29

Integrated Pest Management of the Southern Pine Beetle

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Abstract

Integrated pest management (IPM) is the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and strategies that are ecologically and economically efficient and socially and politically acceptable. It is explicit that the actions taken are fully integrated into the total forest and environmental management process –in both planning and operation. The concept, methodology, and practice evolved from extensive research and development projects conducted during the 1970s and 1980s. In this chapter we 1. provide a general overview of the IPM concept, 2. place IPM in the broader context of a multitiered management hierarchy, 3. define the forest settings where the southern pine beetle (SPB) is considered to be a pest, 4. examine the structure and component activities of an SPB IPM system, and 5. summarize the major research, development, and management actives in need of further study and elucidation.

29.1. INTRODUCTION

Integrated pest management (IPM) is a concept, methodology, and practice that was formulated from extensive research and development conducted during the 1970s and 1980s. Impetus for the forest component of this work came as a result of cyclic outbreaks of several prominent forest insects; e.g., southern pine beetle (*Dendroctonus frontalis* Zimmermann) (SPB); the western pine beetle, *D. brevicomis* LeConte; the mountain pine beetle, *D. ponderosae* Hopkins; the gypsy moth, *Lymantria dispar* Linnaeus (Lepidoptera: Lymantriidae); the Douglas-fir tussock moth, *Orgya pseudotsugata* McDunnough (Lepidoptera: Lymantriidae), the spruce budworm, *Choristoneura fumiferana* Clemens (Lepidoptera: Tortricidae); and the western spruce budworm, *C. occidentalis* Freeman. Much of the work on the SPB centered on ways to manage the economic, ecological, social, and political impact of the insect on southern forests (Branham and Thatcher 1985, Coulson 2003, Thatcher and others 1980). Attributes of the natural history of the SPB, particularly the occurrence of infestations in spatially discrete patches (spots), and the innovations of the digital age (e.g., global positioning systems, geographic information systems and related technologies, Internet delivery systems) greatly facilitate application of IPM concepts for the SPB in southern forest landscapes. Accordingly, in this chapter our goal is to examine IPM as related directly to the SPB. The specific objectives are: 1. to provide a general overview of the IPM concept; 2. to place IPM in the broader context of a multi-tiered management hierarchy; 3. to define the forest settings where the SPB is considered to be a pest; 4. to examine the structure and component activities of an SPB IPM system, and 5. to summarize the major research, development, and management activities in need of further study and elucidation.

29.2. INTEGRATED PEST MANAGEMENT

The term "pest" is an anthropocentric designation given to certain forest insects and other organisms when they adversely affect ecological, economic, social, and political values associated with the resources and conditions of the forest environment. The philosophy, concept, and methodology of IPM evolved over a period of years, and therefore, so has the definition. Our working definition of IPM is as follows: Integrated pest management is the maintenance of destructive agents, including insects, at tolerable levels by the planned use of a variety of preventive, suppressive, or regulatory tactics and/or strategies that are ecologically and economically efficient and socially and politically acceptable. It is explicit that the actions taken are fully integrated into the total forest and environmental management process –in both planning and operation (Coulson 2003).

The definition of IPM contains four key points of emphasis. First, the foundation of IPM is based on the principles of ecology. Second, the methodology involves a combination of tactics; that is, discrete techniques aimed at suppression or prevention of population growth. When combined, several tactics constitute a strategy for regulating or modifying population distribution and abundance. In some instances more than one strategy can be applied. Third, the functional goal of IPM is to reduce or maintain pest populations at tolerable levels. Economic, ecological, social, and political values are used in judging what tolerable levels are. Fourth, IPM is a component of forest protection, which is a component of forest management, which is a component of environmental management (Coulson 1981).

29.3. MANAGEMENT HIERARCHY

To manage is to take charge of or care of. Management is a directed activity. IPM is the approach used to manage destructive agents in the forest environment by the planned use of preventive, suppressive, and/or regulatory tactics and strategies. The effects of IPM are propagated through a management hierarchy consisting of three levels of activity: forest protection➔forest management➔environmental management.

The base of the management hierarchy is forest protection, which we define as the applied component of forest management that deals with the agents that cause undesirable change in the conditions and resources of the forest landscape. The actual practices of IPM are part of the domain of forest protection. However, forest protection is a component of the next level in the hierarchy, forest management, which we define as follows: the orchestrated modification or manipulation of landscape structure, function, or rate of change. The specific type of forest (e.g., extensively managed, intensively managed, specialized forest setting, urban/suburban) and the impact of the pest species will dictate the need for and extent of IPM. The effects of IPM must be considered in the context of specific forest management goals. Finally, forest management is a component of environmental management. Herein we define the term, environment, as the external conditions and resources, living and nonliving, that affect an organism or other specified system (e.g., a forest) during its lifetime. Environmental management is defined broadly to mean the orchestrated modification or manipulation of the chemical, physical, and biological surroundings of an organism or other specified system during its lifetime. The tactics and strategies of IPM are directed to specific pest organisms, but the effects are often distributed through the forest landscape. For this reason, IPM actions are often evaluated through a formal environmental impact assessment (EIS) prior to implementation. In the United States, the EIS procedure is a formal process defined by NEPA (National Environmental Policy Act of 1969 as amended) legislation. A multivolume EIS has been prepared for the SPB (USDA, FS, EIS 1987).

29.4. WHERE IS THE SOUTHERN PINE BEETLE A PEST?

There are several different kinds of forests where the SPB is considered to be a pest. The prominent types are intensively managed forests, specialized forestry settings, and urban/suburban forests. Each forest type varies in the degree of human intervention involved in management (Figure 29.1). As IPM is a costly and complicated endeavor, application of the approach is often reserved for those circumstances where forest resources and conditions have extraordinary value. Although the SPB is associated with conservation forests (e.g., wilderness areas) and extensively managed forests, IPM in these environments is reduced and tailored to meet unique management objectives. In the following sections, we examine SPB in intensively managed forests, specialized forestry settings, and urban/suburban forests.

29.4.1. Intensively Managed Forests

Much of the impetus for the research into principles and procedures of IPM came from interest in protecting the valuable resources associated with intensively managed forests. Although these forests are managed for multiple values, maximizing timber and fiber production is often the overriding goal. Specific attributes of forest sites and stands have a great impact on forest productivity. The effects that insects have on forest trees are related to site and stand conditions (Figure 29.2).

Southern Pine Beetle and Site Relationships

A site can be considered as a localized area within a forest landscape where a particular tree species, along with associated vegetation, grows. The site consists of both abiotic (nonliving) and biotic (living) components. Our focus here is centers of sites predominately stocked with southern yellow pine (*Pinus* spp.) as these species are the main host of the SPB. The condition of the site has a major influence on productivity of a pine forest. The concept of site is expressed in production forestry in a variety of ways; e.g., site class, site index, site quality. A pine forest landscape consists of a mosaic of different site conditions. The condition of the site changes throughout the life cycle, or rotation time, of a tree species.

