	_	226	_
51	Corn-total shoot	*Zea mays*	345	62	_	_
52	Corn-lower leaves (below the ear)	*Zea mays*	109	12	_	_
53	Corn-upper leaves(above the ear)	*Zea mays*	72	9	_	_
54	Corn-stem and tassel	*Zea mays*	50	8	_	_
55	Corn-ear and shank	*Zea mays*	228	53	_	_
56	Corn	*Zea mays*	69	_	0	_
57	Corn	*Zea mays*	138	_	80	_
58	Corn	*Zea mays*	191	_	161	_
59	Corn	*Zea mays*	253	_	321	_
60	Corn	*Zea mays*	159	_	223	_
61	Corn	*Zea mays*	143	_	223	_
62	Corn	*Zea mays*	137	_	223	_
63	Rice-grain	*Oryza sativa*	128	23	_	_
64	Rice-straw	*Oryza sativa*	67	4	_	_
65	Upland Rice-grain	_	37	5	_	_
66	Upland Rice-straw	_	28	2	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
33	Semi-arid, grain harvested-straw returned	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
34	Semi-arid, grain + straw harvested	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
35	Semi-arid, grain harvested-straw returned	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
36	Semi-arid, grain + straw harvested	Frissel 1977	Migda, Isreal	Deep fine sandy loess	_
37	_	Fageria et al. 1991	Tropics and subtropics	_	_
38	_	Fageria et al. 1991	Tropics and subtropics	_	_
39	Continuous winter wheat	Frissel 1977	Eastern England	_	_
40	_	Fageria et al. 1991	Tropics and subtropics	_	_
41	_	Fageria et al. 1991	Tropics and subtropics	_	_
42	0% Crop residue rate	Power et al. 1986	_	_	_
43	50% Crop residue rate	Power et al. 1986	_	_	_
44	100% Crop residue rate	Power et al. 1986	_	_	_
45	150% Crop residue rate	Power et al. 1986	_	_	_
46	_	Frissel 1977	Northern Indiana	_	_
47	_	Barber and Olson 1968	_	_	_
48	_	Barber and Olson 1968	_	_	_
49	_	Barber and Olson 1968	_	_	_
50	_	Barber and Olson 1968	_	_	_
51	_	Fageria et al. 1991	South Carolina	_	_
52	_	Fageria et al. 1991	South Carolina	_	_
53	_	Fageria et al. 1991	South Carolina	_	_
54	_	Fageria et al. 1991	South Carolina	_	_
55	_	Fageria et al. 1991	South Carolina	_	_
56	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
57	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
58	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
59	100-cm Irrigation	Tanji et al. 1981	Davis, California	_	_
60	0.8 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
61	1.15 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
62	1.5 Evapotranspiration irrigation regime	Rao et al. 1981	Nebraska	Sandy	_
63	1983 Dry Season	Fageria et al. 1991	Calauan, Laguna Province, Phillipines	_	_
64	1983 Dry Season	Fageria et al. 1991	Calauan, Laguna Province, Phillipines	_	_
65	IAC 25 Cultivar	Fageria et al. 1991	Brazil	_	_
66	IAC 25 Cultivar	Fageria et al. 1991	Brazil	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus
67	Upland Rice-grain	_	41	6	_	_
68	Upland Rice-straw	_	29	1	_	_
69	Upland Rice-grain	_	29	4	_	_
70	Upland Rice-straw	_	36	3	_	_
71	Upland Rice-grain	_	33	5	_	_
72	Upland Rice-straw	_	18	1	_	_
73	Upland Rice-grain	_	25	4	_	_
74	Upland Rice-straw	_	45	3	_	_
75	Upland rice, wheat, barley, sweet potatoe		79	11	58	33.6
76	Paddy rice	_	86	20	86	40
77	Cowpea-grain	_	36	7	_	_
78	Peanut	*Arachis hypogaea*	158	_	0	_
79	Peanut	*Arachis hypogaea*	128	_	179	_
80	Peanut	*Arachis hypogaea*	21	_	0	_
81	Peanut	*Arachis hypogaea*	46	_	179	_
82	Russet Burbank Potatoes-tops	*Salanum tuberosum*	125	6	_	_
