HAZARD RATING FOREST STANDS FOR GYPSY MOTH[1]

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ABSTRACT

A gypsy moth hazard exists when forest conditions prevail that are conducive to extensive damage from gypsy moth. Combining forest hazard rating with information on insect population trends provides the basis for predicting the probability (risk) of an event occurring. The likelihood of defoliation is termed susceptibility and the probability of damage (mortality, growth loss, reduced aesthetics, etc.) is called vulnerability. Hazard rating systems are usually developed by making empirical observations of forest stands that are exposed to a gypsy moth outbreak and formulating a prediction model that can be used to estimate susceptibility and/or vulnerability of other stands.

The value of hazard rating is in forecasting where the problem is likely to be most severe and how severe it is likely to be. Using this information, forest managers can target gypsy moth population monitoring in stands that have high hazard and high value. When potentially damaging population levels are detected, the manager can then deploy one of several intervention strategies in the appropriate stands.

INTRODUCTION

The term hazard is given several definitions in the dictionary, but the one which most closely approximates my use of the word in pest management is "something causing danger, risk, or peril". Risk can be further defined as "the degree of probability of loss". Thus hazard rating helps establish conditions where a damaging event is most likely to occur and how extensive the damage is likely to be (Hicks and others 1987). Risk assigns a probability to these likelihoods and is determined by the dynamic relationship between forest conditions and insect population levels. For example, a high hazard can exist in combination with a low risk when insect populations are absent or low. This situation is particularly appropriate to an introduced pest like gypsy moth as it moves into previously unexposed areas.

When a defoliator like gypsy moth consumes the leaves of a tree, the direct effect is a lowered amount of total photosynthesis for the tree, thus less carbohydrate is available for metabolism and storage. Heavy defoliations trigger a refoliation response of trees which further depletes starch reserves from the roots. This physiological stress results in lowered vigor. Multiple years of defoliation tend to compound the problem and defoliation coupled with any other stresses that are normally experienced by trees (drought, heat, cold, shade) often predisposes trees to attack by secondary organisms such as two-lined chestnut borer and *Armillaria* root disease. Either of these organisms directly causes tree mortality (Fig. 1). Because defoliation *per se* doesn't directly cause tree death and because not all trees are equally likely to be defoliated or to die, hazard rating systems to predict "susceptibility" (likelihood of defoliation) and "vulnerability" (likelihood of death or damage) to gypsy moth have been developed (Campbell and Standaert 1974; Valentine and Houston 1979; Herrick and others 1979).