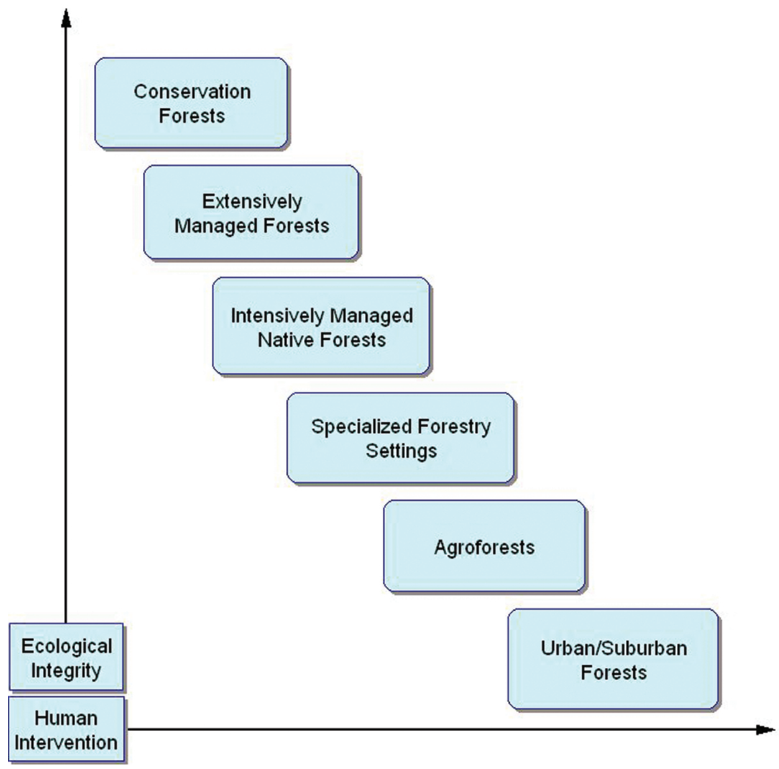

Figure 29.1—Types of forests illustrating a range of human intervention from modest to great. IPM is practical in intensively managed forests, specialized forestry settings, urban/suburban forests, and (to some extent) agroforests. (KEL image)

Figure 29.2—Southern pine beetle infestation on an intensively managed forest (Indian Mounds Wilderness, northeast, Texas). (photograph by Ron Billings)

Site condition is an important consideration in IPM of the SPB for two reasons. First, the site contains the host material, *Pinus* species, in various stages of growth that the SPB utilizes for food and habitat. The availability of suitable preferred host species is a primary requisite for the development of SPB populations. The opportunity for SPB populations to grow in size varies on different sites. Second, site condition, in combination with weather, determines the rate of growth and general vigor of host trees present. To initiate infestations the SPB exploits trees that are physiologically weakened as a result of stress created by nutrient deficiencies, drought, flooding, overcrowding, and so on.

Southern Pine Beetle Stand Relationships

In production forestry, the basic unit of management is the forest stand. A stand is a somewhat arbitrary subdivision of a forest landscape. It is an aggregation of trees and other vegetation occupying a specific area. It is sufficiently homogeneous in species composition, age, size, structure, and condition to be distinguishable from the forest and associated vegetation on adjoining areas.

Certain activities involved in the cultivation of pine forests create conditions that enhance or reduce the likelihood that the SPB will have a significant impact on forest resource values. In circumstances where we are attempting to maximize wood or fiber production, forest structure is tailored in a number of specified ways: 1. generally one pine species will be planted; 2. within a particular stand, the species selected will be planted at or about the same time—that is, the stand will be even-aged; 3. there will usually be an attempt made at controlling unwanted hardwood species; and 4. the density of the trees will be prescribed. Each of these conditions is conducive to the buildup of large populations of the SPB once the stands mature. Variations in site quality, that is poor site quality, and stand conditions within the forest, taken together, often create the opportunity for large SPB populations to develop (Figure 29.2).

29.4.2. Specialized Forestry Settings

There are several different types of specialized forestry settings where tolerance of SPB infestation is much lower than even the intensively managed forests. These settings include seed orchards, recreation areas, arboretums, and research plots. The SPB is commonly a pest in these settings because of the high value of the product sought (or function, in the case of recreation areas) relative to traditional forest values. The strategies taken in managing the SPB in these settings are more closely aligned with the practices used in traditional agriculture than in forest landscapes. For example, pest management practices are more intensive and generally warrant a greater expenditure of capital than is practical in a forest over an entire rotation. There is also a much greater dependence on the use of pesticides in the specialized settings than in forest landscapes, where economic, ecological, social, and political constraints often limit widespread application (Figures 29.3A and B).

29.4.3. The Southern Pine Beetle in Urban/Suburban Forests

The urban/suburban forest can be defined to include trees growing in residential areas at the interface between managed forests and centers of commerce, in yards at residences, along city streets, in city parks, and in recreational areas. Conceptually, the problems with the SPB in urban/suburban forests are similar to those in intensively managed forests and specialized forestry settings. The main difference is that trees in urban areas are cultured primarily for aesthetic purposes and because of their usefulness in buffering the effects of weather.

Urban areas throughout the range of the SPB periodically have outbreaks of the insect. The commercially valuable pine species are common ornamental trees, and residential developments are often built in remnant mature forests. Cultural disturbances to sites and trees in urban/suburban forests often trigger local SPB outbreaks and infestations of individual hosts trees. Examples of common disturbances include road construction; power transmission line clearing; photochemical oxidation injury; building construction, including site clearance and dressing, placing of sidewalks, driveways, and conduits; and modification of water drainage patterns. Once infestations occur, pest management generally involves use of remedial tactics to remove infested hosts.

29.5. COMPONENT ACTIVITIES OF SPB IPM

The major impetus that fueled the development of concepts of IPM came from concern for managing forest insect pest outbreaks on intensively managed public and private forest lands. The research and development projects of the 1970s and 1980s and subsequent investigations have provided a well-formulated IPM concept and approach. However, the issue of implementation of IPM within the managerial hierarchy of forest protection➔forest management➔environmental management remains a challenging task. The concepts, practices, technologies, and legal statutes of forest protection, forest management, and environmental management have changed significantly since the architects of IPM crafted the initial principles. Following, we present an overview of the basic activities associated with the practical application of IPM for the SPB in forest landscapes.

IPM in forests can be defined, from a functional perspective, to consist of a number of specific but related activities as illustrated in Figure 29.4 (Coulson 2003, Saarenmaa 1992). This activity

Figure 29.3A—Aerial photograph of southern pine beetle infestation in an urban landscape in North Florida. (photograph by J. Meeker)

Figure 29.3B—Remedial suppression tactic, involving the use of pesticides applied to infested pines in an urban landscape. (photograph by J. Meeker)

model is a concise overview of the concept and practice of IPM. It represents a significant advancement over previous constructs in that the research and development components of IPM are integrated with activities needed for implementation of the concept in a real-world forest environment. Figure 29.4 represents IPM to consist of 11 separate activities that are related as illustrated by connections and directions of arrows. The basic activities include the following: effects of climate on the forest environment, assessment of pest population dynamics, assessment of tree and forest dynamics, impact assessment, evaluation of control alternatives, monitoring, database management, diagnosis, environmental assessment, management planning, and decision and execution. Each of these activities is examined below.

