# Upper Mississippi River System

# Floodplain Forest Habitat Model

June 2021

# 1 Model Background

## 1.1 Introduction

The floodplain forests of the Upper Mississippi River System (UMRS) is a valuable native wetland plant community that provides habitat for numerous wildlife species. At the landscape scale of the Upper Midwest Region, floodplain forests (also known as “bottomland forests” and “wooded swamps and floodplains”) are a rare and unique plant community, constituting a small portion of the overall regional landscape. There is growing concern among natural resource management agencies regarding forest loss at the landscape level (Urich et al., 2002; Johnson et al., 2008; Guyon et al., 2012; McCain et al., 2018), with floodplain forests being explicitly identified as high priority habitats of concern in management documents (e.g. the Upper Mississippi River National Wildlife and Fish Refuge 2019 Habitat Management Plan (USFWS 2019), the Upper Mississippi River Systemic Forest Stewardship Plan, and Corps of Engineers Master Plans for Natural Resource Management in St. Paul, Rock Island and St. Louis District). Floodplain forests provide critical stopover habitat for migrating birds, nesting habitat for avian species of concern (raptors, colonial water birds, neo-tropical songbirds) (Grettenberger 1991, Kirsch et al 2013) and roosting habitat for endangered bat species (Indiana and northern long-eared bats) (Carter 2010). Community composition and species distribution is influenced by slight changes in elevation, making these forest communities some of the most diverse plant communities on the UMRS. Maintaining this diversity is critical to maintaining the diversity of the wildlife species that utilize them.

## 1.2 Problem Statement

Currently, no specific habitat suitability index (HSI) model exists for floodplain forest habitat. Restoration projects on the UMRS currently use models associated with upland forest wildlife species. However, existing wildlife species models are predominantly built around species that utilize only one forest growth stage. As a result, current restoration projects in the UMRS often use multiple different models for a single forest restoration feature to capture benefits across different forest growth stages. In addition, the existing suite of models used to estimate forest-related benefits on the UMRS are not sensitive to habitat changes caused by traditional forestry measures, also called silviculture practices or forest management activities. Techniques such as thinning, tree planting (reforestation), and invasive species control are proven to improve forest health and habitat value, but the physical changes that these techniques create in forests are not easily captured within the variables measured in existing HSI models.

## 1.3 Model Purpose

The purpose of this model is to provide an evaluation tool that can accurately capture the habitat changes associated with routine silviculture practices and thus provide a tool capable of quantifying benefits resulting from these practices. The model was designed to be applicable across young, mature, and old forests (forest growth stage) found across the UMRS and can be used for all forest community types found in the UMRS including diverse forest communities and variable flooding regimes. The model will be used to evaluate the effectiveness of habitat restoration projects, comparing the habitat value gained from various alternatives involving forest management activities.

## 1.4 Model Summary

The model is intended to be used to evaluate the effects of forest management activities. The model variables are evaluated at the scale of "management areas:" a unit of relatively similar forest where one or more forest management measures will be applied. These management areas are often 5-100 acres, though smaller or larger size areas are acceptable. Forest management practices are often developed in the format of "silvicultural prescriptions" that direct contractors or staff to apply specific activities within management areas. Many of the variables in the model require the model user to develop averages or percentages from multiple samples (often in the form of forest inventory plots) in one management area to arrive at a single value for the variable for that evaluation unit.

The Floodplain Forest Model consists of five variables:

1. Percent Canopy Cover
2. Percent Desired Forest Type
3. Percent Invasive Species
4. Regeneration (Percent of Desired Stocking)
5. Structural Diversity

These five variables represent the quality and health of the floodplain forest and directly capture the results of typical forest management activities. These variables apply to all forest ages and forest community types. Each of the five model variables has an associated index on a scale of 0 to 1, consistent with typical HSI models, and will be discussed in more detail in Section 2.4.

### 1.5 Intent of this Document

This document serves several purposes:

1. Describe the process utilized to develop the floodplain forest model.
2. Describe the model variables and underlying science.
3. Provide a clear set of instructions for applying the model to restoration and mitigation projects.

This document also serves to provide the technical information required by EC 1105-2-412 (USACE, 2011). See the end of the document for a glossary of terms and acronyms.

## 2 Model Development Process

### 2.1 Model Development Workshops

On 9-10 June 2020, the team used an interactive and collaborative model development workshop to begin development of the floodplain forest model. Workshop participants included the MVD (Mississippi Valley Division) model development team, external stakeholders, and model development practitioners from the Corps' Engineering Research and Design Center (ERDC) and Ecosystem Restoration Planning Center of Expertise (ECO-PCX). The MVD model development team included both foresters and biologists from all three districts with management responsibility for the Mississippi River Project lands in the UMRS including staff from the Regional Planning and Environmental Division North (RPEDN) and the Mississippi River Natural Resource Management sections in MVP, MVR and MVS.

The model development workshop followed a common process of conceptualization (Section 2.2), quantification (Section 2.3), evaluation (Section 2.4) and application (Section 2.5) as outlined in pertinent literature (Grant and Swannack 2008, Swannack et al. 2012). A second workshop was held on 9 July 2020 with the MVD model development team and ECO-PCX to further refine the preliminary array of model variables.

### 2.2 Conceptual Model Development

<u>Conceptual Model Purpose</u>

- Conceptual models help guide ecosystem restoration planning and implementation at the earliest stages of the planning process and help describe the functional relationships between essential components of an ecosystem (Fischenich, 2008).
- Conceptual models inform the development of quantitative ecological models used in the assessment of environmental benefits of restoration (Grant and Swannack 2008, Swannack et al. 2012).
- This conceptual model emphasizes how proposed forest management actions impact the key components of floodplain forests in the Upper Mississippi River System (UMRS) and helped guide the model development team in selecting model variables.

<u>Description of the Conceptual Model</u>

- A seven-step model development process was followed (Fischenich 2008, Grant and Swannack 2008), drawing heavily from existing conceptual models addressing general floodplain forest successional processes (De Jager et al., 2019), UMR ecological resilience (Bouska et al., 2018), and alternate floodplain forest regimes (Bouska et al., 2020). Table 1 presents this generalized conceptual modeling process (i.e., Fischenich's 7-steps).

**Table 1.** Stepwise development of the detailed model used to guide the development of the floodplain forest model.

| Step | Floodplain Forest Model Application |
|---|---|
| 1. State the model objectives | This floodplain forest model provides the linkages between a variety of forest management techniques and desired forest condition. The conceptual model is intended as a tool for describing the basic structure of the numerical model within the development team and key stakeholders. |
| 2. Bound the system of interest | The floodplain forest model was developed with specific focus on the forest resources of the UMRS. A management area (typically 5-200 acres, though smaller and larger sizes are acceptable) is the spatial scale that represents the typical scale of a forest management action within the UMRS. Temporal scales of note include the 10-year management cycle under the UMR Systemic Forest Stewardship Plan, as well as the 50-year UMRR project planning horizon. |

| | |
|---|---|
| 3.Identify critical model components within the system of interest | Conceptual model components were compiled in a bottom-up format. First, ecological outcomes were derived from typical forest stewardship and UMRR objectives. Physical, chemical, and biological processes leading to these outcomes were then selected. Second, a suite of potential forest management actions were compiled from existing literature (Guyon et al., 2012). Finally, any redundant variables and model elements were removed. |
| 4. Articulate the relationships among the components of interest | The general flow and intent of the conceptual model was to illustrate the relationship of forest management actions to the ecological outcomes of interest. Model relationships were identified based on prior conceptual models (Bouska et al., 2018 and 2020) and best professional judgment of foresters and biologists familiar with forest management practices and biological responses. |
| 5. Represent the conceptual model | A box-and-arrow flow diagram of the conceptual model (Figure 1) was developed to describe relationships between forest management actions, ecological processes, model variables, and restoration outcomes. Some model elements were removed to simplify the diagram. To provide clarity of flow with relationships and connections of highest significance only the significant relationships are represented. |
| 6. Describe the expected pattern of model behavior | The model development team qualitatively assessed the flow of logic between model components, inviting key stakeholders to participate in these discussions. |
| 7. Test, review, and revise as needed | The model was informed by current views of forest management, developed by the model development team, and presented to key partners and stakeholders for input and revision. |