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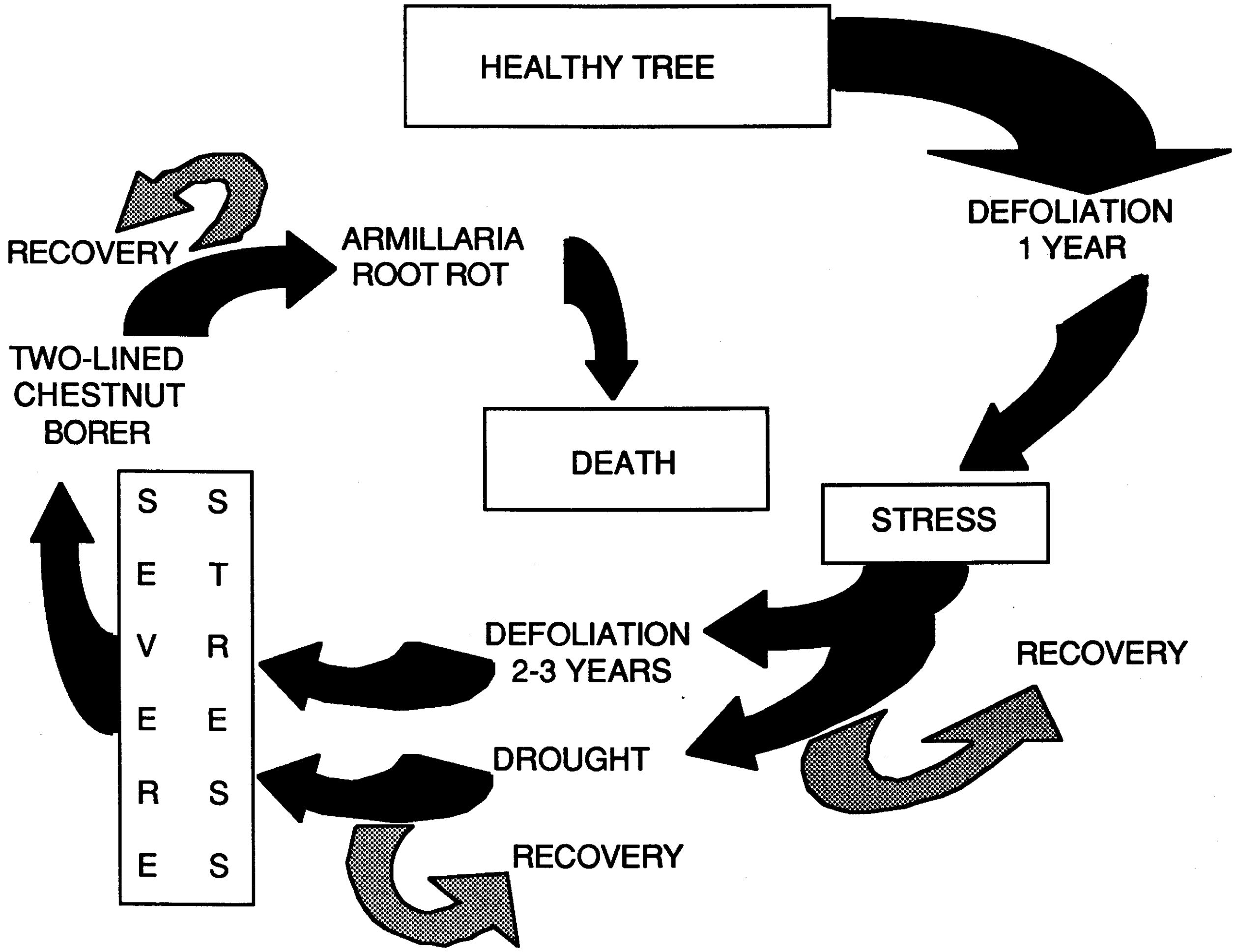

Figure 1. Mortality spiral for trees defoliated by gypsy moth (after Manion 1981).

Insect hazard rating is widely promoted among researchers as a means of targeting activities such as survey and detection, intervention and insect suppression. Unfortunately, many forest managers are slow to implement insect hazard rating as a normal component of their management activities, even though hazard rating systems are available that require standard inventory data, and in some cases have been integrated into total management packages such as SILVAH (Marquis and others 1984). It is the purpose of this paper to develop an appreciation for and an understanding of gypsy moth hazard rating and to illustrate how it can be used in an integrated forest management program.[1]

Developing a Hazard Rating System

Researchers attempting to understand the functioning of natural systems usually have some sort of conceptual model of the system. In the case of gypsy moth hazard rating for vulnerability, that model might be expressed as: Gypsy moth defoliation results in stress to trees which in turn predisposes them to secondary mortality agents; the magnitude of stress can be quantified using measurable variables.

[1]For more on hazard-rating terminology, see "The Revelation" that follows the conclusion of this paper.

Jeffers (1982) refers to this as a "word model". He further discusses "diagram models" which help to organize the problem into a structured form. I have adapted Manion's (1981) "disease spiral" to this purpose (Fig. 1). A primary purpose of modelling is predictions,in this case to forecast hazard or risk of an event happening. Thus to facilitate prediction, some type of quantitative model is required. The dependent variable is some measure of hazard or risk and the independent variables are measures of the state of the system. For example, if we assume that a stressed tree is more susceptible to mortality than a healthy tree, the independent variables we choose should be those that directly or indirectly affect or measure the impact of stress. The variables measured should also be things that are measurable and precise. For example, xylem moisture potential may meet the criterion of being indicative of stress and may be measurable at any point in time, but due to the dynamic fluctuations of tree water balance, it may change drastically in a short period of time and therefore would not be a useful variable for hazard rating. Soil moisture or monthly rainfall, although not direct measures of drought stress would be related to potential for drought stress and could be more useful than the direct measure of xylem water potential.