There are eight fundamental principles of IPM in forests conveyed in Figure 29.4 that pertain to the SPB specifically and forest insect pests in general. These principles include the following:

- The basic premise of IPM is that there is a resource or forest condition in need of protection from pests. From a management perspective, the state of the resource is evaluated through an examination of tree and forest dynamics. This examination usually involves use of simulation models that approximate the expected growth and yield of a valued tree species over at least a rotation period. The condition of the forest is evaluated by integration and interpretation of spatially referenced tabular databases that describe a specific environment. The types of data needed for this purpose include themes such as tree species composition, age, and density; terrain elevation and slope; and soil type.
- Some insect species are periodically pests because they become sufficiently numerous to damage a valued resource or desired forest condition in some way. Generally, there is a direct relation between population size and impact on forest resources and conditions. IPM, therefore, requires evaluation of pest population dynamics. Again, this evaluation can be facilitated through the use of simulation models.
- The actual or potential importance of a pest species is judged by evaluating its economic, ecological, social, or political impact on values we associate with the resource or forest condition.

- In order to assess the actual or potential impact of a pest species, it is necessary to gather contemporary information about the state of insect populations and the resources and conditions of the forest environment. This activity requires monitoring. To monitor is to observe critically in ways that do not affect the resources and conditions of the forest environment. The information collected during the monitoring activity becomes a part of the forest database. The forest database contains spatially referenced and tabular data that describe the forest resources and condition.
- The contemporary information gained through the monitoring activity is used in diagnosis of the cause and extent of a pest problem. This diagnosis is used to establish the need for directed suppression or prevention actions. Human judgment by experienced individuals is often an important component of the diagnosis.
- Pest population size can be modified (e.g., pesticides) or regulated (e.g., natural enemies) by the application of treatment tactics. The procedures may be targeted to suppression of existing populations or prevention of forest conditions that lead to pest outbreaks.
- Decisions to consider application of specific control tactics must be evaluated for their effect on the forest management plan and their environmental impact. These activities link forest protection to the higher levels of the management hierarchy; i.e., to forest management planning and environmental assessment.
- Decision and execution of an IPM program follows from interpretation of the environmental assessment and an evaluation of the effects on the forest management plan. Typically, this activity (decision and execution) requires integration and interpretation of both qualitative and quantitative information, and computer-based decision support is often a necessity. The results of the decision and execution activity directly affect the pest population and forest tree dynamics.

In the following subsections we examine each of the basic activities associated with IPM of the SPB. The interrelations of the various elements of the activity diagram (Figure 29.4) are also illustrated.

29.5.1. Climate and the Forest Environment

Climate is the combination or aggregate of weather conditions experienced in a particular area. It includes both averages and extremes measured over an extended period of time. The most important determinates of climate are temperature and precipitation. Climate affects the population dynamics of host species and the SPB (Figure 29.5). Climatic conditions

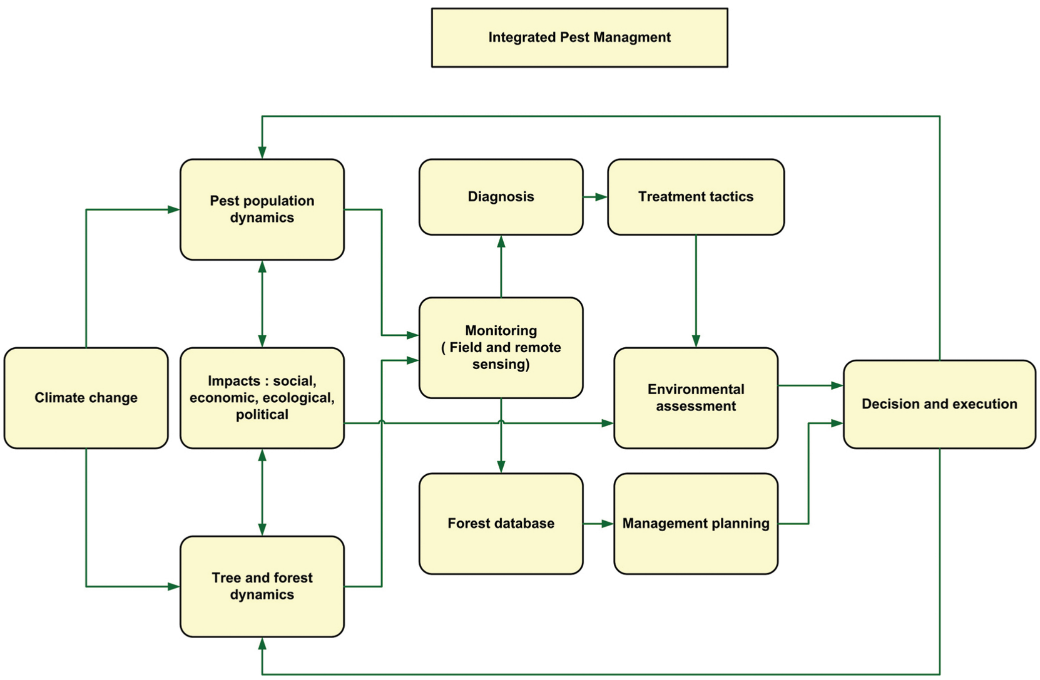

Figure 29.4— Activities associated with integrated pest management and their relation to one another. (modified from Coulson 2003)

influence the host/insect interactions directly. Climate also establishes the geographic range in distribution of preferred *Pinus* hosts and the SPB. Global climate change has greatly expanded the traditional geographic range of the SPB (Ayers and Lombardero 2000), and this circumstance must now be factored into IPM decisionmaking.

29.5.2. Pest Population Dynamics

Pest population dynamics (Figure 29.6) is the change in the distribution and abundance of an organism through space and time. The spatial framework for the SPB encompasses a range of square centimeters to hectares, and the temporal framework may vary from minutes to years. Within this spatial-temporal framework, it is possible to focus attention on populations of the SPB within a unit of habitat (a tree), within a stand, or within a forest landscape, and within an ecoregion (Coulson and Wunneburger 2000).

The SPB is of major importance in forest management because it consumes resources, alters the conditions of the forest landscape, and disrupts management plans and schedules. Our interest in managing the SPB includes immediate short-term response to outbreak conditions involving current population levels and damage as well as long-term planning to anticipate and prevent population levels that lead to outbreaks. Obviously, the approaches used in population management under these two circumstances are quite different.

