DOE/RA/50316 --T1
Attachment VI

METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

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Florida's Eucalyptus Energy Farm
The Natural System Interface

May 1982

MASTER

Prepared by
EcoImpact, Inc.

For

Biomass Energy Systems, Inc.
Lakeland, Florida

And the

U.S. Department of Energy
Office of Alcohol Fuels
Under Grant No. DE-FG07-80RA50316

DISCLAIMER

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METHANOL PRODUCTION FROM EUCALYPTUS WOOD CHIPS

Working Document 6

Florida's Eucalyptus Energy Farm - The Natural System Interface

Principal Investigator:
Henry H. Fishkind

May 1982

Prepared by
EcoImpact, Inc.
For
Biomass Energy Systems, Inc.
1337 Gary Road
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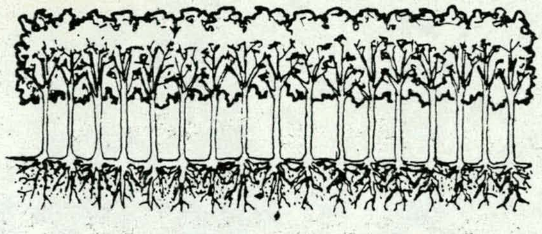
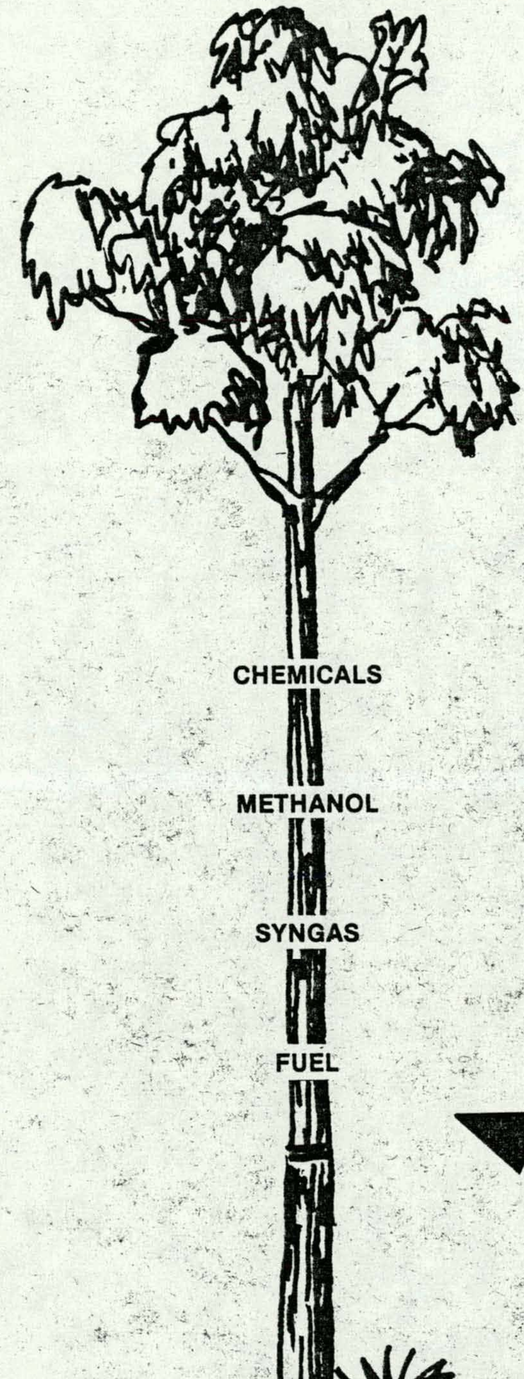
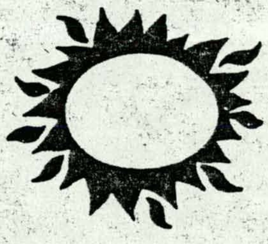
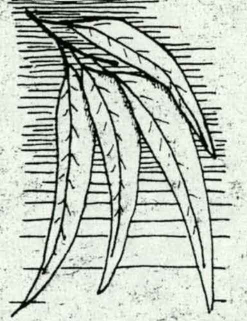


FLORIDA'S EUCALYPTUS ENERGY FARM:

THE NATURAL SYSTEM INTERFACE







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"HARVESTING RENEWABLE ENERGY RESOURCES NOW"

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24 May 1982

Dr. George W. Cornwell, President
Biomass Energy Systems, Inc.
1335 Gary Road
Lakeland, FL 33801

Reference: Transmittal of a resource document entitled "Florida's Eucalyptus Energy Farm: The Natural System Interface"

Dear George:

The following report is a compilation of field and literature research relative to an ecological perspective of eucalypt paltntations in Florida, both existing and proposed. I have attempted to be concise in presenting my research findings, field survey analysis and professional opinions.

The information contained herein has been synthesized from three primary sources: field studies of existing plantation sites and old homesteads in central and southcentral Florida; pertinent research papers; and some memoranda and correspondence forwarded to me from Biomass Energy Systems, Inc. (BESI). Photographs are not part of this product since BESI staff members accompanying me on the April 1-3, 1981, field studies took several dozen pictures of the salient features, often at my direction.

In the text, I offer facts and impressions gathered during my field studies, and responses to some of the points and queries proffered in correspondence by Messrs. Levin, Cowan and Franklin. Appendix I is a tabulation of plant species encountered in the various associations visited, while Appendix II is a comprehensive faunal list. A synopsis has been provided of background information gleaned from the available literature on the interaction between introduced eucalypts and the environment.

I hope this resource document will prove useful to BESI and informative to reviewers and decision-makers. You have my best wishes for the success of an admirable and important concept in "home-grown" energy for our State and Nation.

Sincerely,

Kevin Atkins
Executive Officer/Consulting Ecologist

KA/lbr

Attachment

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FLORIDA'S EUCALYPTUS ENERGY FARM: THE NATURAL SYSTEM INTERFACE

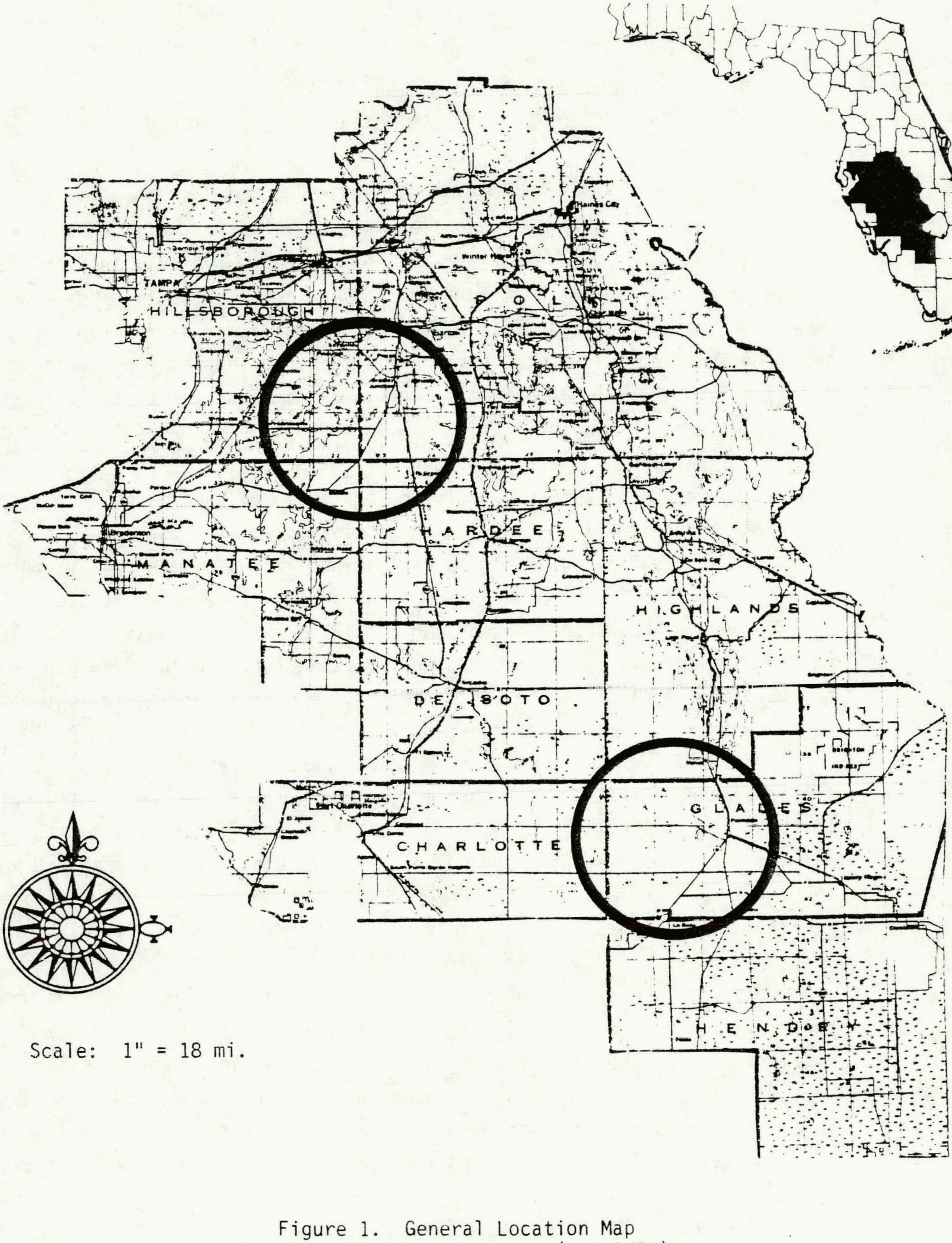
Introduction

EcoImpact, Inc., an ecological consulting firm headquartered in Gainesville, Florida, was retained by Biomass Energy Systems, Inc. (BESI) to conduct field studies pertaining to the ecological aspects of growing eucalypt biomass plantations in Florida. A compilation of relevant information drawn from a review of pertinent literature supplements the field research findings. Ecological opinions on certain aspects of the eucalypt/Florida natural system interaction are included.