Once a list of dependent and predictor (independent) variables has been selected, a sampling scheme must be developed. No matter how conscientious one is about sampling, at best only a very small proportion of the total area can realistically be sampled. For example, our study of gypsy moth mortality involves some 400 tenth-acre plots in southwestern Pennsylvania, western Maryland and eastern West Virginia (roughly a circle containing 5 million acres). That works out to about one acre sampled per one hundred twenty thousand acres or a sampling intensity of 0.0008%.

The population of samples should include plots representing the principal forest cover types and sites and should include both defoliated and undefoliated forests. In our study we divided the sample plots roughly evenly between the Appalachian Plateau and Ridge and Valley physiographic provinces since these provinces represent clearly different environments (forest types, soils, geology and climate). It is also important to accurately record the defoliation history of plots since stands receiving different levels of defoliation would be expected to respond differently even when other factors are equal. After a sufficient post-defoliation time period has elapsed for the effects of defoliation to be manifested, tree mortality, growth, development of understory, etc. should be assessed. These are the dependent variables to use in subsequent analyses.

The final step in the model development process is the generation of a mathematical model. Since such sample data generally contain a good deal of variation, the appropriate technique is one which produces a "best fit". Examples are multiple regression and stepwise discriminant analysis. The goal of a model is prediction. In the case of hazard prediction, it can be accomplished as the classification (or probability of classification) of individual trees in a particular state (e.g. dead v. alive). Discriminant analysis or logistic regression are useful techniques for accomplishing this (Valentine and Houston 1979). Predicting hazard for a stand of trees in terms of such dependent variables as number of dead trees or percent dead basal area, etc. can be accomplished by using multiple regression or automatic interaction detection (Herrick and others 1979).

Testing and validation is an often overlooked aspect of model development. Certain techniques can be employed using the sample data. For example, an independent data set can be withheld from the analysis (regression, etc.) and the model developed from the other data can be applied to the independent set to see how well the model predicts. Another statistical validation technique which allows the use of the whole data set for model development is the leave-one-out method. Each observation (plot, stand, tree) is systematically excluded from the data set. The model is developed using all the others and tested against the one left out. These statistical procedures are useful as far as they go, but the true test of a model is whether or not it will work on other stands, in other environments and at other times. Such validation is an on-going and necessary process to determine where, when and if a model provides acceptably reliable predictions.

Applying Hazard Rating.

Hazard rating is a component of integrated pest management and IPM is a component of forest resource management. All too often, the tendency to become specialized makes us myopic and so it is with forest pest managers. Although outbreaks of forest pests like gypsy moth become the proverbial "tail that wags the dog" it is still necessary for pest management to be kept in perspective as a component of forest resource management. Figure 2 is a diagram from Gansner and others (1987) outlining an example of how IPM decisions are made. Hazard rating is a key element in this process which enables the manager to target many of the subsequent activities.

Application of hazard rating, as with all forest management, requires knowledge about the forest. The fundamental unit of management is the stand. Once stands have been delineated, data needed for hazard rating can be collected. In many cases the data needed for hazard rating are the same as needed for other facets of forest management (e. g. tree species, site quality, tree size, crown condition, etc.). Programs like SILVAH (Marquis and others 1984) may facilitate stand data collection and processing.