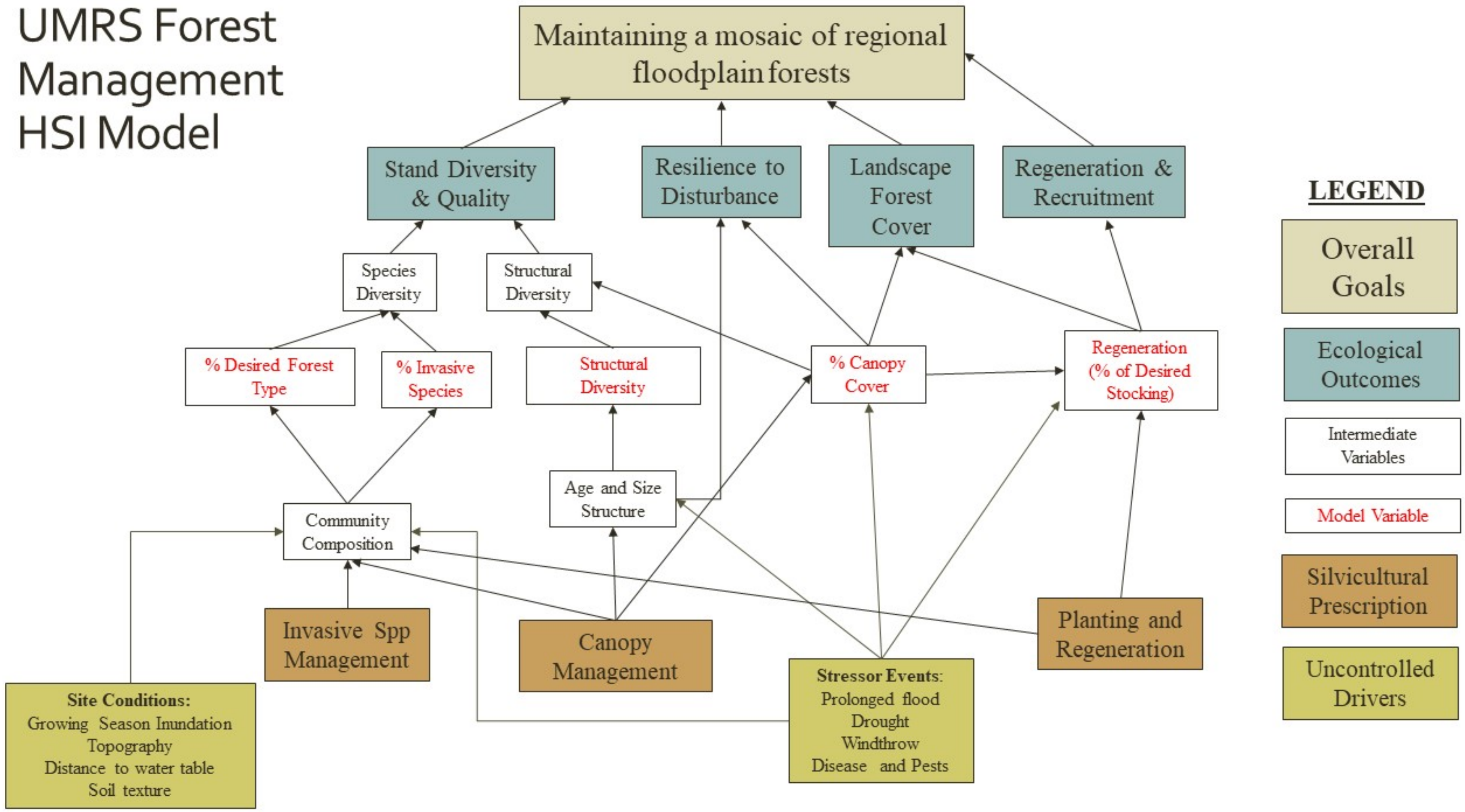



**Figure 1.** Upper Mississippi River System floodplain forest conceptual model. This conceptual model has been simplified to focus on key variables and interactions, and several other variables (regional climate differences, long-term climate change, proximity to water, topographic diversity, and management area density) have been removed.

### 2.3 Model Variable Development

During the June model development workshop, the team utilized a brainstorming approach to identify an initial array of potential model variables. A variety of variables were discussed, with consideration given to variable responsiveness to forest management techniques, variable overlap and interaction, and ease of measurement and application. Using the best professional judgment and scientific knowledge of participants, six variables were initially recommended for inclusion in the model (Section 2.4). Preliminary variable curves were developed, with the intent for refinement during a follow-on workshop, which occurred in July.

During the July workshop, the team revisited the initial array of six variables, worked to refine the variable curves and better define the boundaries of each variable. The team also decided that the sixth variable, biomass, was redundant, as other variables (canopy cover, regeneration, and structural diversity) likely already captured the important components that biomass represented. Thus, the team removed biomass from the final model.

### 2.4 Model Variables

***Variable 1: Percent Canopy Cover***

Percent Canopy Cover is defined as the average percent cover within a given management area and is calculated as the average percent canopy cover across all inventoried plots within the management area (e.g. stand, site, etc.). "Canopy cover refers to the proportion of the forest floor covered by the vertical projection of the tree crowns. Measurements of canopy cover assess the presence or absence of canopy vertically above a sample of points across an area of forest." (Jennings et al, 1999), see Figure 2. To determine canopy cover, delineate the management area using a standard protocol for the project or a standard agency protocol. Once a management area boundary is delineated, use forest inventory or other field collection of canopy cover to develop an average value for the area. All inventoried plots within the area should be included in the average, including any canopy gaps that could be forested, e.g. herbaceous cover, dead trees, or harvests. Users of this model should use a standard land cover mapping protocol for their regional area to account for any potential gaps in the canopy. For example, if the minimum mapping unit for an area is 5 acres, then an inventory plot that falls within an unforested inclusion within the forest management area would be assessed as 0 percent canopy and would be factored into the overall management area canopy cover score. Some portions of the area may not be inventoried because they are inclusions of water, marsh, or other landcover that would not support forest. These areas would not be included in the canopy cover average since there would be no inventory plots and thus no measurement of canopy cover for these portions of the management area.

The team discussed applying this variable at differing scales and determined that at the locally defined management area scale was appropriate and corresponded to the UMR Systemic Forest Stewardship Plan (Guyon et al. 2012). The team also discussed whether this variable should contain options for forests of differing age, as the percent cover desirable at different ages of forest may differ, and the variable curve could potentially be adjusted as a forest aged. However, the team determined that the difference in desirable cover across forest age likely was not significant enough to warrant inclusion in the variable. Canopy cover of 70-80% is optimal because it generally allows enough sunlight for some forest regeneration to establish, but not enough sunlight that invasive species are able to take hold. Canopy cover below 60% is generally an indication that the forest canopy is breaking up and forest is not fully occupying the management area, so the rapid decline below 70% is due to the fact that those levels are indicative of a forest in decline. Over 80% is less desirable because regeneration is unlikely to occur and individual tree growth is reduced due to competition with other trees.

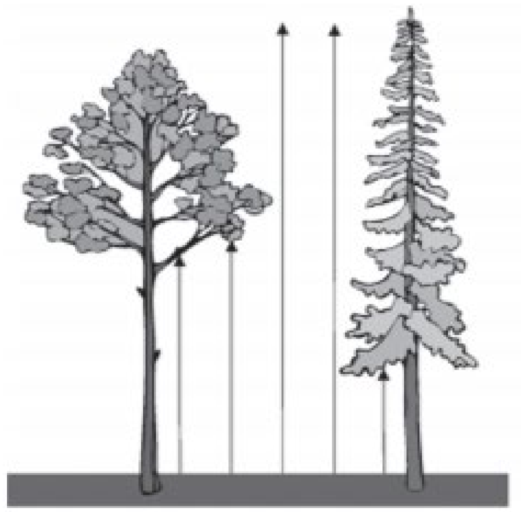


**Figure 2**: Canopy cover measures the area of a polygon covered by tree crowns, measured vertically. From: Korhonen et al, 2006.

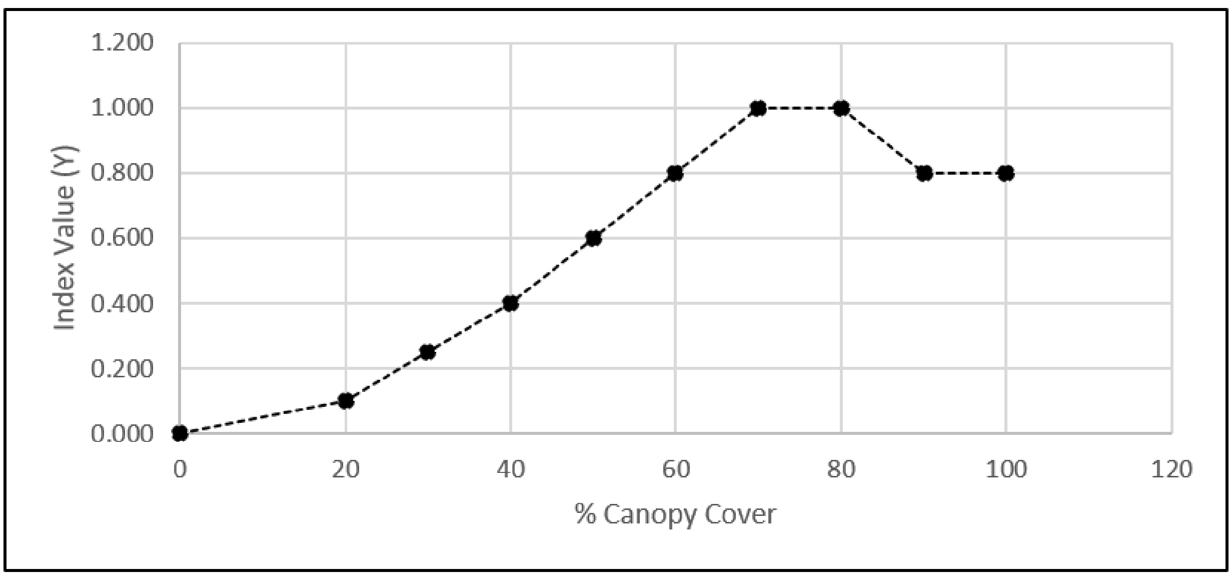



**Figure 3.** HSI curve for the percent canopy cover variable.

***Variable 2: Percent Desired Forest Type***

The percent desired forest type variable measures the differing value of various species compositions (Guyon et al., 2012; Kirsch and Wellik 2017). The percent desired forest type variable was defined as the percent composition of a forest management area made up desirable tree species. The relationship of percentage desired forest type to habitat value is a basic linear relationship, with a slight inflection toward the upper and lower ends. The relationship reflects that management areas with very low percentage of desired forest type will provide less habitat value, while management areas with at least 70% of the desired forest type approach optimal conditions. To utilize this variable, the desired percent forest type should be determined at each project management area based on the existing forest community type, local area conditions (i.e. forest composition potential), and management goals. The desired forest type requires a balance between the site potential as determine by factors such as flood regime, substrate, landform, and past land use and the management goals for the site, such as habitat for wildlife species, forest diversity and interspersion, or other habitat objectives. Forest community types and desirable species could be based on summaries produced by the Corps' Forest Management Geodatabase (FMG) or other native plant community classification system. The percentage of desirable species would be determined based on existing or projected forest community type as determined by inventory summaries of species composition compared to desired forest type.