83	Russet Burbank Potatoes-tubers	*Salanum tuberosum*	252	36	_	_
84	Irish potatoes	*Salanum tuberosum*	129	14	150	90
85	Potatoes, Wheat, Beets, Wheat	_	174	31	272	21
86	Potatoes, Wheat, Beets, Wheat	_	174	31	296	27
87	Cotton	*Gossypium hirsutum*	113	17	160	12
88	Cotton	*Gossypium hirsutum*	36	6	_	_
89	Cotton	*Gossypium hirsutum*	55	10	_	_
90	Cotton	*Gossypium hirsutum*	112	20	_	_
91	Soybean	*Glycine max*	107	12	_	17
92	Soybean	*Glycine max*	89	_	_	_
93	Soybean	*Glycine max*	132	_	_	_
94	Soybean	*Glycine max*	158	_	_	_
95	Soybean	*Glycine max*	174	_	_	_
96	_	*Stylosanthes humilis*	9 to 95	_	_	_
97	_	*Stylosanthes humilis*	26	_	_	_
98	_	*Stylosanthes humilis*	47	_	_	_
99	_	*Stylosanthes humilis*	102	_	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
67	EEPG 369 Cultivar	Fageria et al. 1991	Brazil	_	_
68	EEPG 369 Cultivar	Fageria et al. 1991	Brazil	_	_
69	Jaguary Cultivar	Fageria et al. 1991	Brazil	_	_
70	Jaguary Cultivar	Fageria et al. 1991	Brazil	_	_
71	Batatais Cultivar	Fageria et al. 1991	Brazil	_	_
72	Batatais Cultivar	Fageria et al. 1991	Brazil	_	_
73	IAC 47 Cultivar	Fageria et al. 1991	Brazil	_	_
74	IAC 47 Cultivar	Fageria et al. 1991	Brazil	_	_
75	Intensive arable	Frissel 1977	Japan	_	_
76	Intensive arable	Frissel 1977	Japan	_	_
77	_	Fageria et al. 1991	Tropics	_	_
78	Robut 33-1 Genotype	Fageria et al. 1991	_	_	_
79	Robut 33-1 Genotype	Fageria et al. 1991	_	_	_
80	Non-nod Genotype	Fageria et al. 1991	_	_	_
81	Non-nod Genotype	Fageria et al. 1991	_	_	_
82	79 tons/ha yield	Fageria et al. 1991	Central Washington	_	_
83	79 tons/ha yield	Fageria et al. 1991	Central Washington	_	_
84	_	Frissel 1977	Maine	_	_
85	Crop rotation, beet tops ploughed in	Frissel 1977	Netherlands	Clay	_
86	Crop rotation, beet tops removed	Frissel 1977	Netherlands	Clay	_
87	_	Frissel 1977	Kern County, California	_	_
88	2.5 bales/ha yield	Fageria et al. 1991	_	_	_
89	3.75 bales/ha yield	Fageria et al. 1991	_	_	_
90	7.5 bales/ha yield	Fageria et al. 1991	_	_	_
91	_	Frissel 1977	Northeast Arkansas	_	_
92	0% Crop residue rate	Power et al. 1986	_	_	_
93	50% Crop residue rate	Power et al. 1986	_	_	_
94	100% Crop residue rate	Power et al. 1986	_	_	_
95	150% Crop residue rate	Power et al. 1986	_	_	_
96	_	Probert 1982	Katherine, N.T., Australia	_	_
97	_	Probert 1982	Rodd's Bay, Queensland, Australia	Solodic	_
98	No phosphorus	Probert 1982	Lansdown, N. Queensland, Australia	_	_
99	With phosphorus	Probert 1982	Lansdown, N. Queensland, Australia	_	_

Table B-3 (Cont'd). Herbaceous species

No.	Species common name	Species scientific name	Nitrogen Uptake (lbs/acre/yr)	Phosphorus Uptake (lbs/acre/yr)	Recommended Fertilizer (lbs/acre/yr) Nitrogen	Recommended Fertilizer (lbs/acre/yr) Phosphorus	Nitrogen Uptake (lbs/ton)
100	_	*Phaseolus atropurpureus*	115	_	_	_	
101	_	*Centrosema pubescens*	92 to 109	_	_	_	
102	_	*Pueraria phaseoloides*	116	_	_	_	
103	Siratro	_	39	_	_	_	
104	Mixed legumes	_	72	_	_	_	
105	_	*Desmodium uncinatum*	30 to 77	_	_	_	
106	_	*Stylosanthes guianensis*	48	_	_	_	
107	Tall Fescue	*Festuca arundinacea*	_	_	174-179	13-39	
108	Big bluestem, Little bluestem, Indiangrass	*Andropogon gerardi, Andropogon scoparius, Sorghastrum nutans*	_	_	40		
109	Alfalfa	*Medicago sativa*	_	_		22-112	
110	Eastern gamagrass	*Tripsacum dactyloides*	79-138	_	_	_	