We have been engaged in gypsy moth hazard rating at the West Virginia University (WVU) Forest during the last year and this experience has been helpful in identifying some of the problems of hazard rating. We selected two compartments at the WVU Forest, each of approximately 450 acres (Fig. 3). Stands were located from point samples taken on a 1 x 2 chain grid using a 10 BAF prism. We used the Society of American Foresters cover type designations and descriptions to define the cover types and set a minimum of 10 acres for stand size (smaller stands became inclusions in surrounding stands). The stands identified in these two compartments are indicated in Figure 3. An interesting adjunct to this is the fact that using student labor, the cost of stand mapping and collection of stand data for the two compartments was accomplished at about $1.15 per acre.

We applied several hazard rating equations and methods to the stand data. Table 1 compares the results of these ratings for Compartment 4 of the West Block. The most striking aspect to these numbers is how much they differ, both in magnitude and in relative terms. For example, the equation of Gansner and Herrick (1984) produced very low estimates of percent mortality. Looking at their equation it is apparent that percentage of trees with poor crowns (> 50% dead limbs) is the most important driving variable for predicting mortality. Trees with poor crowns are manifesting pre-existing stress and defoliation simply adds to the stress state of the tree until some threshold is exceeded that allows secondary agents to gain a foothold. Since Gansner and Herrick's sample data were collected from the Pocono Mt. region of Pennsylvania, it is easy to visualize how trees may be under stress in this droughty and poor site region. However, at the WVU Forest where annual rainfall averages about 55 inches and oak site index averages around 72 ft., it is not surprising that the percentage of trees showing poor crowns is generally below 5%. The question is; Does Gansner and Herrick's equation accurately project the rate of mortality that might be expected due to 3 years of heavy defoliation at the WVU Forest? My guess is that it doesn't because we have observed very high levels of mortality in stands that were similar to those at the WVU Forest after heavy defoliation. In-other-words, pre-existing stress may hasten the mortality of trees, but the stress threshold for secondary organism attack can be achieved by defoliation alone. Looking farther at Table 1 reveals that the equation of Crow (1985) gives predicted mortality rates of 20-30%, which is fairly consistent with average rates of mortality we have observed in the Ridge and Valley and Appalachian Plateau of western Pennsylvania and Maryland. However a stand mapped as northern red oak type had a lower projected rate of mortality than one mapped as Yellow-poplar-red oak-white oak. When examining Crow's equation, it can be seen that presence of oaks in the white oak group tends to increase the projected rate of mortality while oaks other than white oaks tend to decrease it. To appreciate how this occurred, one must look at the data base from which Crow's equation was derived. All his stands were from the Ridge and Valley region of eastern West Virginia and were essentially pure oak stands. Thus among the oaks, the trees in the white oak group were most vulnerable.

Table 1. Stand data and hazard rating for stands in Compartment 4, Western Block of the WVU Forest.

STAND	S.A.F. COVER TYPE		OAK S.I.	B.A. OF OAK.
1	55	(NRO)	78	67.2
2	44	(CO)	63	76.2
3	44	(CO)	68	65.1
4	28	(BC/M)	75	20.4
5	59	(YP/WO/RO)	80	25.8

SUSCEPTIBILITY RATINGS

STAND	HOUSTON/ VALENTINE DEFOLIATION	GANSNER, ET AL POTENTIAL DEFOLIATION	GANSNER, ET AL PROJECTED 1990 DEFOLIATION
1	resistant	24%	20% approx
2	"	24	"
3	"	24	"
4	"	9	"
5	"	9	"

VULNERABILITY RATINGS

STAND	REGRESSION GANSNER/HERRICK (# of trees)	A.I.D. GANSNER/HERRICK (# of trees)	CROW (B.A.)
1	3.54%	4.07%	29.2%
2	4.62	--	21.8
3	3.87	4.29	20.0
4	3.50	--	32.1
5	3.50	--	35.6