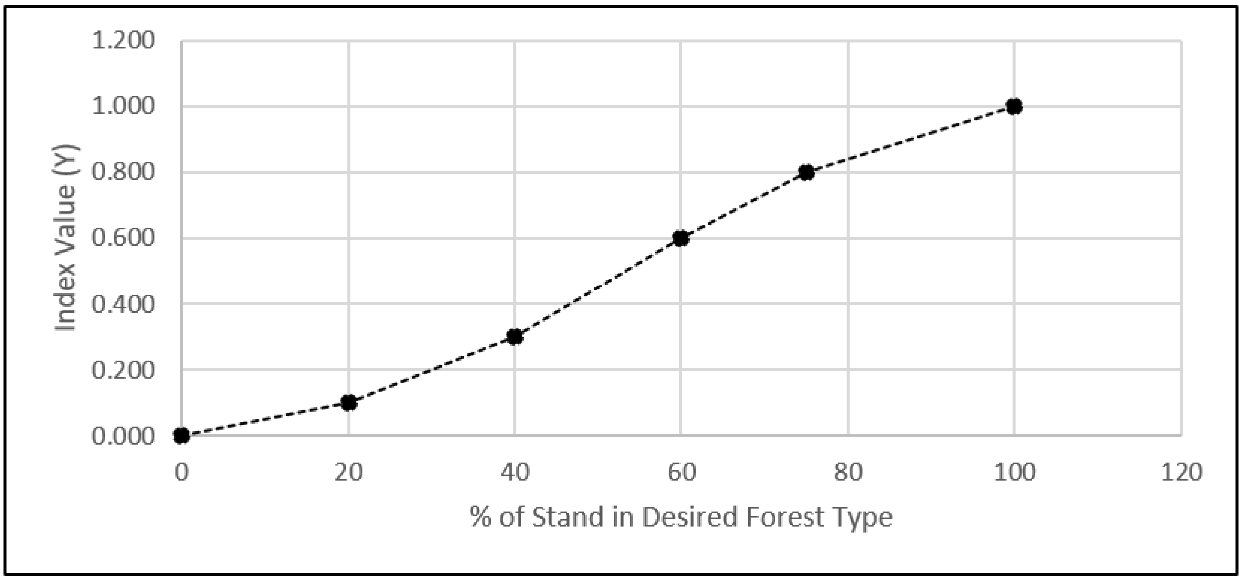



**Figure 4.** HSI curve for the percent desired forest type variable, which is based on the percentage of a management area containing the desired forest type.

***Variable 3: Percent Invasive Species***

This variable is intended to capture the percentage ground cover of existing invasive species present that inhibit the regeneration and development of desirable forest (Thomsen et al., 2012; Miller-Adamany et al., 2019). The relationship between invasive cover and forest regeneration is based on field observations that management areas with greater than 20% invasive cover fail to regenerate trees and eventually convert to non-native or non-forested cover types. The list of invasive species would be user defined, based on project conditions, and is not intended to be limited to non-native species. Some native species become invasive and inhibit forest development (e.g. stinging nettle, trumpet creeper, wild grape), and this variable is intended to capture such conditions. In addition, only invasive species that inhibit forest development should be included. Some non-native or invasive species may be present but do not inhibit forest development. This variable is intended to specifically address those species that inhibit desired regeneration and growth. A list of invasive species that currently inhibit forest regeneration in the UMR is included with the model under Section 8.0 but is not comprehensive. New invasive species may be found in the future, and this list is only for illustrative purposes.

Surveys may be required to quantify existing conditions for a given project under this variable, depending on the level of detail in existing inventory summaries (i.e. presence/absence may not provide enough detail to estimate ground cover). A rapid assessment approach could be utilized to inform this variable, where existing data is insufficient. However, the variable curve is relatively coarse, as invasive species are expected to be most detrimental at medium to high concentrations, with a rapid decrease of forest inhibition expected once the invasive composition drops below 20%. As a result, a high level of precision in invasive species data is not likely necessary.

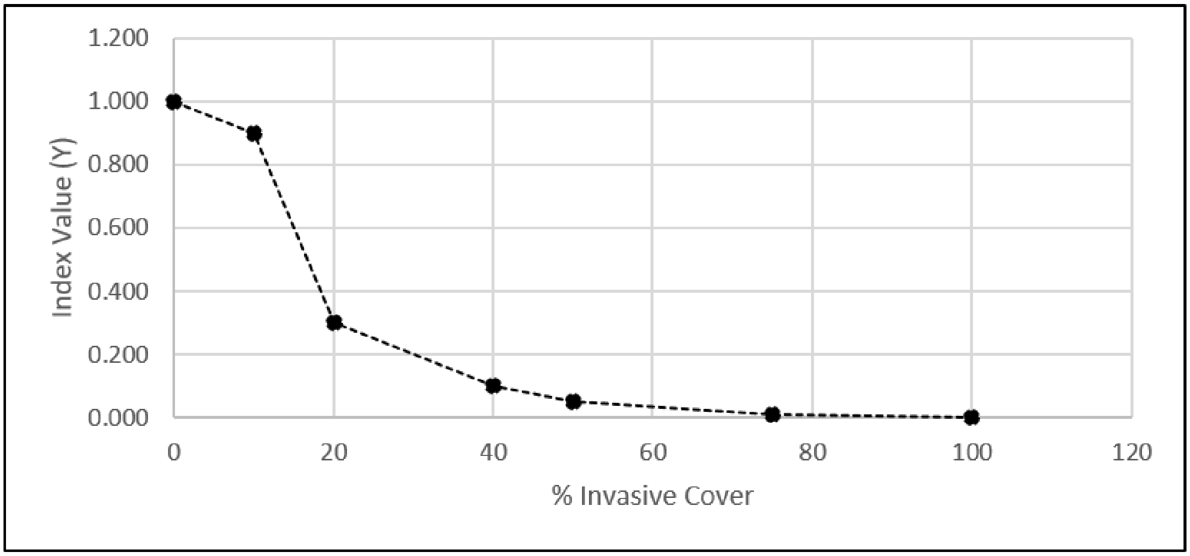



**Figure 5.** HSI curve for the Percent Invasive Species variable.

***Variable 4: Regeneration (Percent of Desired Stocking)***

This variable is intended to capture whether a given management area of forest is regenerating at a desirable rate. The model development team discussed whether a ranking system (low, medium, high) or a more precise quantification (stems per acre) was appropriate. The team determined that the stems per acre approach seemed appropriate, and would align with extrapolations of existing stocking guides (e.g. Williamson 1913; Gingrich, 1967; Johnson and Burkhardt, 1976; Myers and Buchman, 1984; Larsen et al., 2010) to describe optimum stocking rates for regeneration in terms of stems per acre. The model development team also discussed how to handle different forest types and different forest ages, as the desired level of regeneration varies according to both forest type and age. The team discussed whether the model should include two separate curves for early vs. late successional forests, or whether each project should determine a desired regeneration rate based on project-specific forest conditions. In the end, the team determined that a single curve was appropriate, as each project team will need to define the optimal level of regeneration in consideration of forest type and forest age.

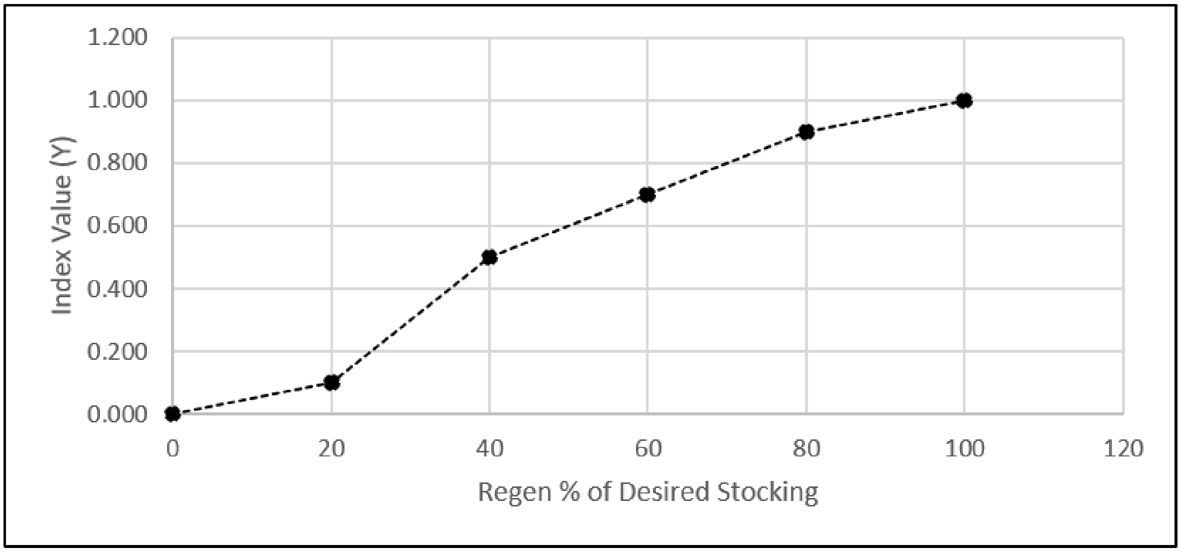



**Figure 6.** HSI curve for the forest regeneration variable.

***Variable 5: Structural Diversity***

The team acknowledged that structural diversity represented an important contribution of the forest to the overall ecosystem (Franklin et al., 2002) but may be difficult to capture in a single metric. In addition, the team recognized that important components of structural diversity in the ecosystem differ depending on context. For example, birds and bats both utilize the forest structure in different ways and the optimal components of structural diversity may not be the same for each species. As a result, the team discussed whether the structural diversity variable should have a species-based focus or a broader forest health perspective.