111	Eastern gamagrass	*Tripsacum dactyloides*	36-122	_	_	_	
112	Switchgrass	*Panicum virgatum*	_	_	200	_	
113	Clover-grass	_	_	_	_	22-85	
114	Tall Fescue	*Festuca arundinacea*	_	_		71	
115	Clover, White		_	_	_	_	49-66
116	Alfalfa	*Medicago sativa*	_	_	_	_	34-65
117	Bromegrass	*Bromus spp.*	_	_	_	_	14-60
118	Tall Fescue	*Festuca arundinacea*	_	_	_	_	14-54
119	Bermudagrass		_	_	_	_	14-53
120	Timothy	*Phleum pratense*	_	_	_	_	14-44
121	Clover, White		_	_	_	_	18-23
122	Bluestem	*Andropogen gerardi/scoparius*	_	_	_	_	10-27
123	Soybean, straw		_	_	_	_	13-18
124	Alfalfa	*Medicago sativa*	_	_	_	_	10-20
125	Barley, straw		_	_	_	_	10-16
126	Oat, straw	*Avena spp.*	_	_	_	_	9-15
127	Tall Fescue	*Festuca arundinacea*	_	_	_	_	5-18
128	Bromegrass	*Bromus spp.*	_	_	_	_	4-19
129	Bermudagrass		_	_	_	_	5-17
130	Wheat, straw	*Triticum aestivum*	_	_	_	_	7-15
131	Rye, straw		_	_	_	_	6-12
132	Timothy	*Phleum pratense*	_	_	_	_	4-13
133	Corn, silage	*Zea mays*	_	_	_	_	6-9
134	Tall Fescue & White Clover	*Festuca arundinacea, Trifolium spp.*	_	_	0	_	_

Table B-3 (Cont'd). Herbaceous species

No.	System type	Source	Site	Soil	Geology
100	_	Probert 1982	Samford, Queensland, Australia	_	_
101	_	Probert 1982	Wet Coast, Queensland, Australia	_	_
102	_	Probert 1982	Wet Coast, Queensland, Australia	_	_
103	_	Probert 1982	Samford, Queensland, Australia	Red podzolic	_
104	_	Probert 1982	Beerwah, Queensland, Australia	Lateritic podzolic	_
105	_	Probert 1982	Beerwah, Queensland, Australia	Lateritic podzolic	_
106	_	Probert 1982	McDonnell, N. Queensland, Australia	Yellow earth	_
107	_	Burmester & Adams 1983	Alabama	Fine sandy loam	_
108	_	Owensby and Smith 1979	Kansas	transitional udic ustolls	_
109	_	Peaslee 1978	Kentucky	_	_
110	3 year old stand	Brejda et. al. 1996	Missouri	Chequest silty clay loam	_
111	6 year old stand	Brejda et. al. 1996	Missouri	Piopolis silty clay loam	_
112	_	Sladden et. al. 1995	Alabama	thermic typic Kandiudult	_
113	_	Peaslee 1978	Kentucky	_	_
114	_	Miles & Manson 1995	South Africa	_	_
115	15% moisture content	Follett et al. 1991	North America	_	_
116	15% moisture content	Follett et al. 1991	North America	_	_
117	15% moisture content	Follett et al. 1991	North America	_	_
118	15% moisture content	Follett et al. 1991	North America	_	_
119	15% moisture content	Follett et al. 1991	North America	_	_
120	15% moisture content	Follett et al. 1991	North America	_	_
121	75 % moisture content	Follett et al. 1991	North America	_	_
122		Follett et al. 1991	North America	_	_
123	10% moisture content	Follett et al. 1991	North America	_	_
124	75 % moisture content	Follett et al. 1991	North America	_	_
125	10% moisture content	Follett et al. 1991	North America	_	_
126	10% moisture content	Follett et al. 1991	North America	_	_
127	75 % moisture content	Follett et al. 1991	North America	_	_
128	75 % moisture content	Follett et al. 1991	North America	_	_
129	75 % moisture content	Follett et al. 1991	North America	_	_
130	10% moisture content	Follett et al. 1991	North America	_	_
131		Follett et al. 1991	North America	_	_
132	75 % moisture content	Follett et al. 1991	North America	_	_
133	70 % moisture content	Follett et al. 1991	North America	_	_
134	_	Burmester and Adams 1983	Alabama	Fine sandy loam	_