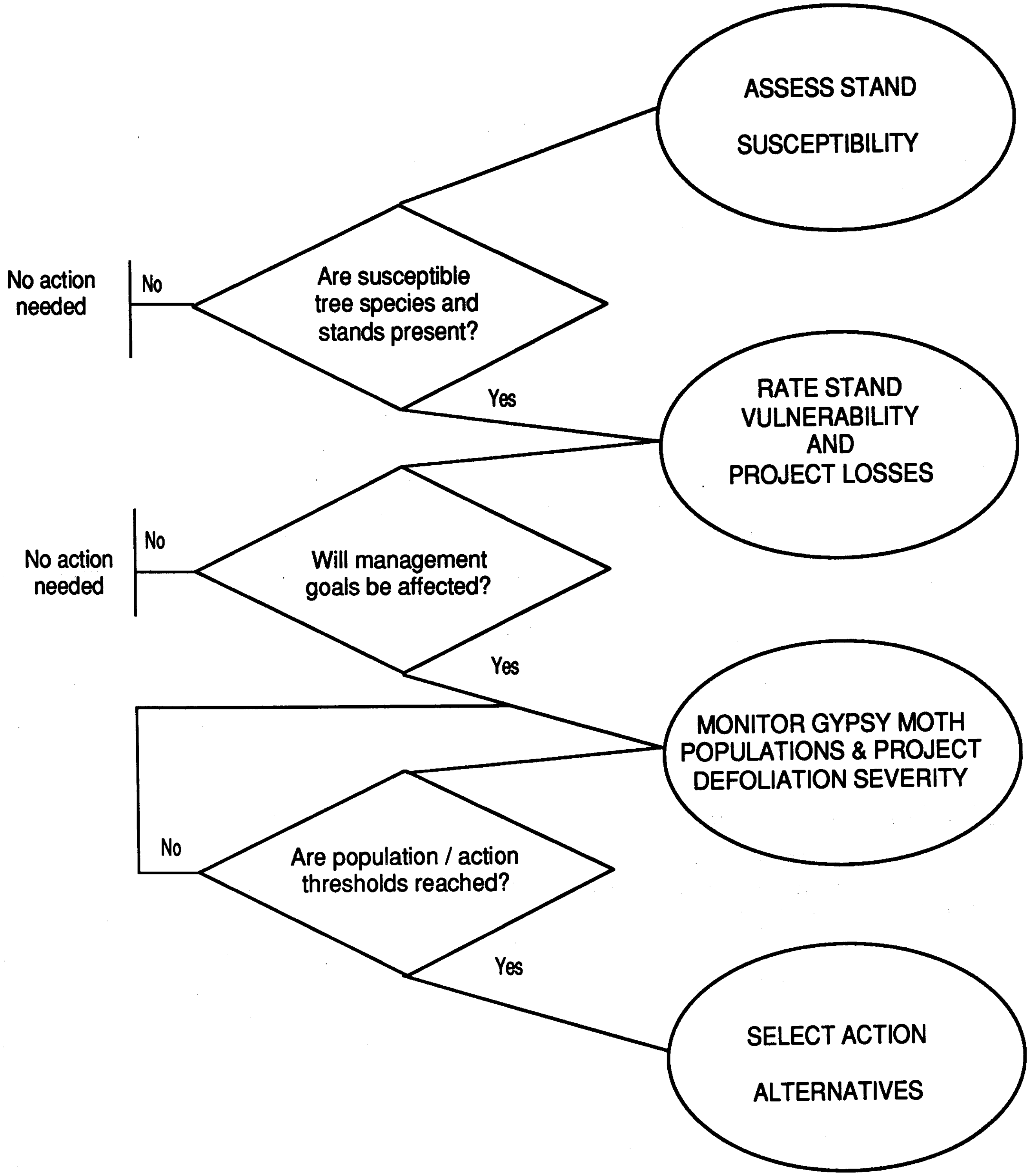

Figure 2. Flow chart of decisions for integrated pest management (from Gansner and others 1987).