The team also discussed several methods in which this variable could capture structural diversity. The team considered a “check-box” approach where the variable would be based on the presence/absence of numerous important structural components. The team also considered utilizing a simpler approach based on a single metric (basal area), or short list of important metrics (tree diameter, tree height, and snags). The team decided that the simplified approach would not appropriately capture all the important components of structural diversity and decided to utilize the index approach and incorporate five important indicators. The team further decided that this variable should not have a species-based focus but would be tied to the overall forest health perspective, as overall forest health is likely to contribute to the utilization of the habitat by numerous species. Each of the five indicators included in this variable are scored on a scale of 0 to 1 and averaged to achieve a single score for structural diversity.

1. Horizontal structural diversity

    - Horizontal structural diversity describes the distribution of trees and other woody vegetation horizontally across a given management area (Ek et al., 2006). This metric is influenced primarily by variability in tree density and canopy cover across a management area. High diversity in this metric would be indicated by a management area that includes a wide range of tree densities, ranging from patches of dense forest with little light available at the forest floor to patches of open canopy associated with forest gaps. Management areas with uniform density throughout would be considered less desirable.

2. Vertical structural diversity
   - Vertical structural diversity includes consideration of the vertical distribution of structural elements such as tree branches, leaves and trunks from the forest floor to the canopy (Ek et al., 2006). Vertical structural diversity is evaluated in the context of canopy layers as well as the distribution of height cohorts of trees and shrubs within a given management area. High vertical diversity is considered desirable. Low vertical density would be indicated by a management area with a single canopy layer and minimal distribution of leaves and branches below that single canopy
3. Size class diversity
   - Size class diversity provides an assessment of the range of tree sizes in a management area. This variable is evaluated by considering the percentage of a management area made up of various size classes of trees (e.g. the Forest Management Geodatabase defines size classes as: poles (6-12 inches dbh), sawtimber (12-18 inches dbh), mature (18-24 inches dbh), overmature (24+ inches dbh)) and the relative dominance of size classes. Variability in size classes and the lack of dominance of a single size class is considered a desirable condition. Size class distribution is focused on the aggregate sizes of individual trees, as compared to horizontal structural diversity which focuses on the overall distribution of forest canopy across a management area.
4. Standing dead wood
   - Standing dead wood includes consideration of the size and abundance of standing dead trees and associated habitat structure (i.e. cavities) across a given management area. This variable focuses on the presence of high-quality standing dead wood (i.e. > 20 inches diameter at breast height) and abundance. This variable also considers the spatial distribution of standing dead wood within a management area. The standing dead wood indicator is maximized when a moderate amount of large standing dead wood is available, with low and very high quantities of large standing dead wood considered undesirable. Well distributed dead wood is considered more desirable than clustered patches of dead wood.
5. Species diversity
   - Species diversity considers the number of species present within a given management area compared to the management area maximum potential to support a diverse assemblage of species, based on location-specific details (i.e. inundation potential based on elevation and general area drainage). For example, there are only five common tree species in the St. Paul District, so a management area that has five or more species would be the most diverse composition possible.

A high percentage of the maximum possible diversity is considered desirable. Maximum species diversity potential would be developed based on knowledge of local forest communities and area conditions.

**2.5 Model Testing and Validation**

Overview of Model Testing Process

To test the floodplain forest model, independent tests were performed by foresters and biologists at St. Paul, Rock Island, and St. Louis Districts. Model testing included both a general testing of the model spreadsheet to ensure functionality, as well as a detailed testing of the model's technical performance. Model tests were performed across different forest community compositions and across varying qualities of forest to ensure the model had a robust performance across a range of possible scenarios. Model testing also evaluated a variety of planned forest management techniques to ensure the model could capture anticipated benefits across the range of typical forest management techniques.

Testing teams utilized available data on existing forest management areas within the UMRS that were subject to planned or upcoming forest management. These management areas were then evaluated in a variety of ways:

1. Evaluation of the existing conditions
2. Evaluation of the anticipated future without conditions
3. Evaluation of the anticipated future conditions following implementation of the planned forest management measures.

By performing evaluations across these three scenarios, testing teams could evaluate model outputs in several ways. First, model outputs for the existing conditions were compared to the existing forest inventory data and the testing team's best professional judgment on the quality of the existing management area to ensure that the outputs matched expectations. Second, model outputs for the future-without project condition could be compared to the existing condition. This allowed the testing team to evaluate whether the model was able to accurately capture any anticipated changes in the management area that were expected to occur. The magnitude of change from the existing condition to the future-without project condition was evaluated using best professional judgment, and the testing team determined whether the magnitude of change reflected by model outputs corresponded to the magnitude of forest decline reasonably expected to occur. Finally, the post-management outputs were compared to both the existing condition and future without project condition. This allowed the testing team to evaluate whether the model was able to capture the anticipated improvements in each forest management area that would occur as the result of the planned forest management actions. In addition, the team was also able to compare the magnitude of this change to the magnitude of change in the future without project condition. This allowed the team to consider whether the differences in these two numbers (i.e. benefits) accurately reflected the team's expectations regarding improvements to the forest management area.

Following the independent testing across the three District's, the team convened to review and summarize testing outputs and evaluate model performance in a group setting.

Model Testing Results

In total, the model was tested across six different management area locations in the UMRS, encompassing several different forest community compositions and forest qualities. A variety of forest management techniques were evaluated, including both tree thinning and tree planting. All three testing teams thought the model performed as expected and was capable of accurately reflecting a variety of forest conditions and treatments. The team decided that a combination of written instructions as well as photographic and diagrammatic examples would be included in the model application guide to assist future model users.

## 3 Model Application Guide

### 3.1 Geographic Area of Applicability

This model would be applicable to any wetland forest system dominated by hardwoods in the eastern United States. Though the conceptual model incorporates floodplain specific conditions, the model variables would be applicable to upland forest systems as well. This model was developed by and for the St. Paul, Rock Island, and St. Louis Districts. The model can be utilized for any hardwood forests within the boundaries of those districts. The model would likely apply in areas beyond these three districts. If teams outside these districts want to use the model, the assumptions and variables should be reviewed to ensure that the model applies to forests in other regions. Flooding is not a critical component to any of the variables described in the model. Upland forest communities are impacted by significant drivers than flooding regimes that result in similar forest dynamic shifts with or without management actions. Variables in this model are able to evaluate change in multiple forest community types and development stages. Though managers outside of the UMRS may use different forest summary tools, the variables described can be readily calculated from any standard forest inventory summary.

### 3.2 Assumptions and Limitations

This model is intended to be used to evaluate habitat quality within forested areas. The model does not quantify habitat changes at a landscape level. For example, the model does not include landscape or site-level characteristics such as connectivity, patch size, interspersion, or cover-type heterogeneity. A project team may wish to consider these aspects of forest habitat when evaluating projects, but this model does not quantify them. This model also does not predict how management measures would change forest characteristics. The model should be used by or in coordination with a forester, forest ecologist, or similar person with an understanding of forest communities typical of the project site. Forest response to management measures and other project scenarios is complex and dependent on many indicators. Implementation of forest management measures such as harvest or thinning is one of the primary methods through which foresters mimic natural disturbances to facilitate regeneration and achieve desirable forest composition and structure. A forester or forest ecologist can interpret forest inventory data, determine the structural changes that would result from various measures, and predict changes in site conditions over time. While the model applies to hardwood forests across the Upper Midwest, the modeler must have experience in the particular forest community types being modeled to understand variables such as how regeneration, invasive species composition, and forest structure responds to various management measures.

### 3.3 Utilizing the Model

The discussion below provides instructions on model implementation for each of the five variables. This includes a discussion of data sources and types that can be used to determine inputs for each variable, as well as instructions and guidance on how variable scores should be determined. Guidance on variable scoring is provided to ensure consistency and remove subjectivity for future model applications.

Variable 1: Percent Canopy Cover

Percent Canopy Cover is defined as the average percent cover within a given management area and is calculated as the average percent canopy cover across all inventoried plots within the management area (e.g. stand, site, etc.). "Canopy cover refers to the proportion of the forest floor covered by the vertical projection of the tree crowns. Measurements of canopy cover assess the presence or absence of canopy vertically above a sample of points across an area of forest." (Jennings et al, 1999), see Figure 2. To determine canopy cover, delineate the management area using a standard protocol for the project or a standard agency protocol. Once a management area boundary is delineated, use forest inventory or other field collection of canopy cover to develop an average value for the area. All inventoried plots within the area should be included in the average, including any canopy gaps that could be forested, e.g. herbaceous cover, dead trees, or harvests. Users of this model should use a standard land cover mapping protocol for their regional area to account for any potential gaps in the canopy. For example, if the minimum mapping unit for an area is 5 acres, then an inventory plot that falls within an unforested inclusion within the forest management area would be assessed as 0 percent canopy and would be factored into the overall management area canopy cover score. Some portions of the area may not be inventoried because they are inclusions of water, marsh, or other landcover that would not support forest. These areas would not be included in the canopy cover average since there would be no inventory plots and thus no measurement of canopy cover for these portions of the management area.

Percent canopy cover data on existing conditions can be derived from a variety of sources, which are expected to provide coverage across much of the UMRS. In the absence of available data, the project forester/biologist can also gather canopy cover data. Canopy cover does not include consideration of whether that canopy is provided by a desirable or non-desirable species, as species composition and desirability is covered in other metrics within the model. A few potential options for acquiring this data are:

1. Overstory closure metric from forest inventory summary data
2. Canopy closure metric long-term resource monitoring (LTRM) landcover layer
3. Field work to collect canopy cover data

The percent canopy cover at the management area scale can be input directly into the model spreadsheet.