The field studies were conducted April 1-3, 1981, by Kevin Atkins, a consulting ecologist with nine years of professional experience in assessing cultural, agricultural and silvicultural impacts on Florida's ecosystems. BESI personnel involved in the field investigations included Messrs. Mark Moorman, Mark Scheller and Thomas Levin. The various study sites were located in Polk, Hillsborough, Manatee and Glades Counties (Figure 1). In this report, information supplemental to the field study assessments is included in Appendix I, a tabulation of plant species encountered in the various associations visited, and Appendix II, a comprehensive faunal list.

Eucalypts are trees native to Australia and Tasmania. They are broad-leaved evergreen trees in the myrtle family (*Myrtaceae*). The first species of the genus *Eucalyptus* was discovered by the French botanist l'Heriter in Tasmania in 1788. Several hundred species have since been described. In 1910, the U. S. Forest Service surveyed Florida for eucalypt occurrence and identified 16 species growing with varying degrees of success at 27 different locations in Florida (Zon and Briscoe, 1911).

Commercial species of eucalypts are said to do best in a climate which permits a distinct period of vegetative rest during the year, and where freezing periods are not long-sustained and occur during the dormant season. The decisive factor is the absolute minimum temperature of a region. The various species are adaptable to extremes in rainfall from regions with average annual precipitation of less than 18 inches to those which average over 70 inches (Zon and Briscoe, 1911). The climate in their native land has higher maximum and minimum temperatures, but the total annual rainfall in Florida is much greater.



Scale: 1" = 18 mi.

Figure 1. General Location Map
Eucalypt Field Study Sites (4/1-3/81)

Review of Pertinent Literature

Eucalypt Background

The earliest plantation of eucalypts in Florida, as far as can be determined authentically, was established in 1878, when Reverend A. H. White planted some six or eight species at Georgiana on Merritt Island in Brevard County. By 1911, only one tree remained (thought to be E. *gonicalyx*) which grew to over two feet in diameter while resisting severe gales and the freeze of 1894-95. Until 1893, E. *robusta* had made the best growth (over 70 feet), but it was blown down in a heavy windstrom (Zon and Briscoe, 1911).

The killing winter freeze of 1894-95 discouraged many citrus growers, and a search for other crops ensued. Many of the earliest homestead and crop plantings of eucalypts were initiated at this time. Most of these eucalypts were planted for ornamental and shade purposes, although some were planted as windbreaks for citrus groves. Only around 1910 did some commercial planting actually begin in Florida (Zon and Briscoe, 1911).

One of the more commonly planted eucalypts in southern Florida has been E. *robusta*, which was first planted before the turn of the century. It was planted primarily by homesteaders wanting to quickly establish shade around their homesites. Some small stands have volunteered from these early introductions, but, in general, natural reproduction of this species has been extremely limited (Franklin and Meskimen, 1973). Even after 70+ years, naturalization has been occasional, very localized, and typically restricted to South Florida. "Wildlings" have not been encountered away from the immediate area of "parent" trees, and only certain species and hybrids seem to have a propensity to reproduce (see Eucalypt Naturalization section).

The eucalypt forests of Australia and Tasmania support a rich and varied fauna of mammals and birds and together form the single most important refuge for wildlife in the region. A greater number of mammal species are found in these forests than in any other broad category of Australian habitat. Wildlife studies in such habitat have identified 57 species of indigenous mammals (Tyndale-Biscoe and Calaby, 1975). Between ten and twenty of the species are wholly dependent on these forests for their survival and have evolved adaptations to suit a stable environment. The rest are less dependent and use the forests mainly as shelter. Of the nondependent species, a few are carnivorous and the remainder subsist chiefly on grasses. Wholly dependent species use the forest trees themselves or some shrub component in the understory to provide the essential requisites of shelter or food.

The Candidate Species

For reasons specified in this and companion working documents, Biomass Energy Systems, Inc. has selected the river red gum (*Eucalyptus camaldulensis*) as the most appropriate eucalypt species for clonal propagation and biomass plantings in Central and South Florida. *Eucalyptus camaldulensis* is the most widespread member of its genus in Australia, where it is primarily a riparian species (Hillis, 1966). This tree is widely planted outside its native Australian habitat and is one of the most important timber trees in the Mediterranean region and elsewhere (Karschon and Heth, 1967). Owing to its suitability to dry areas with a long period of drought it often is used in areas where summer rainfall is close to nil and winter rainfall occurs in relatively low amounts, although it also adapts well to rainy climates. This species seems to prefer sites where soil moisture is derived from incident rainfall and where the water table is beyond the reach of the tree roots. There is no evidence of an adverse hydrological effect caused by E. *camaldulensis* plantations (Karschon and Heth, 1967).

Biomass Plantation Considerations

The United States and Canada have the highest per capita energy consumption of the world, with about 2,700 gallons of petroleum equivalents consumed per person per year (EOP, 1977; CYB, 1977). With fossil energy supplies being rapidly depleted and the continued heavy use of energy by North Americans, an urgent need exists for the development of new energy sources. Wood and other forest products have been suggested as one technology that has the potential of providing an abundant source of fuel (Alich et al., 1976; Inman, 1977; Howlett and Gamache, 1977; Pecoraro et al., 1977). Today, wood supplies a mere one percent of U.S. and four percent of Canadian energy needs (USBC, 1977; CYB, 1977).

A foremost consideration in undertaking large-scale production of fuel wood is the status of available land. Prime agricultural land in North America is at a premium and must be preserved for food fiber crops. Furthermore, much of the more than one billion hectares presently in pasture and rangeland are necessary for livestock production. Some presently unused land is either too steep, too rocky, or too poorly drained to be suited for fuel-wood farming. Given these facts, reclaimed surface mining lands in Central Florida seem ideally suited for biomass plantations.

Erosion rates on fuel-wood farms will be less than those in normal forestry operations because the tree species utilized on biomass plantations would be planted relatively close to one another and would be allowed to regrow by sprouting from the stumps. This type of growth would provide protection from water runoff and the extensive root systems would help stablize the soil. Supplemental erosion control would result if the leaves were not harvested and left at the site to provide barriers to the rainfall. In addition, the organic matter from root and leaf production would contribute to soil quality and structure (Pimentel et al., 1979).

Exploitive timbering, suppression of summer fires, and cultivation have brought about great floristic changes in the southeastern forest (Harris, 1980). About 60 percent of the southeastern land area remains forested today, 90 percent of which is considered commercial (USDA, 1978). Of the 80 million hectares of forest land in the Southeast (Virginia, North Carolina, Tennessee, Arkansas, Oklahoma, Texas, Louisiana, Mississippi, Alabama, Georgia, South Carolina, Florida), slightly more than 70 percent is privately owned. Of this privately owned land, approximately 50 percent is softwood and 50 percent hardwood (USDA, 1978). About 280,000 hectares of pine are planted annually, bringing the total area of pine plantations to approximately 8 million hectares. Florida's forest acreage has been reduced by an average of nearly 50,000 hectares per year for the last 25 years (USDA, 1978).

Forests still constitute the major wildlife habitat in the Southeast. Forestry is superior to alternative, competitive land uses, such as agriculture, pasture, and urbanization. The implementation of favorable silvicultural practices seems the single best avenue for future wildlife conservation in the Southeast (Harris, 1980). A recent study has shown that breeding bird densities are much higher along sharp edges created by clearcutting than along ecotones in similar, but imperturbed habitat (McElveen, 1978). Different types of edge provide different food and habitat requirements. Edges where three or more community types abut are believed to be superior to those where only two communities abut. The number of breeding bird species inhabiting patches of forest habitat is doubled by every seven-fold increase in acreage (Harris, 1980).

In a study of wildlife utilization of cottonwood plantations in the southeast, Wesley et al. (1981) reveal pertinent findings concerning animal use and management implications. Wildlife importance values for all wildlife food plants in the plantations studied peaked in the fourth, fifth, or sixth growing season. Of 127 plant species or groups identified in the study, 50 percent showed evidence of browsing by deer and 27 percent by rabbits. Understory vegetation of cottonwood plantations was similar to vegetation in forest clearings.

Substantial wildlife production is possible where timber management is the primary objective. Cottonwood plantations may benefit wildlife populations by increasing total forest community diversity. Plantations provide cover, nest sites, and brood-rearing habitat. The edge of plantations should be maximized to improve the quality of habitat for certain species, particularly wild turkey and deer. The major disadvantage of the plantations to wildlife may be the paucity of hard mast. The primary factors which determine the ultimate quality of cottonwood plantations as wildlife habitat are shape and plantation size relative to the total forest community. To improve wildlife habitat, managers should establish irregularly shaped plantations, use spacings and thinning regimes which encourage understory growth, and intermesh plantations with other land uses and habitat types (Wesley et al., 1981).