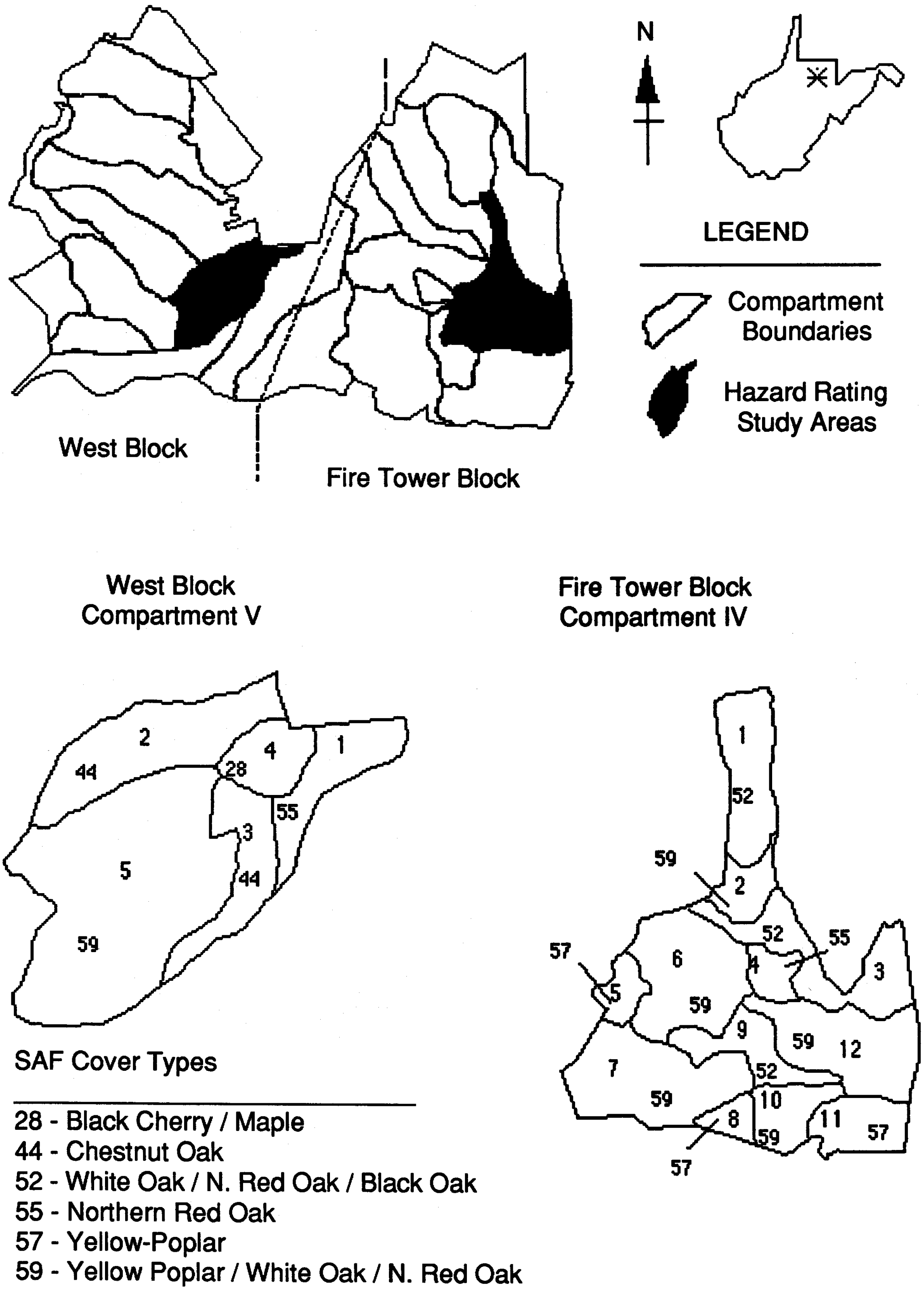

Figure 3. Study sites at the WVU Forest.

The point of all this is that one should be very careful to use hazard rating equations that were developed under conditions similar to those where they are being applied.

A final note concerning the application of IPM and hazard rating concerns the timing of these actions. IPM is not a good system to employ during "crisis management". That is to say, IPM should be an on-going component of resource management and should be implemented to give adequate time to use long-term preventative measures such as silvicultural control. The aim is to prevent the need for crisis management, a situation where forest management is subjugated to gypsy moth and not the landowners objectives.