Variable 2: Percent Desired Forest Type

The percent desired forest type variable is represented in the model by the percentage of the forest that is comprised of the desired forest type. To calculate this percentage, two parameters are necessary: the current percent forest type (or expected future forest type) and the percent desired forest type. The desired percent forest type should be determined at each project location by the project forester and/or biologist, based on the existing forest community type, location-specific conditions (e.g. elevation and flood inundation frequency and general area drainage), and management goals. Forest community types and desirable species would be based on forest inventory data summaries. Once the desired forest community type is identified, the percentage of the forest management area that is occupied by this forest type can be derived from existing data or from data gathered specifically for the project. Data on the presence or absence of desirable species (i.e. species consistent with the desired community type) may be available in forest inventory data summaries or may potentially be available from the current land management agency.

Once the desired community type has been identified, and the percentage of the existing or expected future forest occupied by this forest type has been calculated, the percentage can be entered directly into the spreadsheet.

Variable 3: Percent Invasive Species

The invasive species variable is a measure of the percent cover across the management area being evaluated. Data on invasive species may be available within existing forest inventory data summaries or can be collected specifically for the project. Depending on the size of the forest component for any given project, the level of detail available in existing forest inventory data summaries may not be sufficient. If teams need to collect additional data on percent invasive species, careful consideration should be paid to the model curve regarding the level of detail necessary. A percentage of invasive species above 20% is expected to have a significant detrimental effect on forest quality, while a percent below 20% is generally expected to have a much lesser influence on forest quality. As a result, determining a precise percentage of invasive species is not as important as determining whether the invasive species percentage is above or below the 20% threshold.

Variable 4: Regeneration

Of the four single-parameter variables in this model, regeneration is the most challenging to implement in a consistent manner. The most important step in applying the regeneration variable is determining what the desired level of regeneration is for a given forest management area. The desired regeneration for a specific forest management area depends on many variables including species composition, forest type, forest age, and location-specific habitat goals. As a result, this model does not identify a single target regeneration rate and the level of desirable regeneration must be user-defined.

There are many sources potentially available to foresters to identify a desired regeneration for a given forest management area, including species and community-specific stocking charts, regeneration guidelines in existing management plans, and literature on forest stand dynamics (Colbert et al., 2002; Larsen et al., 2010). Since the desired state of this variable is user-defined, the desired regeneration rate and source should be clearly identified in the model documentation for each project.

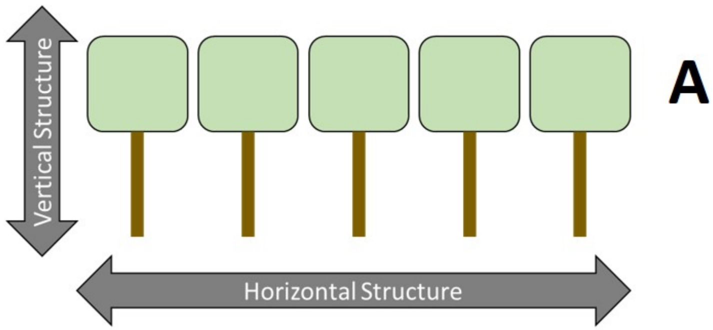
Once the desired level of regeneration for the forest management area has been identified, the existing regeneration can be determined based on a variety of sources. These include forest inventory data from the forest inventory data summary, surveys performed specifically for the project, or best-professional judgment of the project forester.

It is important to note that regeneration is highly variable from year to year. Flood conditions, mast production, drought, and other factors influence regeneration. The team should consider recent conditions when evaluating forest inventory to understand recent regeneration potential. When projecting future regeneration potential, the team should consider the stochastic nature of regeneration. Planting, seeding, and natural regeneration may not be successful in the first few years of a project, but over a longer timeframe, the conditions for regeneration are likely to occur.

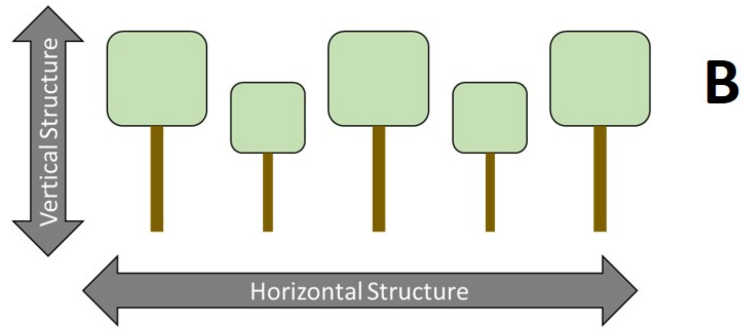
Variable 5: Structural Diversity

The structural diversity variable consists of five indicators ranked on a scale of 0 to 1 that are averaged together. Each indicator was designed to be ranked in increments of 0.2, the model spreadsheet provides a description of each increment for each indicator. In addition, the model spreadsheet includes high-score and low-score indicators that should be considered when ranking indicators. To further aid model users, a detailed user's guide for this variable (Section 4.0) was developed, which includes a series of diagrams and photos illustrating a range of different conditions across the five structural diversity indicators. Model users should consider a combination of the increment descriptions, high and low score indicators, and user's guide when scoring is performed.

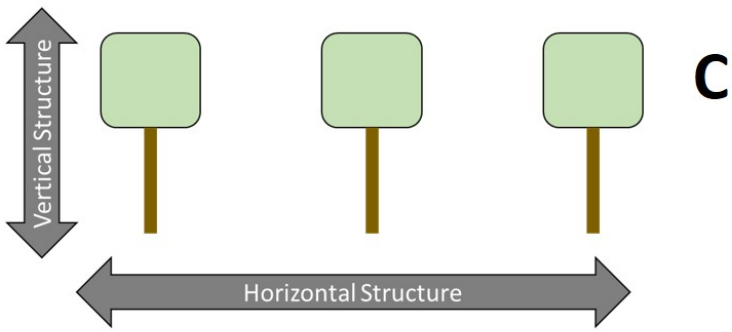
### 4.0 Structural Diversity User's Guide



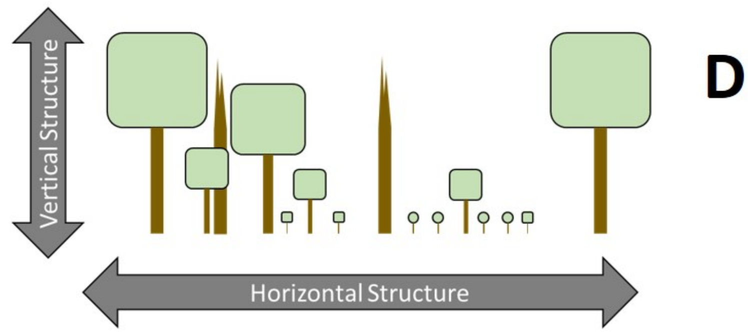

| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |




| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 0.4 | 0.2 | 0.6 | 0.0 | 0.0 | 0.24 |

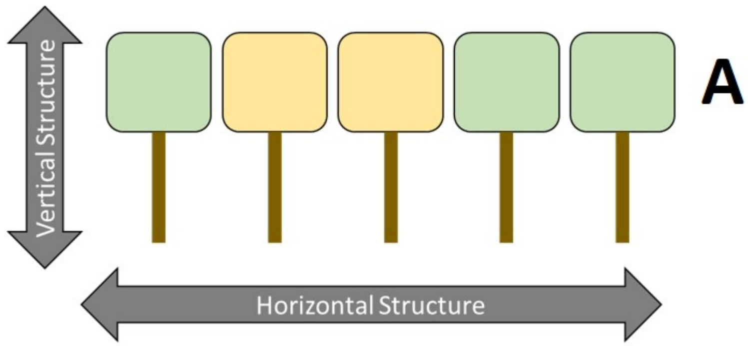


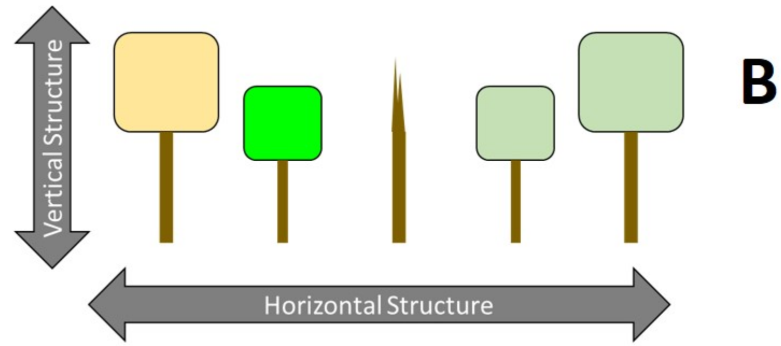

| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 0.4 | 0.0 | 0.0 | 0.0 | 0.0 | 0.08 |




| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 1.0 | 1.0 | 1.0 | 1.0 | 0.0 | 0.80 |

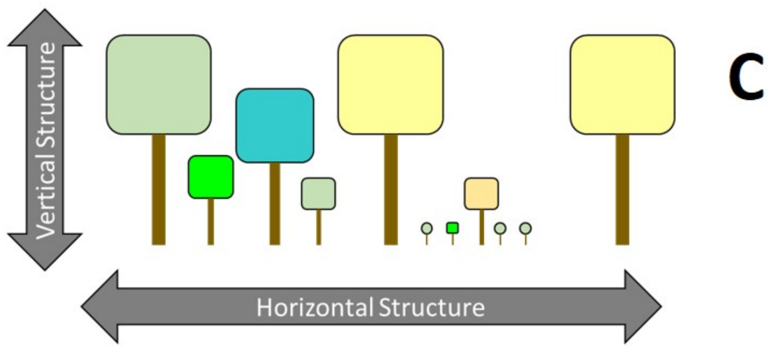
**Figure 7.** A: single species, single canopy layer, no gaps or dead trees; B: two canopy layers, two size classes, variability in canopy heights across the management area; C: canopy gaps add horizonal structure, but all trees the same species and size; D : canopy gaps and variable heights across the management area add horizontal structural diversity, three canopy layers plus shrubs (round plants) provide high vertical diversity, trees of multiple sizes and dead wood add additional diversity, but only one tree species is present.