Effects of Site Preparation

Eucalypts are especially sensitive to competing vegetation, and plantations are threatened with stagnation unless the native vegetation is effectively controlled for at least a year after planting (Meskimen, 1971). The effects of eucalypt site preparation on dry prairie vegetation in South Florida was studied by Moore and Swindel (1981). They found that all site-prepared and fertilized plots except those on the beds had significantly more herbage than controls. Herbage production between rows averaged 1,455 lbs/ac after one year. Production within bedded rows averaged only 114 lbs/ac after one year. Control plots contained 755 lbs/ac. The same trends continued into the second year, with all plots yielding an increase.

Plant species composition was altered by site preparation and fertilization, with wiregrass (*Aristida*) and bluestems (*Andropogon*) significantly reduced. Standing biomass of a number of species increased with mechanical site preparation and fertilization. *Panicum* grasses were most abundant, and little blue maidencane and barestem paspalum were increasers during the second growing season. Generally, grasses increased significantly, grass-likes (sedges and rushes) increased to some extent, and forbs (annual composites) increased considerably. Primary conclusions of the Moore and Swindel (1981) studies were as follows:

1) Eucalypt stand site preparation and fertilization on South Florida dry prairie significantly increased herbage species important as food for bobwhites and cattle, particularly the first year after treatment.
2) Grasses accounted for over 95 percent of standing biomass on control plots, and about 80 percent on treated plots.
3) The treatments converted a wiregrass community to one dominated by *Panicums*.
4) Intensive site preparation, including bedding, appears successful in reducing competition to newly planted eucalypts, and does not appear to be detrimental to cattle forage and bobwhite food values.
5) A decline in bobwhite and cattle forage is expected with increasing plantation age.

Leachate and Allelopathy

Leaching concerns the removal of water soluble compounds from leaves due to the action of an aqueous solution. Presumably better growth under certain trees is due to nutrients leached down from the overhead canopy. The substances that are leached out from the plants include both inorganic and organic compounds (Morgan, 1963; Tukey and Morgan, 1964; Tukey, 1966). Large amounts of organic substances such as free sugars, pectic substances and sugar alcohols are often present in the leachates (Saxena and Singh, 1978). Practically all plant amino acids, many of the organic acids, vitamins, alkaloids and phenolic substances (Bode, 1958; del Moral and Muller, 1969) have been detected in leachates. Several authors have observed that the growth of herbaceous plants beneath the canopy of beech (*Fagus*) and maple (*Acer*) trees was better as compared to that under poplar (*Populus*) and willow (*Salix*) (Tukey, 1970).

There are also some allelopathic (plant inhibitory) effects of the leachate on the undergrowth species. Certain *Eucalyptus* plantations (del Moral and Muller, 1970), oak woods (Yardeni and Evanari, 1952; del Moral and Muller,

1969) and a number of coniferous forests are found with fewer ground flora elements in contrast to other forests in similar environments (Whittaker, 1965). Leachates of different species show different allelopathic effects on the growth of other plants (Saxena and Singh, 1978). In nature, leaf absorption is the main mechanism through which leachates from the overhead canopy influence the growth of ground flora.

Allelopathic mechanisms in some eucalypt species involving terpenes adsorbed to soil colloids and phenolic acids leached from the leaf litter are known to exist. In *Eucalyptus globulus*, fog drip acting alone appears to be capable of producing inhibition of growth in some herb species. Thus, the mechanism of leaching by rain or fog drip may affect the diversity and impose a distinct structure upon a plant community by altering the distribution of inorganic and organic chemicals within the system. Dominant populations may influence the ecosystem not only by purely physical or competitive means, but also by the action of inhibitory organic materials leached from intact, living plant organs. This phenomenon is important to the ecology of Florida scrub communities, for example.

Investigations by del Moral and Muller (1969) of several aspects of herb-*Eucalyptus* interactions, demonstrated that there were no edaphic reasons for exclusion of herbs from *Eucalyptus* stands, that light and nutrients were adequate for herb growth (nutrient levels were nearly always greater within the stand than within adjacent grassland), and that small animals did not inhabit or visit *Eucalyptus* stands frequently enough to influence the herb vegetation (del Moral and Muller, 1970). Soil moisture was nearly always as favorable within the stand as in grassland. On several occasions, particularly after a fog, soil moisture was greater within the stand than in the adjoining grassland.

Allelopathy is an ecological factor capable of influencing succession, dominance, vegetation dynamics, species diversity, community structure, productivity, and other processes and factors. The production or release of toxic chemicals by plants and their subsequent effective action in the environment constitute a process of obvious ecological significance (del Moral and Muller, 1970). Allelopathic factors are subject to mitigation or intensification by other environmental factors. The degree of impact of allelopathy depends markedly on available soil moisture, the edaphic situation, and the soil microflora. Abundant soil moisture compensates partially for the effects of allelopathy, whereas scanty soil moisture enhances its effects.

Loamy soils adsorb significantly higher concentrations of terpenes than do sands and, thus, are rendered more inhibitory (del Moral and Muller, 1970). Loam concentrates toxins much more efficiently than does sand. Under natural conditions, the differences in toxicity are further accentuated by less percolation through loam than through sand. The capacity of a soil to retard the flow of phenolic compounds is a significant factor in determining whether or not plants will be inhibited. Most peninsular Florida and mined land soils do not appear to favor allelopathic effectiveness by *E. camaldulensis* since understory and ground cover vegetation often is substantial (see Appendix I). The production, release, and stability of toxins from *E. camaldulensis* are subject to seasonal variation. On an annual basis, the building of soil toxicity appears to be balanced by the activity of soil microorganisms. Apparently these organisms ameliorate the effects of allelopathy by denaturing, over a period of time, the compounds produced.

Some Exotic Flora Considerations

The number of plants of all groups that have been brought into the U.S. in the past few decades is said to exceed 200,000 named species and varieties from all over the world (Bates, 1964). About 1,800 exotic plant species have escaped in the U.S., and a large portion have become naturalized (Ripley, 1975), or about ten percent of continental U.S. flora. However, comparatively few exotics introduced into Florida have become established, and even fewer are causing vegetation problems (Austin, 1978). According to Long (1974), about 16 percent of Dade, Broward, and Collier Counties' flora is exotic, with about 170 species naturalized in Southeast Florida. Virtually all of these plants are intolerant of freezing temperatures. Stability in an ecosystem usually is proportional to its diversity, therefore, exotic plant composition that displaces native flora typically is an adverse influence on native species composition. However, plantations of clonally produced *E. camaldulensis* on Central Florida's reclaimed mined lands and poor quality rangeland will not result in displacement of ecologically valuable systems, and will produce woody biomass with a variety of beneficial uses for man.

Three naturalized plants are responsible for most of the "noxious exotic" vegetation problems in South and Central Florida: punk tree (*Melaleuca quinquenervia*), Australian pine or beefwood (*Casuarina spp.*); and Brazilian pepper (*Schinus terebinthifolius*). Dense colonies of these species, distributed far and wide over a variety of habitat types, tend to exclude almost all native plant associates and most formerly occurring animals. Field observations of biomass eucalypt stands have revealed comparatively less natural system perturbation in this regard (see following sections). Mazzotti et al. (1981) conducted relevant studies on the effects of the exotic plants *Melaleuca* and *Casuarina* on small mammal populations in the Florida everglades. The following conclusions resulted from these studies:

1) All exotic habitats are not equal in terms of faunal support and food chain structure.
2) Each habitat must be evaluated separately for suitability for animal populations.
3) Low species richness of plants, per se, does not determine rodent distribution and abundance.
4) Exotic plant communities can no longer be intuitively classified as biological deserts since there are differences in their ability to support native wildlife.

Plantation eucalypts must have fast growth and high production on sites suitable for logging during almost any season. There is no justification for growing exotics which produce pulpwood at rates equal to or lower than native species at comparable costs. High-cost plantation hardwood must be available when other supplies are not. Typically, all-weather logging sites are the higher dryer sites of inherently moderate or low quality, i.e., uplands and sandhills rather than fertile bottomlands. Moreover, nontarget species in plantations on the best sites either require prohibitively expensive competition control measures or create an unmanageable plantation environment. So the successful eucalypt must do more with less than native species in plantations or managed natural stands (Franklin, 1978).

Most eucalypt species and provenances introduced into the southeastern United States produce moderate to large quantities of seed except *E. camaldulensis*, but reproduction under natural conditions has been limited to areas of a few acres in central and southern Florida. The species most frequently found is E. *robusta*, but E. *grandis* and closely associated species, as well as hybrids, are also found. The ecological limitations that constrain natural reproduction are not known. The limited reproduction is consistently associated with abandoned shade and ornamental plantings rather than with modern plantation culture (Franklin, 1978).

Comparative Eucalypt Field Survey

Mined Land Stands

The following information was gathered on April 1, 1981, while making a survey of eucalypts planted on previously mined phosphate company landholdings in Polk, Hillsborough, and Manatee Counties. Field studies were performed on foot with the goal of gathering a maximum amount of information on ecosystem dynamics without collecting quantitative data.

Agrico Eucalypts. This plantation was established in 1974 by planting *Eucalyptus camaldulensis* on the south and *E. tereticornis* on the north (Figure 2, #1). The site is on Agrico land near Walker Road and Payne Creek. Rows on apparent overburden are 10' apart, with 6' - 8' between stem centers. In a pattern later found to be typical, the greatest vegetative diversity of associated plants occurs within about 100' from the stand periphery. On mined land in particular, Saltbush (*Baccharis*), a wind-dispersed composite abundant on unmanaged mined soils, is probably the most common woody understory species. Satintail grass (an introduced, wind-dispersed, rhizomatous plant) is common in topographic depressions. Isolated colonies of this grass probably occur around low spots because wind-blown seeds are accumulated by rainfall runoff.