When one considers all the variables that affect birth, death, immigration, and emigration in a population of the SPB, it is not surprising to find that mathematical models of population systems are utilized to abstract key elements (Coulson and others 1989, Feldman and others 1981a, Lih and Stephen 1989, Stephen and Lih 1985). The accuracy and precision of predictive models of population dynamics are related to space-time resolution. Both accuracy and precision diminish as the space-time framework is enlarged, primarily because of the difficulties in forecasting weather over long periods of time. Therefore, best results in modeling populations have been obtained at the stand level of organization and in a period of time ranging from several weeks to several months. In management planning for potential SPB outbreaks, variables such as stand age, species composition and density, localized site conditions, physiographic conditions, and climatic zones within the range of the insect are used in predicting the likelihood of pest problems occurring at various age intervals of forest growth.

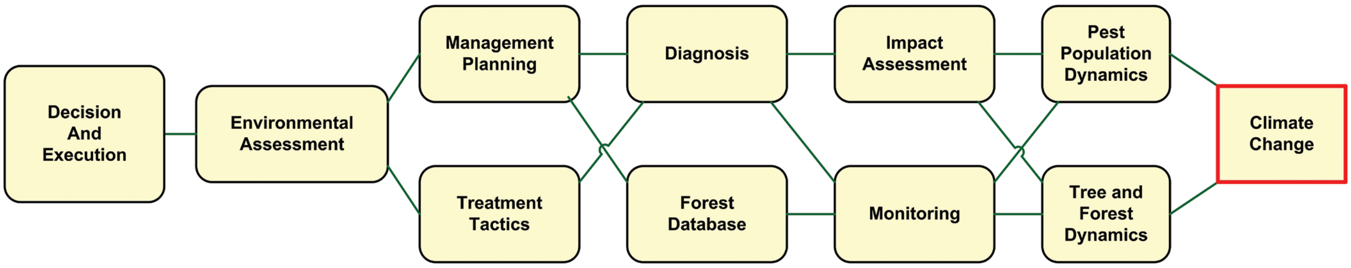

Figure 29.5—Dependency network for the Climate Assessment IPM activity.

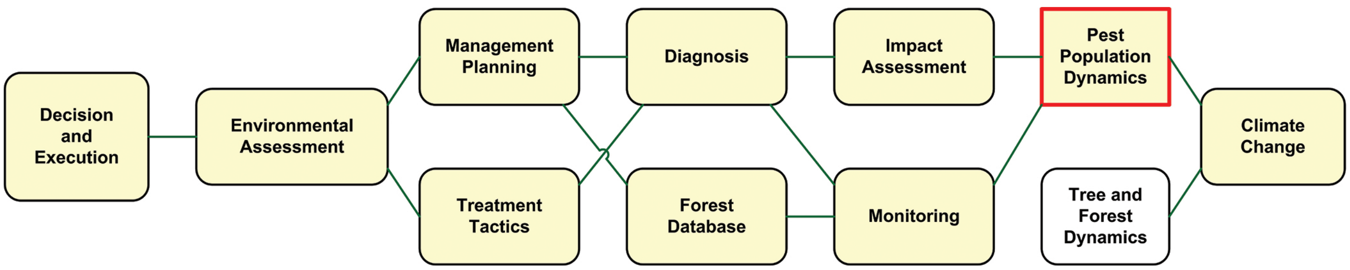

Figure 29.6—Dependency network for the Pest Population Dynamics IPM activity.

29.5.3. Tree and Forest Dynamics

The forest stand is often the focal point of IPM because it is the basic unit used by foresters for inventory, planning, and operations. Tree and forest dynamics (Figure 29.7) include consideration of causes for changes in the distribution, abundance, and size of a host tree species through space and time. In the context of IPM, we may be interested in either 1. the role of the SPB in the population dynamics of the host tree species or 2. the role of the host in the population dynamics of the SPB. In the first case, where interest is in the role of SPB in the population dynamics of the host, the temporal framework spans the rotation time for a particular tree species, which can range from about 6 to 150 years. Typically the SPB begins to affect pine forest stands at about 35-40 years. The spatial framework will normally be in hectares. In the second case, where we are interested in the role of the host in the population dynamics of the SPB, the spatial framework can range from a single tree, to stands, and to forests composed of stands in different age classes. The temporal framework can span from hours to several years. Host trees vary in susceptibility to colonization by the SPB and suitability as food and habitat. Tree species, age, and general vigor are variables that influence both susceptibility and suitability. Furthermore, many tree species possess defense mechanisms that deter insects; for instance, the resin system of pines is considered to be a primary defense against certain bark beetle species.

Foresters have developed mathematical models to predict forest stand growth and yield for many of the commercially important tree species. Data for these models are collected as part of the normal forestry inventory conducted on Federal, State, and private lands. Growth and yield models have proved to be useful in IPM, particularly when we are interested in defining costs associated with tree mortality or growth reduction resulting from the activities of pest species.

Significant advances in both the theory and practice of spatial modeling of forest landscapes have been made in recent years (Cairns and others 2008a, 2008b; Gustafson 1998; Mladenoff and Baker 1999; Rauscher and others 2000; Xi and others 2008). Major emphasis has centered on advancing scientific understanding of forest landscapes (e.g., forest succession and disturbance, vegetation dynamics, impact of deforestation, harvesting effects on landscape structure) (Lafon and others 2007, Mladenoff and Baker 1999, Waldron and others 2007) and on applications to enhance forest management practice (e.g., forest management decisions for wildlife, decision analysis for forest ecosystem management, assessment of watershed condition) (Rauscher and others 2000).

29.5.4. Impact Assessment

The concept of pest impact on forest resources and conditions is a central issue of IPM. Impact (Figure 29.8) is broadly defined to mean any effect on the forest environment resulting from the activities of insects. From an ecological perspective forest insects can act as herbivores, carnivores, or detritivores. Through these activities insects can cause changes in forest conditions (the abiotic environment, biotic environment, and forest configuration) and valued forest resources (timber production, hydrology, fish and wildlife, recreation, grazing, real estate, biodiversity, endangered species, cultural resources, and nonwood forest products). The degree of insect impact is evaluated using ecological, economic, social, and political criteria.

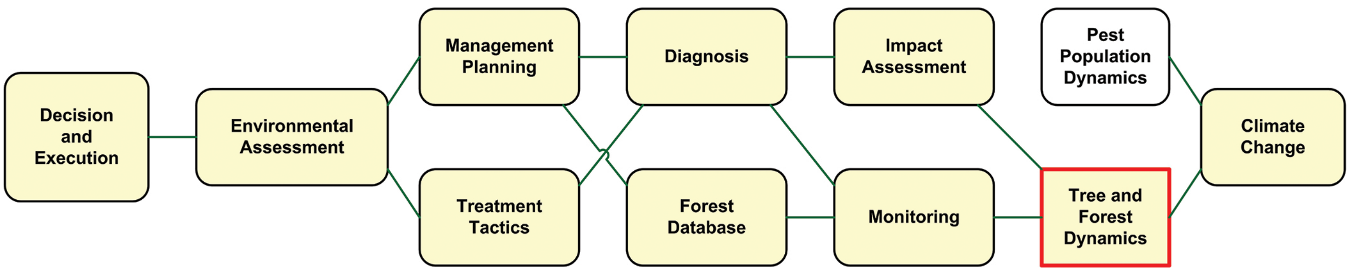

Figure 29.7—Dependency network for the Tree and Forest Dynamics IPM activity.