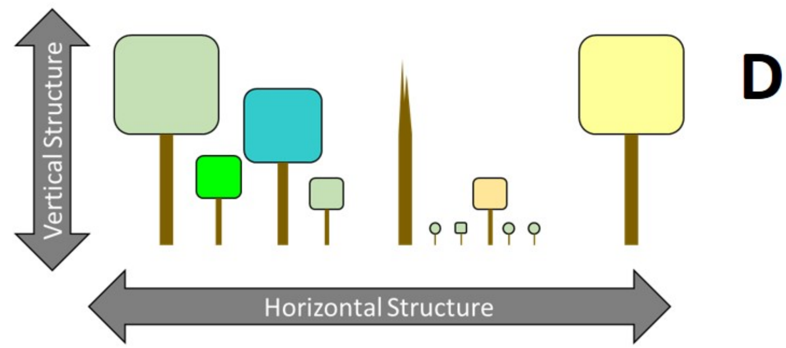



| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 0.0 | 0.0 | 0.0 | 0.0 | 0.2 | 0.04 |

| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 0.4 | 0.4 | 0.6 | 0.4 | 0.6 | 0.48 |




| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 1.0 | 1.0 | 1.0 | 0.0 | 1.0 | 0.80 |

| *Indicator* | HORIZONTAL STRUCTURAL DIVERSITY | VERTICAL STRUCTURAL DIVERSITY | SIZE CLASS DIVERSITY | STANDING DEAD WOOD | TREE SPECIES DIVERSITY | *Avg score* |
|---|---|---|---|---|---|---|
| *Score* | 1.0 | 1.0 | 1.0 | 0.6 | 1.0 | 0.92 |

**Figure 8.** A: two species, single canopy layer, no gaps or dead trees; B: two canopy layers, two size classes, variability in canopy heights across the management area, standing dead wood and three species; C: canopy gaps add horizonal structure, three canopy layers plus shrubs, multiple size classes four tree species, but no dead wood; D: canopy gaps and variable heights across the management area increase horizontal structural diversity, three canopy layers plus shrubs, trees of multiple sizes and some dead wood add additional diversity, multiple tree species.

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.0 |
| VERTICAL STRUCTURAL DIVERSITY | 0.0 |
| SIZE CLASS DIVERSITY | 0.2 |
| STANDING DEAD WOOD | 0 |
| TREE SPECIES DIVERSITY | 0 |
| *Avg Score* | 0.04 |

**Figure 9.** Whalen Tract, Upper Mississippi River Pool 9. This management area consists of a continuous unbroken canopy and mostly uniform tree stem density across the management area (no horizontal structural diversity), and single canopy layer (no vertical structural diversity). The area is dominated by the sawtimber (12-18" dbh) size class, though a few small trees are present (low size class diversity) and no standing dead wood. There is only one tree species in the management area.

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.0 |
| VERTICAL STRUCTURAL DIVERSITY | 0.0 |
| SIZE CLASS DIVERSITY | 0.2 |
| STANDING DEAD WOOD | 0.2 |
| TREE SPECIES DIVERSITY | 0 |
| *Avg Score* | 0.08 |

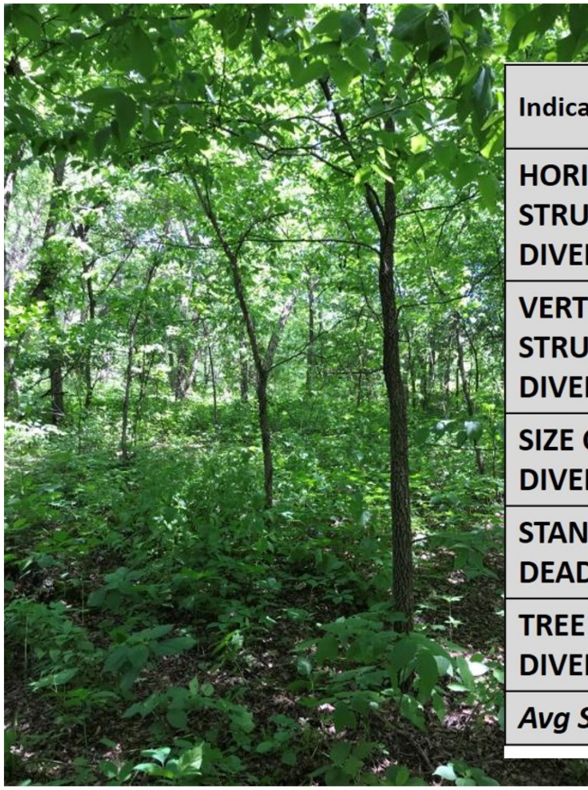
**Figure 10**. Hayshore Lake, Upper Mississippi River Pool 9. This management area consists of a continuous unbroken canopy and mostly uniform tree stem density across the management area (no horizontal structural diversity), and single canopy layer (no vertical structural diversity), heavy dominance in the sawtimber (12-18” dbh) size class, though a few small trees are present (low size class diversity) and a few standing dead trees. A single species dominates the area, so tree species diversity is very low.

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.4 |
| VERTICAL STRUCTURAL DIVERSITY | 0 |
| SIZE CLASS DIVERSITY | 0.6 |
| STANDING DEAD WOOD | 0 |
| TREE SPECIES DIVERSITY | 0 |
| *Avg Score* | 0.20 |

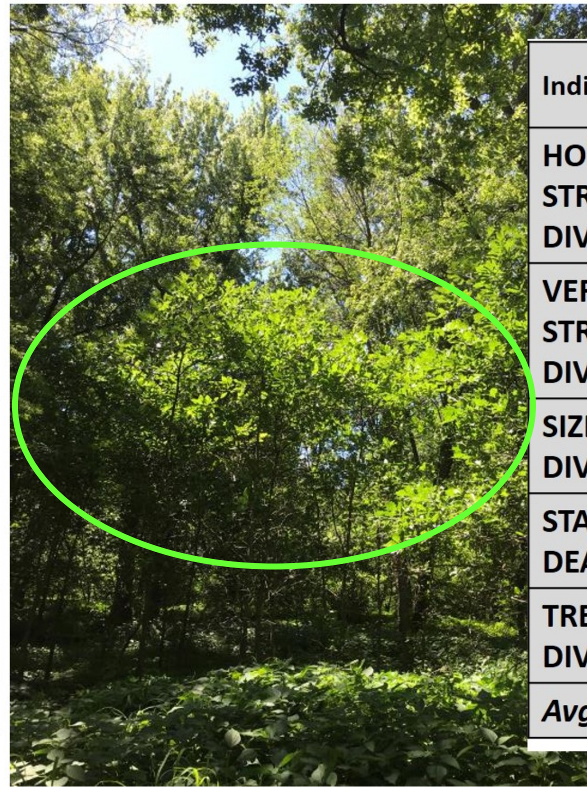
**Figure 11.** Bagley Bottoms, Mississippi River Pool 10. Note the differences in structure between the area on the left circled in green and the area on the right. There is variability in tree density across the area, with lower canopy cover on the right site and higher canopy cover on the left, so there is an intermediate level of horizontal diversity. However, most trees are a similar height and there is no forest canopy below the main canopy, so vertical diversity is low. The area on the left is dominated by smaller trees than the area on the right, so there are two dominant size classes, leading to a moderate level of size class diversity. There is no standing dead wood and only one tree species, so both standing dead wood and tree species diversity score low.

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.4 |
| VERTICAL STRUCTURAL DIVERSITY | 0.2 |
| SIZE CLASS DIVERSITY | 0.4 |
| STANDING DEAD WOOD | 0.0 |
| TREE SPECIES DIVERSITY | 0.4 |
| *Avg Score* | 0.28 |

**Figure 12.** East Channel, Mississippi River Pool 8. In this management area, horizontal diversity is moderate, with a canopy gap in the background and forest in the foreground. Vertical diversity is slightly higher than the minimum because the canopy is mostly uniform but some trees have crowns below the main canopy. Size class diversity is slightly higher than vertical diversity because there is a range of very small to intermediate diameter trees in the foreground. No dead trees are visible in the area and there are two tree species present so species diversity is intermediate.



| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 1.0 |
| VERTICAL STRUCTURAL DIVERSITY | 1.0 |
| SIZE CLASS DIVERSITY | 1.0 |
| STANDING DEAD WOOD | 0 |
| TREE SPECIES DIVERSITY | 0.8 |
| *Avg Score* | 0.76 |



| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 1.0 |
| VERTICAL STRUCTURAL DIVERSITY | 0.4 |
| SIZE CLASS DIVERSITY | 0.6 |
| STANDING DEAD WOOD | 0.2 |
| TREE SPECIES DIVERSITY | 0.4 |
| *Avg Score* | 0.52 |

**Figure 13.** Fountain City Bay, Mississippi River Pool 5A (left) and Horseshoe Bend Stand 1, Mississippi River Pool 5A (right).

The Fountain City Bay management area has a wide range of canopy cover and tree stem densities across the management area (very high horizontal structural diversity). Vertical structural diversity is also very high because there are multiple canopy layers forming a continuum of forest canopy from the forest floor to the top of the main canopy. No tree size class is dominant, though the pole size class is prevalent (high size class diversity). There is no standing dead wood but there are at least four tree species (high species diversity)

The Horseshoe Bend management area is similar to the Fountain City Bay management area. There is a similarly high variability in canopy cover and tree stem densities across the management area (very high horizontal structural diversity). Vertical structural diversity is lower at Horseshoe Bend because there are only two distinct canopy layers; the main canopy and the subcanopy of younger trees at the center (circled in green, moderate vertical diversity). Size class diversity is lower as well, because the management area has a higher dominance by sawtimber-sized trees (12-18” dbh) with a smaller component of pole-sized trees (6-12” dbh, moderate size class diversity). There is a small amount of standing dead wood, so the area scores slightly higher for that indicator, but it scores lower in tree species diversity due to only two species being present (moderate species diversity).