Ruderal or "old-field" grasses and herbs tend to predominate in the ground cover layer, along with those species common to mined land reclamation cover, such as bahia grass and hairy indigo bush (see Appendix I, Association I). Most of the understory and ground cover plant composition is comprised of those pioneer invaders that eventually succeed to a shrubby disclimax association after mining. In general, most woody species occur in the "edge zone," with only those trees and shrubs dispersed by wind or animals (e.g., oaks and black cherry) encountered in the interior.

Burrowing animals and those preferring detrital habitat appear to be most common within the stand, but none were found to be abundant. No bird nests were observed, and mammal sign was scarce. Reptiles, particularly terrestrial snakes and lizards, are likely to be the primary predators in a short-rotation, early successional eucalypt plantation. Wildlife utilization and trophic level development undoubtedly will be proportional to contiguous stand area, amount of edge, diversity of surrounding natural systems, soil

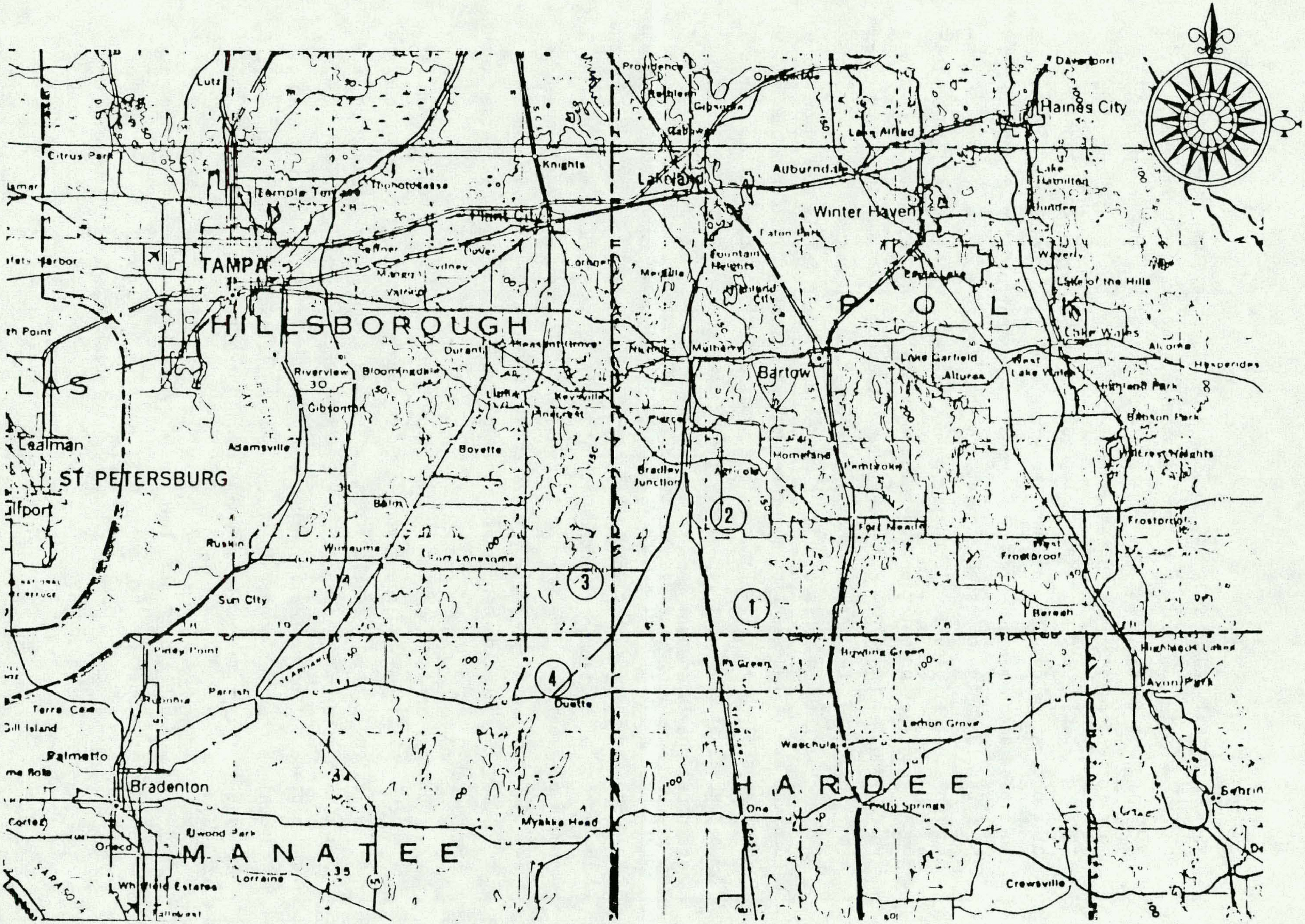


Figure 2. Central Florida Study Sites (4)

Scale: 1" = 11 mi.

types, proximity to aquatic and wetland habitat, understory development, and whether or not "islands" of natural system habitat are incorporated.

A common characteristic of the eucalypt stands visited is an unusual amount of understory light penetration, especially considering the high stocking capacity and evergreen nature of the genus. This condition promotes understory development and, therefore, wildlife forage and cover. Since plantation management requires understory control at planting and for the first 18 months of establishment, this aspect of a stand may not be considered a net silvicultural benefit. In any event, with the tall tree stems, specialized leaf orientation and relatively small canopies, plantation floors typically have about 70 - 80 percent sun exposure. When the sun is not directly overhead, this exposure often increases to ±90 percent.

At least seven types of lichens were found to be fairly common on eucalypt stems, representing all three morphological groups (crustose, foliose, and fruticose). The crustose types definitely are most abundant. Two species of epiphytic air-plants (*Tillandsia setacea* and *T. fasciculata*) are occasionally encountered.

Grace Eucalypts. The W. R. Grace stand is in Polk County just north of State Road 630 and west of Fort Meade/Agricola (Figure 2, #2). Both this stand and the Agrico plantation are bedded with about the same stocking density and growth development. The Grace site consists of E. *camaldulensis* planted in 1974 and about two acres of E. *tereticornis* planted in 1975. This plantation is established on debris and tailings over phosphatic clay, rather than overburden.

Understory plant species composition in both stands is nearly comparable, with the relative abundance favoring those species adapted to more sandy and/or xeric conditions. Notable indicators of this trend include camphor weed and golden aster (*Heterotheca*), natal grass (*Rhynchelytrum*), sorrel (*Rumex*), and smutgrass (*Sporobolus*). Shrubs are limited to lantana and wax myrtle. Young black cherries appear to be the only successfully invading aboreal species at this time. Obvious animal sign is restricted to armadillo diggings.

Fort Lonesome Eucalypts. The third major stand visited was a planting just inside Hillsborough County immediately south of State Road 674 and east of Fort Lonesome (Figure 2, #3). As many as a dozen species were planted on cleared, but unmined ground in 1975 (M. Moorman, pers. comm.). The entire plantation was swept by fire several weeks prior to inspection. The eucalypts remained unscathed, and the emerging ground cover is reminiscent of those species previously observed. The most notable variation from the other sites is an abundance of post-fire dog fennel and camphor weed.

This stand also was bedded and had the same planting design. Saltbush is the most common shrub invader. One 15' tall water oak and a 5' slash pine were found near the periphery. The largest tree in this stand is about 15" dbh (diameter at brest height) and 60 - 70 feet tall. Interestingly, several active and inactive gopher tortoise burrows occur, with armadillos apparently occupying the inactive sites.

Duette Eucalypts. The last mining area site is in Manatee County just north of Estech's Duette Mine and State Road 62, and between State Road 37 and State Road 39 (Figure 2, #4). The stand is located in a pine/oak, unmined, natural system and has been bedded, but without the typical full clearing of the understory. Although woody plants were removed during site preparation, the ground cover still includes a dense association of saw palmetto, wire grass, pawpaws, goldenrods, broomsedge, St. John's wort, ground huckleberry, fleabane, hat pins, and some young longleaf pines. After about five years of growth, this stand is the least vigorous of those surveyed, but is an interesting mix of native vegetation and eucalypts, including *E. grandis* and *E. tereticornis*. A meaningful assessment of wildlife utilization was not readily achievable due to the density of the ground cover, which approaches 100 percent. Presumably, the adverse competition by native vegetation has played a role in the lack of eucalypt stand vigor.

Unmined, South Florida Stands

Follow-up field studies of eucalypt plantings on unmined, but site-prepared lands in South Florida's Glades County were conducted on April 2-3, 1981. The following descriptions synthesize the gathered information on specific eucalypt stands, including stand age and species where definitively ascertained. The most intensively studied sites occur on Lykes Brothers property west of Palmdale and were investigated in cooperation with the land manager. Virtually all study sites discussed in this section are located within the delineated area in Figure 3.