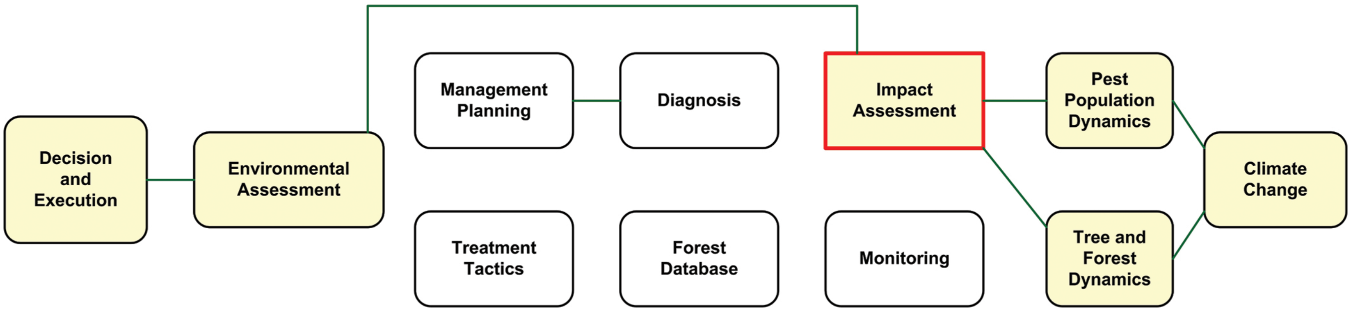

Figure 29.8—Dependency network for the Impact Assessment IPM activity.

Typically, for an insect or other organism to be considered a pest in a forest management context, the impact must be substantial; i.e., of sufficient magnitude to cause a human reaction. Because any reaction will involve expenditure of capital (human or monitory), pest management programs are often associated with high value forest environments; i.e., intensively managed forest, specialized forestry settings, and urban/suburban forests. In these environments, the reaction is to suppress or prevent the activities of the pest.

Evaluating impacts of the SPB can be extremely complicated. The insect can have both negative and positive impacts, depending on the criteria used in judgment and the particular forest management goal. For example, herbivory by the SPB serves to truncate community development at a time when the forest has become senescent, and thereby it reinitiates the process of ecological succession. At the same time, herbivory also causes economic loss at the stage in the rotation of the pine stand when the trees are most valuable. Because of the difficulties involved in assessing impacts, it is not surprising to find, again, that mathematical models are used for interpretative, as well as predictive purposes.

In the activity dependency diagram for IPM (Figure 29.4), impact evaluation involves a reciprocal interaction with the pest population dynamics and tree and forest dynamics components. The results of the impact evaluation feed directly to the environmental assessment component. This flow illustrates how forest protection activities link directly to the upper echelons of the management hierarchy.

29.5.5. Monitoring

Recall that to monitor is to observe critically in ways that do not affect the resources and conditions of the forest environment. Monitoring (Figure 29.9) involves collecting data about the forest environment. Forest landscapes are monitored for a variety of reasons; e.g., 1. to inventory the resources and conditional states of the forest environment, 2. to demonstrate compliance with legal forest management statutes, 3. to evaluate the impact of disturbance events, and 4. to survey the activities of pest organisms.

In the context of IPM, surveys involve monitoring tree and forest dynamics and the distribution and abundance of actual or potential pest insects or the damage they cause. There are several types of insect surveys

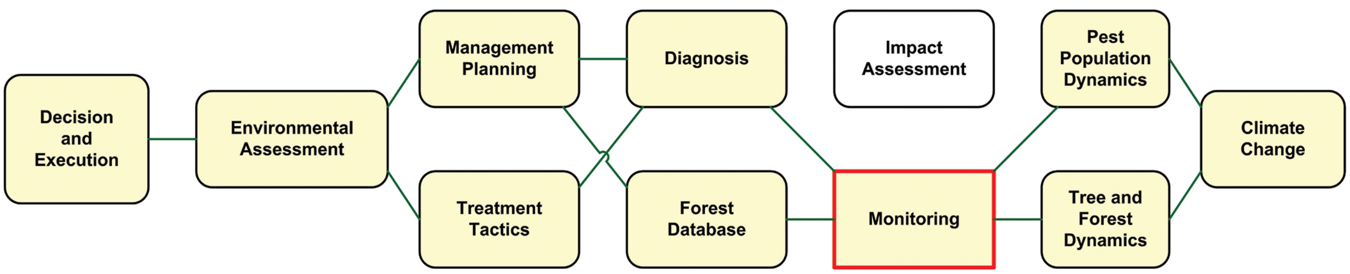

Figure 29.9—Dependency network for the Monitoring IPM activity.

that can be applied in intensively managed forests, specialized forestry settings, and urban/suburban forests. Forest surveys can be quantitative or qualitative with regard to the type of data collected. Surveys are often classed according to their purpose in the following way: 1. detection surveys, 2. biological evaluations, 3. loss or damage surveys, 4. pest control evaluations. The specific procedures used depend on the type of forest situation being sampled, the type of survey being conducted, and the intended use of the data collected.

The data collected in a survey are used for two purposes: to diagnose the nature and extent of the pest problem, and to enrich the forest database. Because of the importance of correct and contemporary information for use in IPM decisionmaking and the high costs associated with surveying pest populations, advanced technologies are often used to capture (remote sensing), analyze (spatial statistical procedures) (Gustafson 1998), display (geographic information systems or GIS), and interpret (decision support systems or DSS) (Coulson and others 1999c) survey data.

29.5.6. Diagnosis

To diagnose is to recognize and identify by examination and observation. There are two aspects of diagnosis (Figure 29.10): the first involves identification of the cause of the pest problem, and the second involves evaluation of the extent of damage. Monitoring forest insects through the various types of surveys provides basic information about the activities of pest species. The surveys often are routinely scheduled for important pest species. For example, most of the States in the Southern United States conduct aerial surveys to detect the presence and estimate the abundance the SPB. These surveys are usually initiated in April and May. Diagnosis is closely coupled with monitoring. It involves inspecting infestations on the ground (ground checking) and verifying the causal agent after pest activity has been detected. The pest species could be the SPB or another bark beetle species. Verifying the pest to be the SPB is important, as this insect is capable of causing significant tree mortality. Diagnosis involves examination of the host material to identify the causal agent and an appraisal of the extent of damage that occurred.

Forest entomologists and forest pathologists diagnose the cause and extent of pest problems. Their diagnoses are based on fundamental understanding of insect pests and the damage they cause. This understanding is founded on knowledge of the natural history of the pest species.

