

Pest Vulnerability Matrix (PVM): A graphic model for assessing the interaction between tree species diversity and urban forest susceptibility to insects and diseases

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Abstract

The limited tree diversity in urban areas increases the likelihood of mass mortality from outbreaks of insects and disease. Although information is available on pest susceptibility of individual tree species, it is difficult to determine from such data the vulnerability of a multi-species assemblage, such as an urban forest, to insects and diseases, or to assess the effects of either changing the tree species composition or the arrival of new pests. Our model, the Pest Vulnerability Matrix (PVM), enables municipal arborists and urban foresters to evaluate the overall vulnerability of their urban forest, to display this information and communicate it to others, and to evaluate the potential effects of emerging pests and diseases. PVM is a Microsoft Excel spreadsheet that provides a means for rapid graphic display of the interaction between tree species diversity and the susceptibility of the urban forest to pests by displaying each tree–pest interaction as a colored cell in a table. PVM calculates the percentage of trees affected by each insect or disease, and enables the urban forester to quickly identify (1) the most important pests and (2) the most vulnerable tree species. The model is designed to be flexible and easily modified by the user, and includes several newly emerging pests to allow the exploration of future “worst-case” scenarios. Two case studies of Northern California cities are presented demonstrating two potential applications of PVM. We conclude with a brief overview of the diversity–stability debate in the context of urban forests.

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Introduction

The limited species diversity of trees in many cities and suburbs, often caused by the dominance of a few tree species in the overall tree community, remains a persistent challenge in the practice of urban forestry.

Ecologists define diversity as comprising both the count of species (species richness), and the distribution of individuals among the species (‘equitability’ or ‘evenness’), so both the number of tree species and commonness/rarity of the individuals of each tree species must be known if we wish to estimate urban forest diversity (Begon et al., 1996). Another factor that must be considered is the spatial scale (citywide, neighborhood, or street-level), and Sanders (1978) and Sun (1992) provide helpful overviews and examples of diversity

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calculations at different scales. In addition, the spatial arrangement and age distribution of trees are additional aspects of urban forest composition that can be evaluated in the context of diversity. Interestingly, the overall species richness of urban trees is often greater than that of the pre-settlement vegetation (McBride and Jacobs, 1979). It is the equitability, i.e. distribution of individuals among the species, which is often a problem in urban areas and contributes to a lower diversity. For example, there is now a worldwide prevalence of London planetree (*Platanus × acerifolia*) as a street tree, sometimes to the almost complete exclusion of other species (e.g. Lawrence, 2006).

Tree species diversity in urban areas is a function of many factors, including the local climate, site history, the autochthonous pre-urban vegetation (McBride and Jacobs, 1979), and the economic and social environment (Hope et al., 2003). It is notable that many urban micro-environments (e.g. streets) are generally unfavorable to trees, and the number of different tree species that consistently survive and grow in congested urban areas remains limited (Sanders, 1978, 1981). Furthermore, when the site-specific factors are considered, such as the size of planting space, tree cost and availability in local nurseries, and current societal preferences (e.g. in North America, a preference for flowering trees without allergenic pollen), the list of potential trees to be used in future plantings shrinks even further. Thus, the limited species diversity of today's urban forests has a good chance of persisting into the future, as reflected in the dominance of a handful of tree species (*Platanus × acerifolia*, *Pyrus calleryana* Decne cultivars, *Pistacia chinensis* Bunge) in the newly constructed (<10 years ago) residential subdivisions in central California (USA, personal observation).

From a practical management perspective, the principal negative effect of a single-tree species dominance is the possibility of severe mortality from outbreaks of pests (insects and diseases, often non-native) that are specific to that tree species (Sanders, 1978). A classic example of this problem was (and remains) the devastation of the American elm (*Ulmus americana* L.) and other susceptible elm species by the Dutch elm disease (DED, caused by the fungus *Ophiostoma novo-ulmi* Brasier). The result has been a dramatic and permanent change to the landscape of most of the cities and towns in the Northeastern and Midwestern United States where elms had been the “signature” urban tree that had defined the cityscape for the preceding 150 years (Campanella, 2003). The preponderance of elms was in part a result of historical factors, but was also the result of the elm's tolerance of difficult urban environments. The elm had developed a reputation as a “perfect” urban tree, especially when used as a street tree, and was thus planted widely to the near-exclusion of other tree species. Unfortunately, this attitude of seeking a “perfect urban tree”, and then relying on it

almost exclusively for urban plantings, continued even after the DED disaster (Bassuk, 1990), so that in some areas the dying elms were replaced largely by another single genus of trees: ash (*Fraxinus*; Poland and McCullogh, 2006). Thus, the current destruction of ash trees in some Midwestern states (USA), caused by the emerald ash borer (“EAB”, *Agilus planipennis* Fairmaire), is not entirely unexpected, and serves as a sad reminder of the very real dangers of relying on single-species urban and suburban plantings (for other examples, see Bassuk, 1990; Galvin, 1999). The popularity of ash trees in cities has resulted in enormous potential cost of removing these trees (if EAB were to spread further), which is now estimated at 20–60 billion US dollars (Poland and McCullogh, 2006), and this cost does not include the loss of environmental benefits provided by ash.

Conceptually, the importance of tree species composition in pest management can be illustrated with the “plant disease pyramid”, which applies also to pest insects. According to this model, four interacting elements are required to produce damage: (1) a suitable tree host (or the susceptible age/stage of development), (2) a pest (insect or pathogen), (3) appropriate environmental conditions, and (4) time for the three factors to interact. While all of these elements can to some extent be managed, the urban forester can most reliably control one of them – the presence or absence of the susceptible tree host – by selectively planting some tree species and avoiding others. This link between the low tree species diversity and pest outbreaks has been long recognized, and suggestions have been made about the best way to diversify the urban forest as a means of preventing catastrophic tree losses (see e.g. Sanders (1978), for an early example). In a recent article, Michael Raupp and colleagues (2006) provide a comprehensive review and critique of the various formulas for increasing urban tree diversity that were proposed over the years in North American literature. Perhaps the best-known of these diversity formulas was published by Santamour (1990), who discussed in detail the issue of urban tree diversity vis-à-vis pest problems, and offered practical advice in what has since become known as the “10–20–30” approach:

“For maximum protection against the ravages of “new” pests or outbreaks of “old” pests the urban forest should contain:

1. No more than 10% of any single tree species.
2. No more than 20% of species in any tree genus.
3. No more than 30% of species in any tree family.”

(Santamour, 1990, p. 64; see Galvin (1999) for an example of the application of the “10–20–30” formula).

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