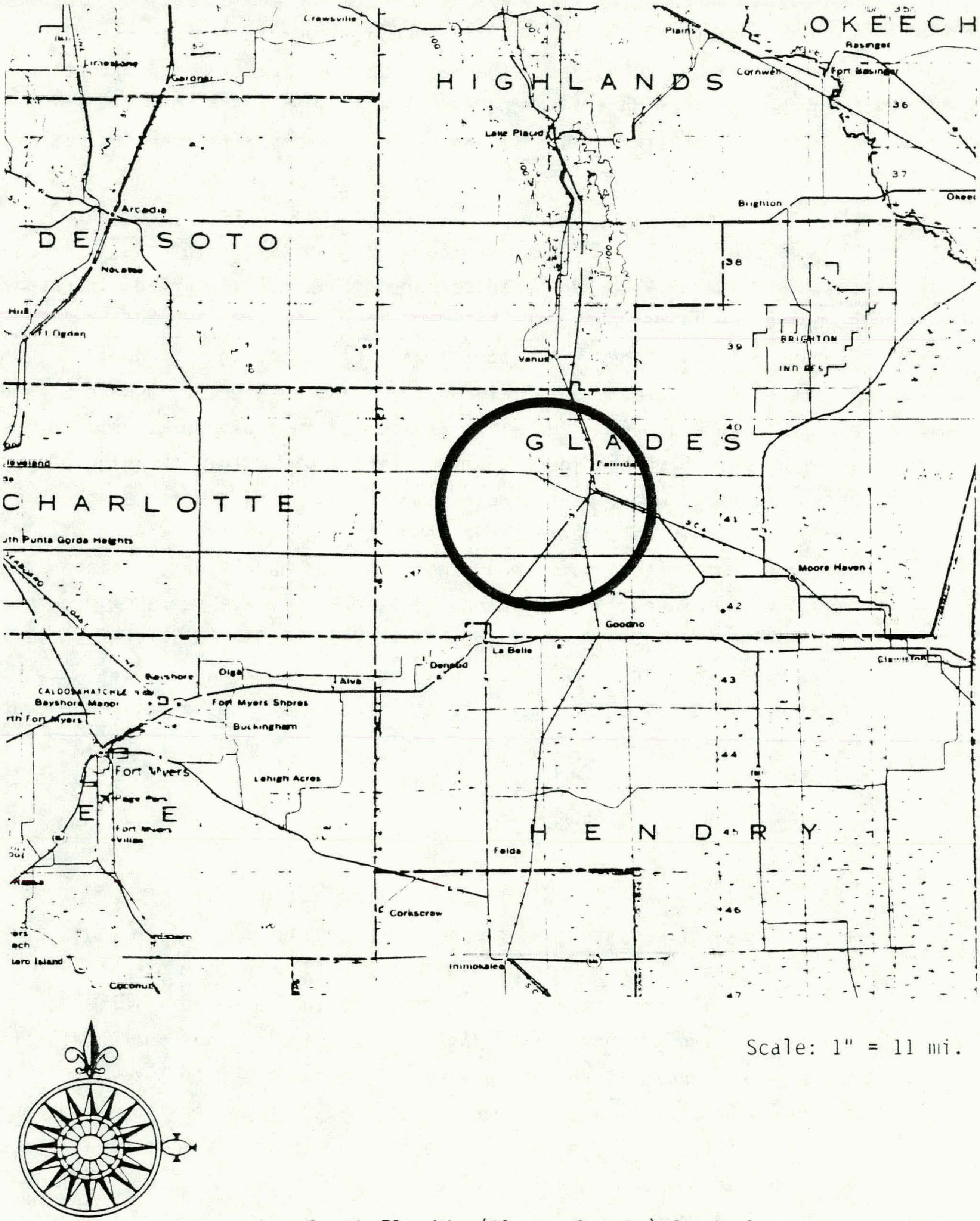


Figure 3. South Florida (Glades County) Study Area

Ferguson Stand. Planted in 1969 on beds site-prepared in an area of dry, palmetto prairie, this is the oldest plantation studied. The eastern half is *Eucalyptus robusta*, while the western half is *Eucalyptus grandis*. Generally, a better developed understory occurs within the *Eucalyptus robusta* stand. In terms of animal populations, the plantation exhibited virtually no burrows, trails, tracks, nests, or noises which would indicate the presence of an on-site vertebrate community, although deer sign has been reported (G. W. Cornwell, pers. comm.). Obvious invertebrates similarly were scarce.

Four plant species tend to predominate in the understory: broomsedge (*Andropogon virginicus*); saw palmetto (*Serenoa repens*) (from viable rhizomes remaining after site preparation); staggerbush (*Lyonia ferruginea*); and some gallberry (*Ilex glabra*). Somewhat less common are the following: goldenrods (*Solidago*); panic grasses (*Panicum/Dicanthelium*); another staggerbush (*Lyonia fruticosa*); runner oak (*Quercus pumila*); ground huckleberry (*Vaccinium*); wire grass (*Aristida stricta*); saltbush; St. John's wort (*Hypericum*); and a few other herbs and grasses. Vines seem to be limited to grapes (*Vitis*), greenbriers (*Smilax*), and poison ivy (*Rhus radicans*). The rough, fissured bark of *Eucalyptus robusta* provides a superior substrate for vine and epiphyte establishment.

The bedding seems higher than for the mined land stands, averaging a two foot difference between the top of the bed and the furrow bottom. A considerable slash/duff layer of leaves, bark strips (especially E. *grandis*) and branches fills the furrows several inches deep with eucalypt detritus. Probably in concert with other site factors, this amount of fairly "durable" detritus, simply by its physical presence if not allelopathy, seems to inhibit ground cover plant establishment. Assessing the stand as a whole, the northeastern quarter has up to 50 percent ground and shrub cover, while the more typical condition approaches 20 percent. Nearby evidence indicates that after cutting and during coppice establishment, ground cover plants apparently increase to 80 - 100 percent cover until shading and detritus again become limiting factors.

A diameter of 13.8" was recorded on the largest stem encountered (E. *grandis*), and most trees were estimated to be 65' - 80' tall. There are numerous 1' - 8' tall E. *robusta* seedlings in the understory and within a 100' radius from the stand in both grassland and dense saw palmetto associations. Generally, "wildlings" seem to be established within a range of 20' - 50' from the parent tree.

"Ferguson Pine" Stand. Immediately west of the above-described plantation is a companion stand of planted slash pine. The site preparation techniques and original habitat appear to be the same as for the eucalypts. The pines also were planted in 1969 in order to provide a basis for comparative eucalypt/pine stand analysis. This situation provided the best opportunity during the field studies to compare and contrast planted pines and eucalypts under similar site and age conditions.

Needle-leaf litter in the pine plantation generally forms a more complete cover (crest to furrow) and becomes more of a "mat" in contrast to the "textured" broad leaf detritus of eucalypts. There also is more shading in the pine understory. Generally, however, a basic similarity of associated plants occurs within the two systems. A comparison of the respective plant assemblages is presented in Appendix I.

A notable difference is the taller, more vigorous and more abundant saw palmetto in the pine understory. This condition is exemplified to a lesser extent by gallberry, ground oaks, and pawpaw. There appears to be less "cover" by graminoid and herbaceous species, but woody plants appear to thrive, relatively speaking. Given the negative aspects of non-commercial plant competition, this condition appears to be an advantage for the eucalypts. Commonly, unmanaged pine plantations attain a vigorous palmetto/oak understory and eucalypts may require less management in this regard. Of course, the shorter rotation time also mitigates against dense understory and hardwood establishment, as well as allelopathic effects, if operative.

All intensively site-prepared eucalypt stands surveyed had significantly more exposed soil and less dense canopies. Both plantation types exhibit a higher diversity and abundance of associated plant species along the periphery, typically within 100' from the edge. Vines are less common under the pines, grasses tend to form small, nonvigorous clumps, and herbs and forbs generally occur as scattered individuals rather than as colonial or associational groups. Seed germination, especially for nonmast (ground cover) species, undoubtedly is more difficult in the matted duff layer which approaches 100 percent cover under the pines.

The average dbh of the pines is about 6" and the average height to the canopy tops is about 25'. Because they are young pines, they tend to have branches and needles for half of their erect stem length, as opposed to the higher, more open aspect of plantation eucalypts. This condition creates more cover, overall, within the pines, but the lack of forage plants and protection in the understory presumably makes the site similarly unattractive to wildlife, since little distinction can be made between the two systems concerning vertebrate utilization. As with the eucalypts, the only obvious sign was sporadic armadillo diggings. No birds, mammals, or herpetiles were actually observed, nor were any nests or burrows.

The general conclusion drawn from surveying the two adjacent plantations is that the pines are associated with somewhat more total plant species and good vigor of woody species, while the eucalypt stand has greater coverage by understory plants and vines, although typically with less vigor. Both sites suggest very low resident, foraging, and transient wildlife utilization.

Other Eucalypt Stands - Glades County

Several additional eucalypt stands of varying size, age and selected species were surveyed less intensively during the mid-Spring field studies in Glades County. Most sites were similarly site-prepared on former palmetto prairie habitat. Some generalized observations can be made as a result of these surveys.

Impressions concerning vegetative aspects of eucalypt plantations on unmined land include the following:

1) One to two-year old plantations typically have 80 - 90 percent cover, primarily by grasses. There appears to be a trend away from carpet-type grasses after the second year and toward more clumpy species, e.g., *Andropogon* and *Aristida*.
2) There appears to be an inverse relationship between the amount of ground cover and the degree of eucalypt vigor, at least in terms of canopy foliage.
3) Livestock grazing decreases the abundance and possibly diversity of understory plants within the plantation, as does "double-chopping" during site preparation.
4) Although several dozen indigenous, South Florida plant species apparently can coexist with eucalypt stands, the probable associated flora in the Central Florida phosphate mining region largely will be different and generally more ruderal and shrubby when on mined land.

Observations regarding the animal utilization of South Florida eucalypt plantations in early April suggest the following:

1) The greatest observed wildlife utilization of eucalypts occurred where a plantation was adjacent to natural system xeric habitat.
2) Resident vertebrate animals appear to be rare and primarily represented by reptiles and the armadillo.
3) Insects and insect predators seldom were encountered, and those insects observed are typically associated with the detrital layer.
4) Virtually all of the vertebrate sign and sightings are associated with the edge zone, or within about 100' of the plantation periphery. This coincides with the zone of maximum understory plant diversity.