Diagnosis often includes consideration of experiential knowledge provided by foresters who are familiar with a particular forest environment; i.e., diagnosis is a collaborative activity that may involve the technical expertise of more than one specialist. Because it is often difficult to assemble technical specialists to address each forest pest problem, computer-based technologies have been employed to capture the heuristic knowledge of experts. Expert systems, which are computer programs designed to mimic the reasoning process of human experts, are suitable for this purpose (Coulson and Saunders 1987, Saarenmaa 1992, Saarenmaa and others 1994, Saunders and others 1993, Stone and others 1986).

29.5.7. Treatment Tactics

One outcome of the diagnosis activity can be that an insect pest is causing sufficient impact to warrant human intervention. Treatment tactics (Figure 29.11) are planned procedures that are used to modify or regulate the distribution and abundance of a pest species. As with the other elements of IPM, treatments have time and space components. That is, we are interested in ways and means of suppression of

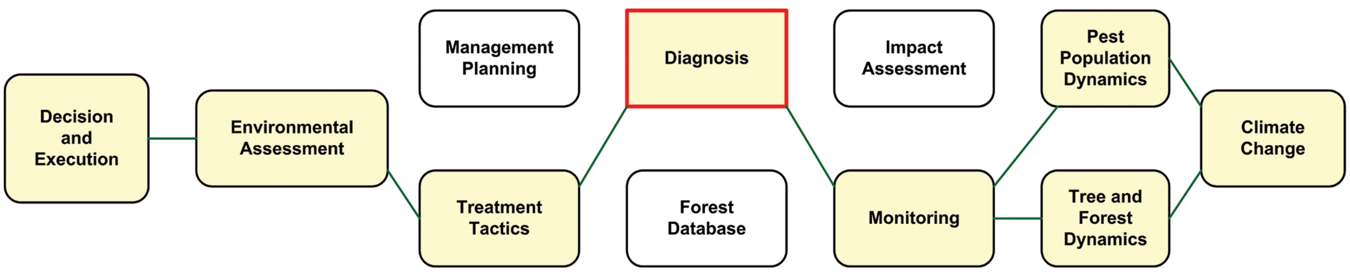

Figure 29.10—Dependency network for the Diagnosis IPM activity.

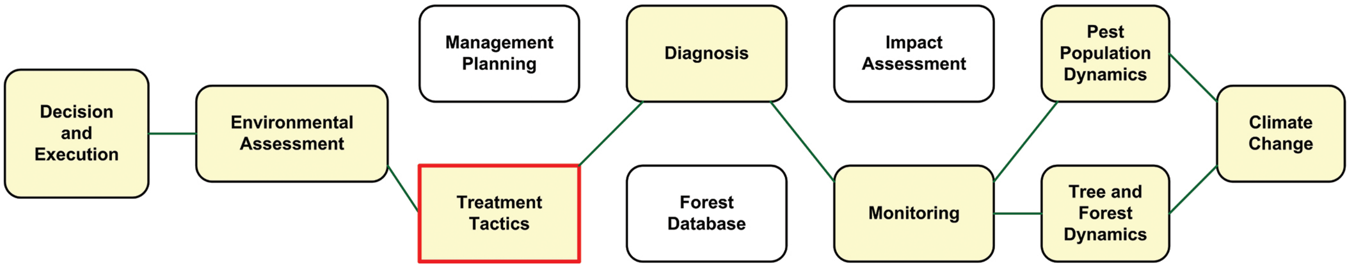

Figure 29.11—Dependency network for the Treatment Tactics IPM activity.

an existing pest population and in prevention of potential pest population outbreaks. In the case of suppression, the timeframe may range from several weeks to months, and the space framework from single trees to stands. However, more than one stand within a forest landscape can be affected. In the case of prevention, our time framework may span the rotation period for a tree species, and the space framework may include stands within forest landscapes. Obviously, the procedures used in suppression and prevention are quite different.

Historically, a great deal of attention has been given to development of treatments for specific pest problems. As concepts, these tactics affect reproduction, mortality, immigration, and emigration. There are numerous ways to manipulate these population system components. The specific procedure is often referred to as a control procedure or control tactic. Billings (see chapters 25 and 27, this volume) reviews the procedures used against the SPB. Following are several examples that illustrate various tactics used in suppression and prevention.

Suppression tactics are directed to existing pest populations. Examples of tactics are: 1. biological control, including augmentation of insect parasitoids, insect predators, avian predators, and disease; 2. chemicals, including various pesticides and herbicides; 3. behavioral chemicals (semiochemicals), including compounds that result in attraction and dispersal; 4. utilization, which involves harvesting of infested host materials; 5. various mechanical procedures, including felling infested hosts and burning infested hosts; and 6. use of genetically altered (transgenic) host plants.

Techniques used in prevention of insect outbreaks include: 1. regulatory controls, which are designed to prevent introduction of pests into uninfested forests or contain them through quarantine in localized areas, and 2. cultural or silvicultural controls that include management of stand characteristics such as species composition, age, and density; site maintenance; and avoidance of disturbances to both stands and sites.

The concept of IPM stresses that a variety of tactics can be used simultaneously to manage pest populations. These tactics collectively constitute a strategy. It is possible to develop strategies for both suppression and prevention goals. For a particular treatment tactic to be included as part of a strategy, it must be efficacious, safe, cost-effective, legal, and socially acceptable. Reference to Figure 29.4 indicates that treatment strategies are directly linked to environmental assessment.

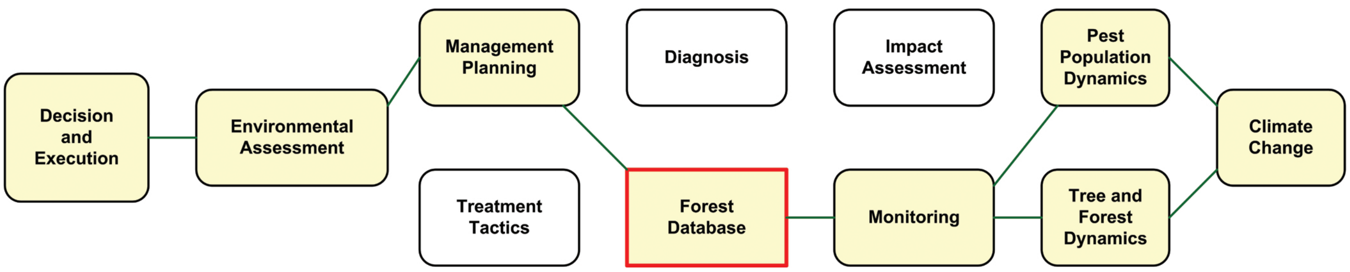

Figure 29.12—Dependency network for the Forest Database IPM activity.