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.6 |
| VERTICAL STRUCTURAL DIVERSITY | 1.0 |
| SIZE CLASS DIVERSITY | 1.0 |
| STANDING DEAD WOOD | 0.2 |
| TREE SPECIES DIVERSITY | 1.0 |
| *Avg Score* | 0.76 |

**Figure 14.** Peterson Lake, Mississippi River Pool 4. Canopy cover and tree stem densities are only somewhat variable (moderate horizontal structural diversity) in the management area. Vertical structural diversity is very high because there are multiple canopy layers forming a continuum of forest canopy from the forest floor to the top of the main canopy. No tree size class is dominant, with all size classes represented to a certain extent (high size class diversity). There is a small though negligible amount of standing dead wood. This management area consists of five tree species (very high species diversity).

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.8 |
| VERTICAL STRUCTURAL DIVERSITY | 0.6 |
| SIZE CLASS DIVERSITY | 0.6 |
| STANDING DEAD WOOD | 0.6 |
| TREE SPECIES DIVERSITY | 0.8 |
| *Avg Score* | 0.68 |

**Figure 15.** Black River Bottoms, Mississippi River Pool 8. This management area has canopy cover and tree stem densities that are somewhat variable (moderate horizontal structural diversity). Vertical structural diversity is moderate because, though there is evidence of some development of lower canopy layers, the upper canopy remains distinct and separate from the lower canopy layer. In this management area, the mature (18-24" dbh) and overmature (24+" dbh) size classes dominate with minor representation from smaller size classes (moderate size class diversity). However, standing dead wood is present at moderate densities. The management area has four tree species (high species diversity)

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 1.0 |
| VERTICAL STRUCTURAL DIVERSITY | 0.8 |
| SIZE CLASS DIVERSITY | 0.8 |
| STANDING DEAD WOOD | 0.4 |
| TREE SPECIES DIVERSITY | 0.6 |
| *Avg Score* | 0.72 |

**Figure 16.** Horseshoe Bend Stand 2, Mississippi River, Pool 5A. Canopy and tree stem densities in this area are quite variable, with patches of canopy gaps and patches of high tree density (very high horizontal structural diversity). Vertical structural diversity is also high because there are multiple distinct canopy layers, and, in places, there is a continuous distribution of leaf area between the forest floor and the main canopy. In this stand, the mature (18-24" dbh) and overmature (24+" dbh) size classes are present but do not dominate, while lower size classes are also widely distributed (high size class diversity). Standing dead wood is present at moderate densities. This management area consists of three tree species (moderate species diversity).

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 1.0 |
| VERTICAL STRUCTURAL DIVERSITY | 0.4 |
| SIZE CLASS DIVERSITY | 0.6 |
| STANDING DEAD WOOD | 1.0 |
| TREE SPECIES DIVERSITY | 1.0 |
| *Avg Score* | 0.80 |

**Figure 17.** Jackson Island, Mississippi River Pool 10. This management area has patches of canopy gaps mixed with patches of high tree density (very high horizontal structural diversity). Vertical diversity is moderate because there are only two to three canopy layers. In this stand, the pole (6-12" dbh) size classes dominate, while other size classes are present (moderate size class diversity). Large standing dead wood is present at desirable quantities. This management area consists of five tree species (high tree species diversity)

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 0.8 |
| VERTICAL STRUCTURAL DIVERSITY | 0.8 |
| SIZE CLASS DIVERSITY | 1.0 |
| STANDING DEAD WOOD | 0.6 |
| TREE SPECIES DIVERSITY | 1.0 |
| ***Avg Score*** | 0.85 |

**Figure 18.** Richmond Island, Mississippi River Pool 7. This management area has substantial variability in tree densities, though canopy gaps are infrequent (high horizontal structural diversity). Vertical structural diversity is also high because there are multiple distinct canopy layers, and, in places, there is a continuous distribution of leaf area between the forest floor and the main canopy. In this management area, the mature (18-24" dbh) and overmature (24+" dbh) size classes are present but do not dominate, while lower size classes are also widely distributed (very high size class diversity). Standing dead wood is present at moderate densities. Tree species diversity is high, with ten tree species present.

| Indicator | Score (0-1) |
|---|---|
| HORIZONTAL STRUCTURAL DIVERSITY | 1.0 |
| VERTICAL STRUCTURAL DIVERSITY | 1.0 |
| SIZE CLASS DIVERSITY | 1.0 |
| STANDING DEAD WOOD | 0.8 |
| TREE SPECIES DIVERSITY | 1.0 |
| *Avg Score* | 0.96 |

**Figure 19.** Belvidere Slough, Mississippi River Pool 5. This management area scores the highest of all example stands. There is substantial variability in canopy densities and tree densities across the stand (very high horizontal structural diversity) along with a continuous distribution of leaf area between the forest floor and the main canopy (very high vertical diversity). Sawtimber-sized (12-18” dbh) and mature (18-24” dbh) size classes most common, but all other size classes are also well represented (very high size class diversity). Numerous standing and downed dead trees are also present in the stand. The area has five tree species (very high species diversity)

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## 6.0 Glossary

**Adaptive Management** – An approach to natural resources management that acknowledges the risk and uncertainty of ecosystem restoration and allows for modification of restoration measures to optimize performance. The process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans. A mechanism for integrating scientific knowledge and experience for the purpose of understanding and managing natural systems.

**Biodiversity** – The variety of living organisms considered at all levels of organization, from genetics through species, to higher taxonomic levels, and including the variety of habitats and ecosystems, as well as the process occurring therein. Biodiversity occurs at four levels: genetic diversity, species richness, ecosystem diversity, and landscape diversity.

**Biomass** (woody) **-** The mass of the woody parts (wood, bark, branches, twigs, stumps, and roots) of trees (alive and dead) and shrubs and bushes. Excludes foliage.

**Canopy cover** – Average percent cover across a given area (stand, management unit, etc.…) of trees $\geq$ 10 inches in diameter at breast height (dbh, 4.5 feet above ground level).

**Co-dominant tree** – A tree that extends it crown into the canopy and receives direct sunlight from above but limited sunlight from the sides. One or more sides of a co-dominant tree are crowded by the crowns of dominant trees.

**Community** – A grouping of populations of different species found living together in a particular environment.

**Conservation** – Active management to ensure the survival of the maximum diversity of species, and the maintenance of genetic diversity within species; implies the maintenance of ecosystem functions; embraces the concept of long-term sustainability. A careful preservation and protection of something, especially planned management of a natural resource to prevent exploitation, destruction, or neglect.

**Disturbance regime** – The spatial and temporal characteristics of disturbances affecting a particular landscape over a particular time (e.g., fire, flood, drought). Any relatively discrete event in time that disrupts the ecosystem, community or population structure and changes resources or the physical environment.

**Dominant tree** – Trees with crowns receiving full light from above and partly from the side; usually larger than the average trees or shrubs in the stand, with crowns that extend above the general level of the canopy and that are well developed but possibly crowded on the sides.

**Ecological (or biological) integrity (resilience)** – The ability of an ecosystem to retain its complexity and capacity for sustainability (i.e., its health).

**Ecosystem** – Dynamic and interrelating complex of plant and animal communities and their associated nonliving environment; a biological community together with the physical and chemical environment with which it interacts.

**Ecosystem function** – Processes that drive the ecosystem; any performance attribute or rate function at some level of biological organization (e.g., energy flow, sedimentation, detritus processing, nutrient spiraling).

**Ecosystem (or environmental) restoration** – Management actions that attempt to accomplish a return of natural areas or ecosystems to a close approximation of their conditions prior to human disturbance, or to less degraded, more natural conditions.

**Environmental sustainability** – The ability of aquatic, wetland, and terrestrial complexes to maintain themselves as self-regulating, functioning systems.

**Even-aged system** - Even-aged harvest methods regenerate and maintain a stand in a single age class. There are two primary types, seed tree and shelterwood.

**Floodplain** – Lowlands bordering a river that are subject to flooding. Floodplains are composed of sediments carried by rivers and deposited on land during flooding.

**Forest ecosystem** – A dynamic complex of plant, animal, and micro-organism communities, and their abiotic environment interacting as a functional unit, where the presence of trees is essential.

**Forest growth stage** – Phase in forest successional patterns. Generally defined in four phases: (i) stand initiation, (ii) stem exclusion, (iii) understory reinitiation, and (iv) steady state.

**Forest type** – A category of forest defined by its vegetation, particularly composition, and/or locality. The broadest general groups are broad-leaved (hardwoods), coniferous (softwoods), and mixed broad-leaved and coniferous.

**Geographic Information Systems (GIS)** – A set of computer hardware and software for analyzing and displaying spatially referenced features, such as points, lines or polygons, with non-geographic attributes, such as species, age, etc., used for mapping and analysis.

**Group Selection Method** - Group selection harvest systems create small openings in which trees are removed and new age classes are established. The width of groups is commonly twice the height of the mature trees with smaller openings providing microenvironments suitable for shade tolerant regeneration and larger openings providing conditions suitable for more shade intolerant regeneration.

**Habitat** – The living place of an organism or community, characterized by its physical or biotic properties; habitats can be described on many scales from microhabitat to ecosystems to biomes; a landscape and an environment suited to meet the needs of a particular species.

**Habitat Model** - allow you to assess and evaluate the quality of habitat before and following implementation of management activities.