Eucalypt Naturalization

An important concern to address in considering eucalypts for wood energy farms in Central and South Florida is the possibility of adverse impacts on the ecosystem as a result of naturalization. The potential for eucalypt naturalization in Florida is not widely discussed in the available literature, but given what is known about the ability of some exotic trees and shrubs to become rapidly established in the accommodating climate, the issue must be addressed.

Correspondence and discussion with particularly knowledgeable members of the commercial forestry industry have laid to rest much of this concern regarding eucalypts. One leading researcher of Florida eucalypts has summarized the situation by suggesting that the evidence is incontrovertible - eucalypts have been in Florida for 100 years with no evidence of major, adverse environmental impact (E. C. Franklin, pers. comm). Experts in other countries with environmental attributes similar to those of peninsular Florida concur. The Senior Professional Officer of the Forestry and Environmental Conservation Department in South Africa has indicated that although more than 150 species of eucalypts (including those planted in Florida) have been introduced, "no likelihood of a population explosion" has been identified (S. P. Fourie, pers. comm.). EcoImpact's field observations on the extent of naturalization in South Florida are recorded below.

Ferguson Plantation Area - Glades County. A reconnaissance of the *Eucalyptus robusta* portion of the 1969 stand revealed a considerable number of understory seedlings ranging from 1' - 8' tall, both on the beds and in the furrows. More significantly, approximately 100 "wildlings" were encountered adjacent to the stand. Most individuals are established 20' - 50' from the stand edge, but many are 50' - 100' distant. Most are found on bare, sandy soil or in grassland areas, including wire grass and bluestem grass associations. Others, however, are coming up through dense saw palmetto that is 4' - 5' high with virtually 100 percent cover.

Somewhat further west, a 10 - 12 year old stand has been cut in the recent past, and coppicing of the cut stems is proceeding rapidly. Also developing rapidly is a stand of seedlings so dense that counts of over 100 stems per square meter are possible. Often such seedling masses are associated with piled or scattered "slash" remaining after harvesting. An adjacent bahia grass pasture with complete ground cover contains wildlings nearly 20' tall, but less than 200' distant from the stand. The site is a relatively small coppice area within a *E. grandis* stand, and literally thousands of wildlings 1' - 10' high blanket much of the area. Of the many sites visited during the field studies, this location had the greatest amount of naturalized eucalypts. Problem-solving approaches to this condition should be incorporated in the on-going research of eucalypt plantation establishment.

Homestead Eucalypts. Just northeast of the town of LaBelle, an old homestead site, known as the "Precinct Stand," with many very large eucalypts was visited. The location was impressive both because of the massive parent trees and the number of younger trees of all sizes. The trees are hybrids, with characteristics of several species. One must presume that the largest trees have been in place for 60 - 80 years, and therefore, the extent of spread could be characterized as slow and relatively unaggressive. However, the wildling stem density and the variety of habitats encroached upon are subjects for further study.

The area between parent trees often attains a stem density sufficient to make walking progress arduous. Other than a few young cabbage palms and smilax vines, there is virtually no native vegetation in the understory or coming up through the duff layer. Recent fires have not adversely affected the trees, and wounds or cutting only stimulates the coppice response. All trees seemingly older than 4 - 5 years produce a quantity of seed capsules. An area of several acres has taken on the aspect of an uneven-aged, monocultural grove.

The wildlings are established in shade, in full sunlight, on sandy soils, on somewhat humic soils, on dry ground and even in a wetland area. Interestingly, small trees invading a shallow marsh system have developed adventitious roots in order to adapt to seasonal surface water conditions.

Two other former homestead sites southwest of Palmdale in the study area delineated in Figure 3 were similarly investigated. At the first location, a single "*robusta* mother" has generated several hundred offspring, which are established in a predominantly natural system setting. Ages vary from new seedlings to trees up to two feet dbh, and many are coming up through saw palmetto stands and other native vegetation. A few individuals were encountered 175' - 200' from the probable source tree.

The last significant site visited revealed a similar trend, but with increased naturalization. The mother tree is located in a small live oak hammock that has been surrounded by palmetto prairie and oak scrub habitat until recent clearing for additional eucalypt plantations. The hammock (about two acres) was spared from site preparation. The following pattern of establishment was observed: near the center is a mother tree nearly 100' tall and several feet in diameter; it is surrounded by about 20 trees nearly half its size; about 300 trees half that size for the next concentric circle; and radiating out from these are hundreds of saplings and seedlings. The overall pattern involves a circular eucalypt grouping about 250' in diameter, with the mother tree at the hub and approximately 1,000 associated offspring.

The extent to which naturalization may have encroached on surrounding natural system habitat could not be determined due to local site preparation. Several small plants were carefully uprooted in order to confirm that reproduction is by seed and not vegetative. Finally, the seedlings and saplings appear to be thriving under the live oak (and eucalypts) canopy, and other understory species generally are lacking. The eucalypts clearly dominate this particular site, but apparently have taken 60 - 80 years to do so.

Discussion. In carefully considering the findings concerning observed eucalypt naturalization as presented above, the capacity for species and hybrids to colonize and dominate a given site seems localized and controllable. Clearly, we are not dealing with a melaleuca, Brazilian pepper, water hyacinth, or hydrilla dilemma, perhaps largely because the dispersal mechanisms of wind, water, and wildlife do not appear to be as effectively operative with eucalypts.

Apparently, certain species of this genus have a naturalization potential that suggests management problems, although the concept of these trees creating "eucalypt epidemics" should be viewed as an unjustified over-reaction. Recognizing the potential for exotic plant establishment problems, then, plantation designers and managers should take a sober approach to the task at hand, and anticipate some local, regional, statewide, private, and public adverse reaction to proposed plantations. Such interested parties should be educated regarding the clonal propagation of E. *camaldulensis* for use in the BESI plantations, the known characteristics of this species, and a realistic assessment of the potential for naturalization in Central and South Florida.

The selection by BESI of E. *camaldulensis* for its feedstock source, using clonal propagation from select trees, has a significant bearing on the issue of potential naturalization. University of Florida forestry pathologist Roger Webb, in association with other researchers, has uncovered important information concerning the relationship between a fungal pathogen and known sterility in virtually all E. *camaldulensis* in Florida. Webb (pers. comm.) has released to EcoImpact the basic findings of his research into the lack of seed viability in this species, which will be detailed in a research paper soon to be published.

The research has revealed that the agent responsible for the seed infertility is a dark, fluffy fungus which is believed to be carried by wind or insects. More specifically, it is an imperfect fungus identified by the Commonwealth Mycological Institute as *Dothiorella eucalypti*, which is derived from an asexual form of *Botryosphaeribis*, a perfect state ascomycete. The ascomycete, present in the Florida environment, releases ascospores which are carried to the seed-bearing trees where they infect the seed capsules, and even bark, by penetration of the woody tissue by the fungal hyphae. The result has been an essentially complete sterilization of E. *camaldulensis* in Florida. In fact, the on-going research has identified only <u>one</u> tree of this species with viable seed in the State.

Furthermore, the genotype remains unchanged through the clonal process; i.e., if the select parent tree is susceptible to the fungus, which virtually always is the case, the clonal offspring will be similarly susceptible. The significant implication is that the proposed biomass tree farms probably can be rendered harmless in terms of their naturalization potential due to the fungal benefactor. The use of clonal propagation, and subsequently post-cut coppicing, eliminates the need for viable seed to produce plantation stock. Thus, the selection of *E. camaldulensis* provides substantial mitigation against fears of this species becoming another problem exotic plant in the Florida environment.

Reviewers of this and companion working documents addressing the feasibility of establishing eucalypt biomass plantations in Florida should bear in mind the "reversibility" of the proposed action. If, for reasons presently unforseen, an established biomass stand was deemed undesirable, or stand elimination was necessary after a particular harvest (6-8 year intervals), the pulling of stumps or their injection with a safe herbicide will eradicate the eucalypts. Those persons adamantly opposed to non-native plantations and those who perceive commercial forests as biologically depauperate monocultures should reflect upon the origin and nature of all of modern man's agricultural cropping systems, both floral and faunal. Unquestionably, a 100-acre corn plantation subjects the land to more adverse environmental impacts and offers poorer wildlife habitat than any of the eucalypt plantations surveyed for this report. The introduced plants which endanger Florida's natural systems are those which aggressively out-compete the native flora. *Eucalyptus camaldulensis* has remained innocuous during the past 80-100 years of existence, and all available evidence suggests that the candidate eucalypt species will not become a future management problem in the Florida environment.

Conclusions

The field and research studies undertaken to produce this resource document stimulated many deductions concerning the qualitative and functional aspects of eucalypt plantation ecology. The following conclusions have been drawn from the overall research experience.

1) Eucalypts have been planted in Florida for ornamental, shade, windbreak and commercial purposes for over 100 years.

2) The eucalypt forests of Australia and Tasmania support a rich and varied wildlife assemblage, and comprise the most important animal refuge.

3) River red gum (*Eucalyptus camaldulensis*), the species selected by Biomass Energy Systems, Inc. for biomass plantations, is the most widespread eucalypt in Australia and is one of the most important timber and biomass trees commercially planted in the world.

4) Erosion rates on a eucalypt biomass stand will be less than those in normal forestry operations due to closer plantings and stump resprouting which necessitates complete site preparation only at 25-50 year intervals.