29.5.8. Forest Database

Accurate information on the state of the environment is a critical component of all forest management programs. The data that provide information about the forest environment are collectively referred to as the forest database (Figure 29.12). The database contains numerical data that describe different attributes of the biotic and abiotic forest environment. The database can also include data on the condition of the atmosphere. Historically, forest landscapes have been organized for management purposes using a hierarchical system. For example on national forests in the United States, the basic unit of organization is the stand. Stands are aggregated into compartments. Compartments are combined to form a ranger district. Ranger districts are combined to form a national forest. Commercial timber companies use a similar system for private forest lands. The basic unit of forest management does not have to be the stand. Landscape management practices could, for example, use the boundaries of a watershed to delimit a management unit. Multiple watersheds could be clustered in manner analogous to the compartment configuration. However, the specific numerical data comprising the various themes of the database are associated with a basic management unit.

Because the forest database is complex, GIS and database management technologies are used to organize, integrate, and display information. Typical spatially referenced themes represented in the database include: a base map, vegetation types, forest tree inventory, terrain features, hydrography, road corridors, and so on. Very detailed data about the management unit can be stored in a separate database management system and accessed, manipulated, and displayed in the GIS. The forest database is used to store the results of monitoring and to guide management planning.

29.5.9. Management Planning

The goals of forest management vary among the different types of forest environments. The management plan (Figure 29.13) for a specific forest environment will be based on accomplishing defined goals. For example, the management plan for a commercial seed orchard would emphasize profitability. The details of the plan to achieve this end will include ways to maximize production of high quality seed that the customers require, while minimizing the costs associated with the operation. The management plan employed by a city government for an urban forest might emphasize scenic beauty as its management goal. The details of the plan to achieve this end would be substantially different from those used by the seed orchard manager. In the United States, the management goal for public forests is sustainability, while providing goods and services to citizens. The National Forest Management Act of 1976 (as amended) specifies this goal. How to achieve this goal is defined by the National Forest System Land and Resource Management Planning rule (as revised). The current rule describes the framework for National Forest System land and natural resource planning (Federal Register 2000). The principal goal for privately owned intensively managed forest properties is profit from the sales of goods and services. The plan to achieve this goal typically will emphasize ways to maximize growth and yield, minimize taxation liability, and minimize negative environmental impacts. The certification programs for sustainable forest management and legal statutes provide boundaries that constrain the management plan.

Pest insects are associated with all of the forest environments, and therefore, management plans must consider their impact. In production forests, insect consumers directly compete with humans for resources. IPM is the approach

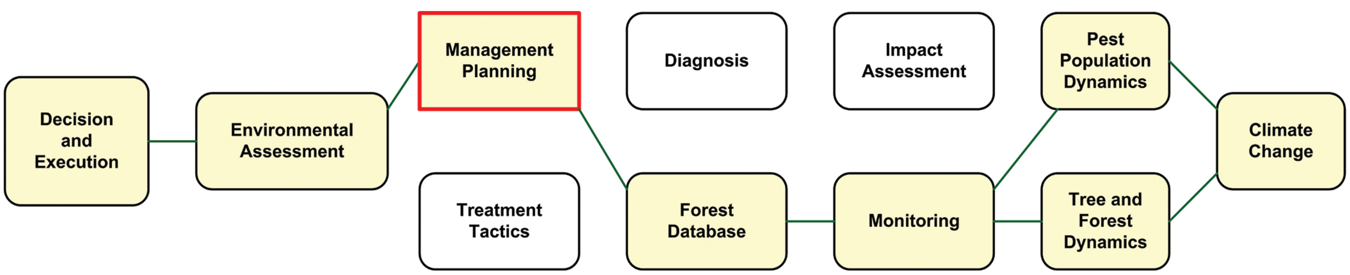

Figure 29.13—Dependency network for the Management Planning IPM activity.

used to deal with insect pests when they disrupt our planned uses of the forest environment.

29.5.10. Environmental Assessment

Environmental assessment (Figure 29.14) deals with evaluating change to the environment resulting from human actions. In the context of IPM, assessment centers on evaluating change in the environment resulting from suppression or prevention activities associated with forest protection. In particular, we are interested in the effects of proposed SPB IPM actions on the forest environment. The terms effect, impact, and consequence are used interchangeably.

In the United States, the substance of environmental assessment is defined by the National Environmental Policy Act of 1969 (as amended) (NEPA). This act requires that Federal agencies assess the environmental impact of implementing their major programs and actions. For projects or actions that are expected to have a significant effect on the quality of the environment, the responsible agency is required to file a formal environmental impact statement (EIS) (Jain and others 1993). The EIS is a substantial undertaking and involves the preparation of a document that addresses the following key issues for a proposed action (Jain and others 1993):

- The environmental impact of the proposed actions
- Any adverse environmental effects that cannot be avoided should the proposal be implemented
- The alternatives to proposed actions
- The relationship between local short-term uses of the environment and the maintenance of enhanced long-term productivity
- Any irreversible and irretrievable commitments of resources that would be involved in the proposed action should it be implemented

The environmental assessment activity follows from the selection of specific treatment tactics and consideration of the impact of the pest species on forest resources and conditions (Figure 29.14). The need for IPM actions is often a result of an SPB outbreak that was not anticipated or predicted. In these instances, it is difficult for the responsible Federal agency to develop an EIS and provide for protection of valued forest conditions or resources in a timely manner. This dilemma is one of the challenges of forest protection. Environmental assessment is a complex, costly, and slow process.

It is noteworthy that the initial models of IPM did not explicitly address the issue of environmental assessment. This activity is a key component of the contemporary view of IPM that is addressed formally for public lands through the NEPA–EIS mechanism. It is dealt with directly on private forest lands through the sustainable forestry certification programs and specific environmental statutes.

29.5.11. Decision and Execution

The final component of the IPM activities model is decision and execution (Figure 29.15). This activity involves both judgment and directed action. The issues associated with these two components are quite different, and we discuss each in turn.

The judgment (decision) component of IPM is an integrative step. To reach this position in the IPM model, we have had to participate in 10 other activities (see Figure 29.15). The data and information that form the knowledge base for a specific forest management problem involving pest insects and diseases often come from several different domain specialties

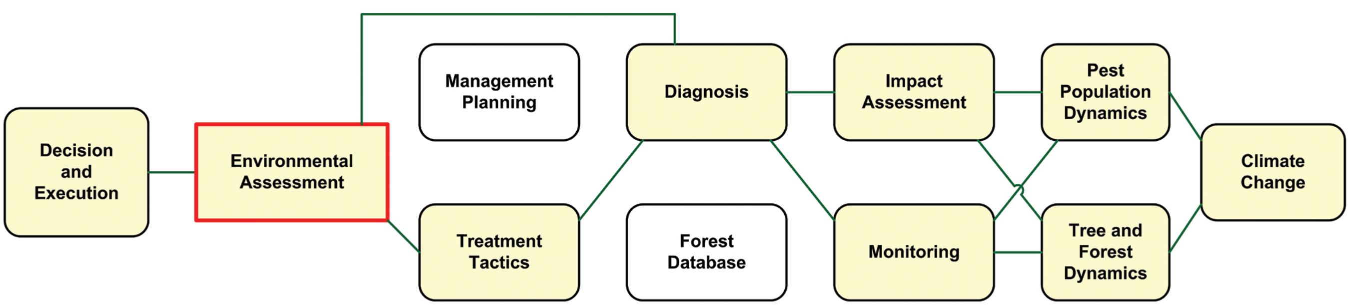

Figure 29.14—Dependency network for the Environmental Assessment IPM activity.