CONCLUSIONS

Hazard rating is a component of integrated pest management, which in turn is a component of integrated resource management. This paper discusses the relationships of hazard rating to IPM and resource management. Methods of developing hazard rating systems are discussed and further discussions elaborate on the application of hazard rating within the context of resource management. Through the course of these discussions a number of needs have been identified or implied. These needs are as follows:

• Data incorporated in hazard rating systems should, to the extent possible, be standard forest inventory data so that special data collection is avoided.

• Hazard rating and IPM should be included as a normal component of forest management.

• Hazard rating should be applied at the stand level, but may also be applied at the landscape level. In both these applications, use of geographic information systems (GIS) will facilitate application and integration into management.

• Hazard rating equations must be applied only to appropriate areas with similar climatic, site and forest cover types to the conditions under which the models were developed.

• Hazard rating equations need to be validated by comparing predicted with actual susceptibility and vulnerability. This validation process should lead to updating and revision of equations to improve predictability.

Finally, several extensive reviews of insect hazard rating have been published recently. An overview of hazard rating was supplied by Hedden (1981) as a part of a conference devoted to the subject. Mason (1987) and Hicks and Fosbroke (1987) reviewed hazard rating in the proceedings of a conference dealing with gypsy moth. Hicks and others (1987) reviewed hazard rating and compared its application to gypsy moth and southern pine beetle. These and other references are useful in orienting managers to the subject of insect hazard rating.

LITERATURE CITED

Campbell, R. W. and Standaert, J. P. 1974. Forecasting defoliation by gypsy moth in oak stands. USDA For. Serv. Res. Note NE-193. 7 p.

Crow, G. R. 1985. Factors influencing tree mortality in mixed-oak stands following spring insect defoliation. M.S. Thesis, West Virginia University, Morgantown, WV. 128 p.

Gansner, D. A. and Herrick, O. W. 1984. Guides for estimating forest stand losses to gypsy moth. North. J. Appl. For. 1: 21-23.

Gansner, D. A., Herrick, O. W., Mason, G. N. and Gottschalk, K. W. 1987. Coping with the gypsy moth on the new frontiers of infestation. South. J. Appl. For. 11 (4): 201-209.

Hedden, R. L. 1981. Hazard-rating systems development and validation : an overview. in Hazard Rating Systems in Forest Insect Pest Management : Symposium Proceedings. USDA Forest Serv. Gen. Tech. Rep. WO-27. 8-11.

Herrick, O. W., Gansner, D. A. and DeBald, P. S. 1989. Predicting forest stand losses from the gypsy moth: an application of automatic interaction detection (AID). J. For. 77 (2): 91-94.

Hicks, R. R., Jr. and Fosbroke, D. E. 1987. Stand vulnerability: Can gypsy moth damage be predicted? *In* Proc. Coping with the Gypsy Moth in the New Frontier. West Virginia Univ. Books. 73-80.

Hicks, R. R., Jr., Coster, J. E., and Mason, G. N. 1987. Forest insect hazard rating. J. For. 85(10): 20-25.

Jeffers, J. N. R. 1982. Outline Studies in Ecology (Modelling). Chapman and Hall, N.Y. 80 pp.

Manion, P. D. Tree Disease Concepts. Prentice Hall, Englewood, Cliffs, NJ.

Marquis, D. A., Ernst, R. L. and Stout, S.L. 1984. Prescribing silvicultural treatments in hardwood stands of the Alleghenies. USDA, Forest Serv. Northeastern Station, Gen. Tech. Rept. NE-96. 89 pp.

Mason, G. N. 1987. Rating stand susceptibility to gypsy moth defoliation. *In* Proc. Coping With the Gypsy Moth in the New Frontier, West Virginia Univ. Books. 65-72.

Valentine, H. T. and Houston, D. R. 1979. A discriminant function for identifying mixed-oak stand susceptibility to gypsy moth defoliation. For. Sci. 25(3):468-474.