5) Forests constitute the major wildlife habitat in the Southeast, and Florida's forest acreage has been reduced by an average of nearly 125,000 acres per year for the last 25 years.

6) Substantial wildlife production is possible where timber management is the primary objective through modern forest management and design techniques.

7) The standing biomass of understory plants in eucalypt plantations can be substantial and supply forage for both cattle and wildlife.

8) According to naturalized Florida plant studies by Mazzotti et al. (1981), exotic plant habitats are not equal in terms of faunal support and food chain structure, each habitat must be evaluated separately, and low species richness, per se, does not necessarily determine faunal distribution and abundance; therefore, exotic plant communities cannot intuitively be classified as "biological deserts."

9) Of the 200,000+ species and varieties of exotic plants brought into the United States over the past few decades, comparatively few have become vegetative problems.

10) Eucalypts appear to be able to thrive in Florida at traditional or above-average stocking densities, with or without a high water table, on mined or unmined land.

11) Although many South Florida plantings with mature *E. robusta*, *E. grandis*, and a variety of hybrids produce localized "wildlings" from seed, no progeny were encountered in the *E. camaldulensis* stands in Central Florida.

12) The literature reports that most eucalypts, including *E. camaldulensis*, have some plant inhibitory (allelopathic) tendencies. The degree of inhibition possible by phytotoxins is directly related to the amount of colloidal (clayey) material present in the soil. Well-drained, sandy soil in humid

regions, similar to the soils proposed for biomass stands, do not concentrate these toxins, and their favorable aeration permits rapid toxin degradation.

13) The Biomass Energy Systems, Inc. approach of utilizing effectively sterile *E. camaldulensis*, propagated *in vitro* by tissue culturing, has virtually eliminated the adverse naturalization potential associated with some introduced Australian trees in Florida.

14) Canopy sunlight penetration to the understory provides an open, park-like appearance with some desirable ground cover when mowed or grazed, and promotes the development of an understory association when unmanaged.

15) The diversity of associated vegetation in observed stands is greatest within about 100' from the periphery, and most invaders have the common element of wind-dispersed seed.

16) On the basis of a limited field comparison, slash pine stands with equivalent site preparation, setting, and young age may have a somewhat greater diversity of understory and ground cover plants, but eucalypt stands provide greater areal plant cover.

17) Epiphytic lichens, some air plants, and many types of insects are supported by eucalypt bark surface habitat, particularly in rough-barked species.

18) Flaking eucalypt bark offers sheltered niches for insect populations, which subsequently attract some birds and other insect predators.

19) Most eucalypts appear to be unscathed by light to moderate fire in the understory.

20) Bedded site preparation provides some topographic diversity in the forest floor which probably facilitates colonization by plants and animals, and retards destructive storm-water runoff.

21) According to visual assessment, dense ground cover by grasses and herbs decreases somewhat the vigor of young eucalypts, but older trees appear less affected, suggesting the importance of proper site preparation.

22) Stands of *E. camaldulensis* on Polk County mined lands are known to have withstood several instances of temperatures below 20°F in recent years without significant consequence.

23) Empirical field studies suggest that wildlife utilization of large eucalypt stands is less than wooded, natural system habitats, but that appropri-

ate land management and wildlife attractors might improve this situation without being detrimental to biomass production.

24) Some burrowing animals and those preferring detrital cover appear to be the most common users of eucalypt habitat.

25) Bird and squirrel nests are occasionally observed, and raccoons may regularly seek shelter in "topped" trees (E. C. Franklin, pers. comm.).

26) Terrestrial snakes and lizards probably are the primary, vertebrate predators.

27) Armadillos and white-tailed deer are the principle large, mammalian foragers known to frequent established eucalypt stands.

28) With fossil energy supplies being rapidly depleted and the continued heavy use of energy by North Americans, an urgent need exists for the development of new energy sources. Wood biomass has the potential to provide an abundant source of fuel and other services beneficial to man.

Literature Cited

Alich, J. A., R. E. Inman, K. Ernest, C. V. Fojo, R. B. Ingersoll, K. A. Miller, P. L. Morse, P. S. Oman, M. Rao, F. A. Schooley, J. S. Smith, P. D. Stent, and C. T. Warmke. 1976. An evaluation of the use of agricultural residues as an energy feedstock. Vol. I. Stanford Research Institute, Menlo Park, California. 174 pp.

Austin, D. F. 1978. Exotic plants and their effects in Southeastern Florida. Env. Conserv. 5(1):25-34.

Bates, M. 1964. Man in nature. 2nd ed. Prentic-Hall, New Jersey. 166 pp.

Bode. H. R. 1958. Beitrage Zur Kenntnis allelopathischer Erscheinungen bei einigen Juglan daceen. Planta 51:440-480.

Costin, A. B. 1961. Forest hydrology of Australian subalpine catchments. [Docum.] 2nd World Eucalyptus Conference, Brazil.

CYB. 1977. Canada year book, 1976-77. Special edition. (B. E. Pearson, ed.) Statistics. Canada, Ministry of Industry, Trade and Commerce.

del Moral, R., and C. H. Muller. 1969. Fog drip: a mechanism of toxin transport from *Eucalyptus globulus*. Bull. Torrey Bot. Club 96(4):467-475.

______. 1970. The allelopathic effects of *Eucalyptus camaldulensis*. Amer. Midl. Nat. 83(1):254-282.

EOP. 1977. The national energy plan. Executive Office of the President, Energy Policy and Planning. U.S. Gov. Print. Off., Washington, D.C. 103 pp.

Franklin, E. C. 1978. Exotics for hardwood timber production in the southeastern United States. In Proceedings: 2nd Symposium Southeastern Hardwoods, USDA Forest Service, Southeast. Area S&PF, Atlanta, Georgia.

Franklin, E. C., and G. F. Meskimen. 1973. Genetic improvement of *Eucalyptus robusta* Sm. in South Florida. In J. Burley and D. G. Nikles (eds.), Proceedings: Tropical Provenance and Progeny Research and International Cooperation, Commonwealth Forestry Institute, Oxford, Great Britain.

Harris, L. D. 1980. Forest and wildlife dynamics in the Southeast. Pages 307-322 In K. Sabol (ed.), Transactions of the Forty-fifth North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C.

Heth, D., and R. Karschon. 1963. Interception of rainfall by *Eucalyptus camaldulensis* Dehn. Pages 7-12 In Contributions on Eucalypts in Israel, II. The National and University Institute of Agriculture, Rehovot, 1963 Series No. 623-E.

Hillis, W. E. 1966. Polyphenols in the leaves of *Eucalyptus* L'Herit: A chemotaxonomic survey - I. Phytochemistry 5:1075-1090.

Howlett, K., and A. Gamache. 1977. Silvicultural biomass farms: Vol. II. The biomass potential of short-rotation farms. MITRE Tech. Rep. No. 7347. 136 pp.

Inman, R. E. 1977. Silvicultural Biomass farms: Vol. I. Summary. MITRE Tech. Rep. No. 7347. 62 pp.

Karschon, R., and D. Heth. 1967. The water balance of a plantation of *Eucalyptus camaldulensis* Dehn. Pages 7-33 In Contributions on Eucalypts in Israel, III. The National and University Institute of Agriculture, Rehovot, 1967 Series.

Long, R. W. 1974. The vegetation of southern Florida. Florida Scientist 37:33-45.

Mazzotti, F. J., W. Ostrenko, and A. T. Smith. 1981. Effects of the exotic plants *Melaleuca quinquenervia* and *Casuarina equisetifolia* on small mammal populations in the eastern Florida Everglades. Florida Scientist 44(2):65-71.

McElveen, D. 1978. The effect of different edge types and habitat sizes on distribution of breeding birds in North Florida. M.S. Thesis, University of Florida, Gainesville. 58 pp.

Meskimen, G. 1971. Fertilizer tablets stimulate *Eucalyptus* in Florida trial. USDA For. Serv. Res. Note SE-162. 8 pp.

Millett, M. R. O. 1944. Evaporation and rainfall inside and outside a forest. Leafl. For. Timber Bur. Aust. No. 57.

Moore, W. H., and B. F. Swindel. 1981. Effects of site preparation on dry prairie vegetation in South Florida. Southern J. Appl. For. 5(2):89-92.

Morgan, J. V. 1963. Occurrence and mechanism of leaching from foliage by aqueous solution and the nature of the materials leached. M.S. Thesis, Cornell University, Ithaca, New York.

Pecoraro, J. M., R. Chase, P. Fairbank, and R. Meister. 1977. The potential of wood as an energy resource in New England. New England Regional Council, Energy Resource Development Task Force, Wood Utilization Group.

Pimentel, D., S. Chick, and W. Vergara. 1979. Energy from forests: Environmental and wildlife implications. Pages 66-79 In K. Sabol (ed.) Transactions of the Forty-fourth North American Wildlife and Natural Resources Conference, Wildlife Management Institute, Washington, D.C.

Ripley, S. D. 1975. Report on endangered and threatened plant species of the United States. Smithsonian Institution, Washington, D.C.: House Document No. 94-51. 200 pp.

Saxena, S., and J. S. Singh. 1978. Influence of leaf leachate from *Eucalyptus globulus* Labill and *Aesculus indica* Colebr. on the growth of *Vigna radiata* (L.) Wilczek and *Lolium pereane* L. Indian J. Ecol. 5(2):148-158.

Tukey, H. B., Jr. 1966. Leaching of metabolities from above ground plant parts and its implications. Bull. Torrey Bot. Club 93:385-401.