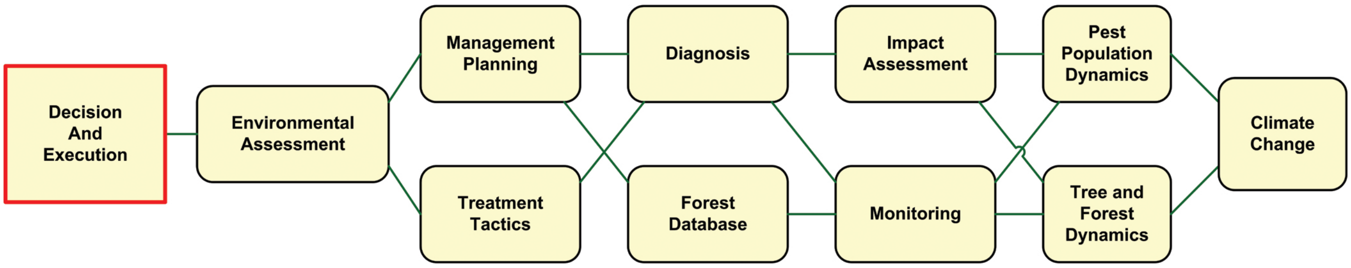

Figure 29.15—Dependency network for the Decision and Execution IPM activity.

such as entomology, forestry, ecology, geography, sociology, and economics. The knowledge base can exist in several forms: 1. tabular information, usually stored in a database management system; 2. spatially referenced data themes, usually associated with a geographic information system; 3. numerical output from simulation models and mathematical evaluation functions; 4. unstructured paper and hypertext documents; and 5. heuristics of experts based on corporate experiences of humans (Coulson and others 1996a). Given this complexity, integrative computer-based technologies have been used to aid in supporting the decisionmaking process of the forest manager (Coulson and Saunders 1987). A variety of approaches have been employed, and Schmoldt (2001) reviews applications developed specifically for insects and diseases; e.g., Potter and others 2000 - (gypsy moth), Power and Saarenmaa (1995) - eastern hemlock looper, Reynolds and Holsten (1996) - spruce beetle. Synthesis for planning, problem-solving, and decisionmaking support involves the use of both qualitative and quantitative information. It is a challenging task that is the focus of considerable ongoing research and development.

The directed action (execution) component of IPM involves application of one or more of the tactics available for pest population suppression or prevention of damage. The arsenal of weapons includes chemical pesticides, biological control with natural enemies, mechanical or physical methods (e.g., trapping, habitat destruction), silvicultural practices, and regulatory (legal) procedures (e.g., quarantines). These actions can be combined to form a strategy for protection that can be integrated into the forest management plan. In some instances, the evaluation phase may suggest that the best response to the pest activity is no action. For example, the cost of an insecticide application may exceed the value of the trees in the forest stand, or the environmental impact may be greater than desirable.

29.6. THE RESEARCH, DEVELOPMENT, AND APPLICATIONS AGENDA FOR SOUTHERN PINE BEETLE INTEGRATED PEST MANAGEMENT

The SPB persists in causing catastrophic economic, social, and ecological impacts across the South. The existing knowledge base for the insect is inadequate to explain the causes for epidemics or provide insight into how they can be managed. Outbreaks cycle within the southern region, and we cannot anticipate when or where they will occur or predict their severity. Consequently, when outbreaks do occur the effects on forest health are devastating. Because of the persistent impact of the SPB on public and private forests throughout the South, this insect is a specific target of the Healthy Forests Initiative and the Healthy Forests Restoration Act, which President George W. Bush signed into law on December 3, 2003. The IPM concept, presented above, is generally acknowledged to be the framework for addressing the depredations caused by the insect.

Managing the impact of the SPB within tolerable limits is a realistic expectation that can be accomplished through a focused research, development, and applications (RD&A) program. To this end, representatives from the Southern State Agricultural Experiment Stations, USDA Forest Service, State Forestry Agencies, and technical specialists from the research community participated in a workshop (held in Mountain Lake, VA, August 11-14, 2003) to define in detail the agenda for an SPB RD&A program and to develop a plan for implementing the RD&A program. The organizing theme for the RD&A program was Integrated Pest Management (IPM) (Coulson 2003). The workshop resulted in the following conclusions:

- The persistent impact of the SPB on public and private forests throughout the South places this destructive pest species at the forefront of the Healthy Forest Initiative. The Healthy Forestry Restoration Act provides the means for addressing the depredations caused by the insect through a comprehensive RD&A program directed to SPB IPM.
- The significant economic, ecological, and social impact of the SPB on the forests resources of the South can be reduced and losses caused by the insect managed within tolerable limits. However, the current knowledge base for the insect is inadequate, and significant new technologies are not being used in the context of contemporary forest and environmental management practices. A substantial and targeted RD&A program will address these issues.
- The IPM concept and methodology provides a framework suitable for structuring an SPB RD&A program that will lead to clearly defined products and procedures needed to reduce economic, ecological, and social impacts.
- Participants in the SPB workshop (scientists, practitioners, and technical specialists from State, Federal, and private agencies and organizations) critically and systematically examined and defined the agenda needed for an SPB RD&A program organized around the IPM approach. This activity resulted in the four products reported in this proceedings: 1. an evaluation of each of the 10 IPM activities, 2. a definition of RD&A questions for each activity, 3. a prioritization of the RD&A activities, and 4. a list of deliverable products that will follow from an SPB IPM program. These products provide an objective and consensus-based agenda for the RD&A program (Adams and others 2003).
- The technical expertise needed to conduct an SPB RD&A program is dispersed among a variety of State, Federal, and private agencies and organizations. A centrally organized and specifically targeted RD&A program will provide the mechanism needed to coordinate and focus human resources needed to address IPM of the SPB.
- There is solidarity among the scientists, practitioners, and technical specialists from the various agencies and organizations in State, Federal, and private sectors regarding the need for a centralized RD&A program to address SPB IPM. Participants in the SPB workshop acknowledged that implementation of a program could be accomplished using a model that includes a high degree of coordination and peer-reviewed evaluation.
- The agenda for the IPM program involved a blend of priorities distributed among research (38 percent), development (40 percent), and application (22 percent) (Table 29.1).

Table 29.1—The priorities for the SPB IPM program involve a blend of activities associated with research, development, and applications

Proportion of effort needed in the SPB RD&A Program		
Research	Acquisition of new knowledge	38%
Development	Integration and interpretation of new and existing knowledge	40%
Application	Use of knowledge for planning, problem solving, decision support	22%