Tukey, H. B., Jr. 1970. The leaching of substances from plants. Ann. Rev. Pl. Physiol. 21:305-324.

Tukey, H. B., Jr., and J. V. Morgan. 1964. The occurrence of leaching from above ground plant parts and the nature of the material leached. Proc. XVI Internatl. Hort. Congr. 4:146-153.

Tyndale-Biscoe, C. H., and J. H. Calaby. 1975. Eucalypt forests as a refuge for wildlife. Aust. For. 38(2):117-133.

USBC. 1977. Statistical abstract of the United States, 1977. 98th ed., U.S. Bureau of the Census, U.S. Gov. Print. Off., Washington, D.C.

USDA Forest Service. 1978. Forest statistics of the United States, 1977. Review draft. U.S. Gov. Print. Off., Washington, D.C. 133 pp.

Wesley, D. E., C. J. Perkins, and A. D. Sullivan. 1981. Southern J. Appl. For. 5(1):37-41.

Whittaker, R. H. 1965. Dominance and diversity in land plant communities. Science 147:250-260.

Yardeni, D., and M. Evanari. 1952. The germination inhibiting, growth inhibiting and phytocidal effects of certain leaves and leaf extracts. Phyton 2:11-16.

Zon, R., and J. M. Briscoe. 1911. Eucalypts in Florida. USDA Forest Service Bull. 87. 47 pp.

APPENDIX I

APPENDIX I

BESI: Eucalypt Field Reconnaissance, April 1-3, 1981

Plant species lists by associational type

I. Eucalyptus plantation (5-7 years) - Mined land in Polk, Hillsborough, and Manatee Counties, Florida.

Woody Species

Asimina pygmaea	Pawpaw
Asimina reticulata	Pawpaw
Baccharis glomeruliflora	Groundsel-tree
Eucalyptus camaldulensis	River Red Gum
Eucalyptus grandis	Flooded Gum
Lantana camara	Lantana
Myrica cerifera	Wax Myrtle
Pinus elliottii	Slash Pine
Prunus serotina	Black Cherry
Psidium guajava	Guava
Quercus geminata	Sand-live Oak
Quercus nigra	Water Oak
Rhus copallina	Winged Sumac
Vaccinium myrsinites	Blueberry

Herbaceous Species

Ambrosia artemisiifolia	Ragweed
Cirsium horridulum	Horrid Thistle
Cyperus esculentus	Galingale
Erechtites hieracifolia	Fireweed
Eupatorium capillifolium	Dog Fennel
Eupatorium compositifolium	Dog Fennel
Eupatorium leptophyllum	Fennel
Galactia elliottii	Milk-pea
Gnaphalium obtusifolium	Rabbit Tobacco
Heterotheca graminifolia	Silver Sword
Heterotheca subaxillaris	Camphor Plant
Indigofera hirsuta	Hairy Indigobush

Lepidium virginianum	Pepper Grass
Linaria canadensis	Toad-flax
Passiflora incarnata	Apricot Vine
Phyla nodiflora	Match-heads
Richardia scabra	Carpet Weed
Rubus spp.	Dewberry
Rumex acetosella	Red Sorrel
Smilax bona-nox	Catbrier
Solidago chapmanii	Goldenrod
Solidago microcephala	Goldenrod
Sonchus asper	Spiny-leaved Sow-thistle
Tillandsia setacea	Air-plant
Urena lobata	Caesar Weed

<u>Grass Species</u>

Andropogon virginicus	Broomsedge
Cynodon dactylon	Bermuda Grass
Imperata cylindrica	Satintail Grass
Paspalum notatum	Bahia Grass
Paspalum spp.	Paspalum Grasses
Rhynchelytrum repens	Natal Grass
Sporobolus poirettii	Smutgrass

II. Eucalyptus Plantation (12 years old) - Glades County (Lykes Brothers)

<u>Woody Species</u>

Asimina spp.	Pawpaw
Baccharis glomeruliflora	Saltbush
Callicarpa americana	American Beautyberry
Eucalyptus grandis	Rose Gum
Eucalyptus robusta	Swamp Mahogany
Ilex glabra	Gallberry
Lyonia ferruginea	Staggerbush
Lyonia fruticosa	Staggerbush
Pinus elliottii	Slash Pine
Quercus pumila	Running Oak

Serenoa repens	Saw Palmetto
Vaccinium myrsinites	Blueberry

<u>Herbaceous Species</u>

Cnidosolus stimulosus	Treadsoftly
Cuthbertia graminea	Roseling
Gnaphalium obtusifolium	Rabbit Tobacco
Habenaria quinqueseta	Michaux's Orchid
Heterotheca graminifolia	Silk Grass
Hypericum spp.	St. John's Worts
Hypoxis juncea	Yellow Star Grass
Opuntia sp.	Prickly Pear Cactus
Oxalis dillenii	Yellow Wood Sorrel
Pterocaulon pycnostachyum	Black-root
Rhus radicans	Poison Ivy
Smilax spp.	Smilax
Solidago spp.	Goldenrods
Tillandsia fasciculata	Giant Air-plant
Tillandsia setacea	Air-plant
Vitis rotundifolia	Muscadine

<u>Grass Species</u>

Andropogon virginicus	Broomsedge
Aristida spp.	Three-awn Grasses
Aristida stricta	Wire Grass
Dichanthelium spp.	Low Panic Grasses
Panicum spp.	Panic Grasses

III. Slash Pine Plantation (8-12 years old; adjacent to Eucalyptus plantation) - Glades County (Lykes Brothers)

<u>Woody Species</u>

Asimina spp.	Pawpaw
Baccharis glomeruliflora	Saltbush
Callicarpa americana	American Beautyberry
Ilex glabra	Gallberry

Lyonia ferruginea	Staggerbush
Lyonia fruticosa	Staggerbush
Myrica cerifera	Wax Myrtle
Pinus elliottii	Slash Pine
Quercus laurifolia	Laurel Oak
Quercus pumila	Running Oak
Serenoa repens	Saw Palmetto

<u>Herbaceous Species</u>

Ambrosia artemisiifolia	Ragweed
Bidens pilosa	Spanish Needles
Centella asiatica	Coinwort
Circium horridulum	Horrid Thistle
Cnidoscolus stimulosus	Treadsoftly
Cyperus sp.	Galingale
Desmodium canum	Tick Clover
Erechtites hieracifolia	Fireweed
Erigeron quercifolius	Daisy Fleabane
Eriocaulon compressum	Bog Button
Eupatorium compositifolium	Dog Fennel
Gnaphalium obtusifolium	Rabbit Tobbaco
Hypericum spp.	St. John's Worts
Momordica charantia	Wild Balsam Apple
Opuntia sp.	Prickly Pear Cactus
Oxalis dillenii	Yellow Wood Sorrel
Parthenocissus quinquefolia	Virginia Creeper
Pluchea odorata	Marsh Fleabane
Pterocaulon pycnostachyum	Black-root
Rhus radicans	Poison Ivy
Rubus sp.	Blackberry
Smilax spp.	Greenbriers
Solidago spp.	Goldenrods
Tillandsia setacea	Air-plant
Vitis rotundifolia	Muscadine

Grass Species

Andropogon virginicus	Broomsedge
Dicanthelium spp.	Low Panic Grasses
Panicum spp.	Panic Grasses

IV. Other Eucalypt Plantations (3-12 years old) - Glades County

Woody Species

Ilex glabra	Gallberry
Lyonia fruticosa	Staggerbush
Serenoa repens	Saw Palmetto

Herbaceous Species

Eriocaulon compressum	Bog Button
Fuirena scirpoidea	Umbrella-grass
Hypericum spp.	St. John's Worts
Juncus polycephalus	Rush
Rhynchospora spp.	Beak Rushes
Samolus parviflorus	Water-pimpernel
Scleria muhlenbergii	Nut Rush
Schrankia microphylla	Sensitive-brier
Xyris spp.	Yellow-eyed Grass

Grass Species

Andropogon spp.	Broomsedge
Aristida spp.	Three-awn Grasses
Aristida stricta	Wire Grass
Axonopus affinis	Carpet Grass
Dicanthelium spp.	Low Panic Grasses
Panicum spp.	Panic Grasses

APPENDIX II

APPENDIX II

Faunal List for Eucalypt Plantations
Polk, Hillsborough, and Glades Counties, Florida; April 1-3, 1981

MAMMALS

Eastern Cottontail	*Sylvilagus floridanus*
Armadillo	*Dasypus novemcinctus*
Florida Bobcat*	*Felis rufus floridanus*
Raccoon*	*Procyon lotor*
Opossum*	*Didelphis virginiana*
Rodents	*Peromyscus sp./Sigmodon hispidus*

BIRDS

Blue Jay	*Cyanocitta cristata*
Barred Owl	*Strix varia*
Loggerhead Shrike	*Lanius ludovicianus*
Ground Dove	*Columbina passerina*
Whip-poor-will	*Caprimulgus vociferus*
Meadowlark	*Sturnella magna*
Turkey	*Meleagris gallopavo*

REPTILES AND AMPHIBIANS

Gopher Tortoise	*Gopherus polyphemus*
Six-lined Racerunner	*Cnemidophorus sexlineatus*
Ground Skink	*Scincella lateralis*
Green Anole	*Anolis carolinensis*
Florida Scrub Lizard	*Sceloporus woodi*

INVERTEBRATES

Grasshoppers/Crickets	(Orthoptera)
Springtails	(Collembola)
Ants	(Hymenoptera)
Leafhoppers	(Homoptera)
Spiders	(Arachnida)

* Species-specific sign (tracks, scats, burrows, etc.)