**Habitat fragmentation** – The process whereby a larger, continuous area is both reduced in area and divided into two or more pieces. The disruption of extensive habitats into isolated and small patches. Fragmentation has three negative components: loss of total habitat area and smaller, more isolated remaining habitat patches, increased potential for edge effects

**Habitat suitability index (HSI) model -** are a measure of the suitability of habitat for a given species or group of species (i.e. forest communities) based on an assessment of habitat attributes. HSI's are indices in the sense that they usually combine many different variables (such as elevation, soil type, and land cover) into a single composite measure.

**Horizontal diversity** – variation in the distribution of trees and other woody vegetation horizontally across a given stand.

**Indicator** – A measurable surrogate for environmental end points, such as biodiversity, that is sensitive to changes in the environment and can warn that environmental changes are taking place.

**Introduced species –** Any species that is not considered native to that location or niche; many instances outcompetes native species for space and resources.

**Invasive species** – Any species that has the tendency to invade or enter a new location or niche; can be native or introduced; outcompetes desired species for space and resources.

**Invasive species control** - Methods to contain and reduce the spread and populations of established invasive species to minimize their harmful impacts. Acceptable control techniques include chemical, mechanical, biological, fire, and flooding.

**Landscape** – A heterogeneous land area composed of interacting ecosystems that are repeated in similar form throughout; landscapes are variable in size; usually overlaps governmental jurisdictions, thus requiring collaboration from a broad range of participants.

**Levee** – An embankment constructed to prevent flooding.

**Life history** – An organism's patterns of growth, reproduction, and longevity that are related to specific demands for survival.

**Management Unit** – Defined area of interest that is being managed for a specified set of objectives. For the Floodplain Forest Habitat Model, it is the unit/area that is being evaluated for a singular or group of management activities.

**Mitigation** - process of addressing impacts to the environment caused by human action.

**Pool** – The area of water that is impounded and maintained at a higher level behind a navigation dam; generally refers to the entire length of river between sequential dams.

**Reach** – A continuous stretch or expanse. In reference to rivers, it can be used to define portions of rivers at different scales (i.e., floodplain reach, pool reach, and reach between two river bends).

**Recruitment** - the process by which new individuals are added to a population.

**Reforestation** - Reforestation includes planting of trees in abandoned agricultural fields, cabin sites, and other abandoned man-made features as well as in areas where timber stand improvements and harvests have been conducted.

**Regeneration** - act of renewing tree cover by establishing young trees naturally or artificially.

**Release** - Release is a treatment to free young trees from undesirable competition and can be used to improve the composition, structure, condition, health, and growth of a stand.

**Resilience** – The ability of a system to maintain its structure and patterns of disturbance in the face of disturbance.

**Restoration** – The objective of ecosystem restoration is to restore degraded ecosystem structure, function, and dynamic processes to a less degraded, more natural condition (ER 1105-2-100). As defined under Section 519, in its broadest usage, restoration encompasses the following concepts: conservation, enhancement, naturalization, preservation, protection, rehabilitation, restoration, and stabilization.

**River stage** – The elevation of the water surface, usually above an arbitrary datum.

**Salvage Harvest** - Damaged forest resources will be salvaged, if permissible, to recover lost wood products. This includes forests damaged by wildfire, wind throw, flood events, disease, and insect damage.

**Sapling** – A tree at least 4½ feet tall and up to 5 inches in diameter.

**Seed Tree Method** - This method involves cutting of all trees except for a small number of widely dispersed trees (10-30 BA/acre) retained for seed production and to establish a new age class. The seed trees method can be spaced either uniform or non-uniform depending on existing stand structure.

**Shelterwood Method** - This method includes the cutting of most trees, leaving those needed to produce sufficient shade to produce a new age class in a moderated microenvironment.

**Silviculture –** The art and science of controlling the establishment, growth, composition, health, and quality of forests to meet diverse needs and values of landowners and society on a sustainable basis.

**Single Tree Selection Method** - This method removes individual trees of all size classes, uniformly throughout the stand, to promote growth of remaining trees and to provide space for regeneration.

**Size class distribution** – A measure of the variability in tree sizes within a stand or management unit. For this model, tree sizes evaluated were grouped into poles (6-12 inches dbh), sawtimber (12-18 inches dbh), mature (18-24 inches dbh), and overmature (24+ inches dbh).

**Species** – One or more populations of individuals that can interbreed, but cannot successfully breed with other organisms.

**Species diversity** – The richness, abundance, and variability of plant and animal species and communities.

**Species richness** – A simple count of the number of species in an area.

**Stand** - contiguous community of trees sufficiently uniform in composition, structure, age, size, class, distribution, spatial arrangement, site quality, condition, or location to distinguish it from adjacent communities.

**Stocking rate** - quantitative measure of the area occupied by trees, usually measured in terms of well-spaced trees or basal area per hectare, relative to an optimum or desired level of density.

**Structural diversity** - refers to the amount of three-dimensional variation in the forest.

**Succession** – Sequential change in the vegetation at a particular location over time.

**Sustainable/sustainability** – A level and method of resource use that does not destroy the health and integrity of the systems that provide the resource; thus the long-term resource availability does not ever diminish due to such use.

**Sustainable forest management** – The stewardship and use of forests and forest lands in such a way, and at a rate, that maintains their biodiversity, productivity, regeneration capacity, and vitality, and their potential to fulfill, now and in the future, relevant ecological, economic, and social functions at local, national, and global levels, and that does not cause damage to other ecosystems.

**Thinning** - A treatment made to reduce stand density of trees. Utilized primarily to increase growth, enhance forest health or reduce potential mortality.

**Threatened and endangered species** – Those species that are listed as threatened or endangered under the Federal Endangered Species Act (ESA) of 1973 and those species that are candidates or proposed as candidates for listing under the ESA; listing can occur at the Federal or State level or both.

**Timber Stand Improvement (TSI)** - includes activities or treatments that improve the composition, structure, condition, health and growth of even-age or uneven-age stands.

**Uneven-aged System** - Uneven-aged methods regenerate and maintain a multi-aged structure by removing some trees in all size classes either singly or in small groups. The two major types are group selection and single tree selection.

**Upper Mississippi River – Illinois Waterway (UMR-IWW)** – The narrow (300- to 500-meter) 1,200 miles of 9- foot navigation channel, 37 lock and dam sites (43 locks), and thousands of channel training structures of the Upper Mississippi River and Illinois Waterway.

**Upper Mississippi River System (UMRS)** – The entire floodplain area and associated physical, chemical, and biological components of the Upper Mississippi and Illinois Rivers.

**Vertical diversity** - consists of having multiple layers of trees, shrubs, forbs and grasses in a single forest type

**Watershed** – The geographic area that naturally drains into a given watercourse such as a stream or river.

## 7.0 Acronyms

DBH – Diameter at Breast Height

ECO-PCX – Ecosystem Restoration Planning Center of Expertise

ERDC – Engineering Research and Design Center

FMG – Forest Management Geo-Database

HSI – Habitat Suitability Index

LTRM – Long-Term Resource Monitoring

MVD – Mississippi Valley Division

RPEDN – Regional Planning and Environmental Division North

TSI – Timber Stand Improvement

UMR – Upper Mississippi River

UMRR – Upper Mississippi River Restoration

UMRS – Upper Mississippi River System

USACE – United States Army Corps of Engineers

### 8.0 Some Forest-Inhibiting Invasive Species of the UMR

This list contains some of the species that inhibit regeneration or development of floodplain forests in the UMRS, including some herbaceous, some woody, and some vining species. Some of these species are always managed when present on a site, some are rarely managed, and some are managed when conditions warrant. There are species beyond those found on this list that inhibit forest regeneration or development, and this list should not be considered comprehensive. The model user must assess the current conditions of the site to determine whether and which species are inhibiting the regeneration and development of desirable forest conditions. Native species may be considered "invasive" for the purposes of this model if they impede forest regeneration and development.

| | |
|---|---|
| Asian knotweeds | *Polygonum sachalinense, P. cuspidatum* |
| Black locust | *Robinia pseudoacacia* |
| Various honeysuckles | *Lonicera morrowii, L. tatarica, L. x bella, L. maackii, L. periclymenum, L. japonica* |
| Canada thistle | *Cirsium arvense* |
| Coffee weed | *Sesbania herbacea* |
| Common reed | *Phragmites australis* |
| Common teasel | *Dipsacus fullonum* |
| Cow vetch | *Vicia cracca* |
| Crown vetch | *Securigera varia* |
| European buckthorn | *Rhamnus cathartica* |
| European honeysuckle | *Lonicera periclymenum* |
| Garlic mustard | *Alliaria petiolata* |
| Giant ragweed | *Ambrosia trifida* |
| Glossy buckthorn | *Frangula alnus* |
| Japanese barberry | *Berberis thunbergii* |
| Japanese hops | *Humulus japonicus* |
| Johnson grass | *Sorghum halepense* |
| Leafy spurge | *Euphorbia esula* |
| Marsh Smartweed | *Persicaria coccinea* |
| Moneywort | *Lysimachia nummelaria* |
| Mulberry | *Morus sp.* |
| Multiflora rose | *Rosa multiflora* |
| Musk thistle | *Carduus nutans* |
| Oriental bittersweet | *Celastrus orbiculatus* |
| Poison ivy | *Toxicodendron radicans* |
| Purple loosestrife | *Lythrum salicaria* |
| Reed canarygrass | *Phalaris arundinacea* |
| Russian and autumn olive | *Elaeagnus angustifolia, E. umbellata* |
| Saltcedar | *Tamarix sp.* |
| Sericea lespedeza | *Lespedeza cuneata* |
| Siberian elm | *Ulmus pumila* |

| | |
|---|---|
| Smooth bromegrass | *Bromus inermis* |
| Spotted knapweed | *Centaurea maculosa* |
| Stinging nettle | *Urtica dioica* |
| Tall fescue | *Festuca arundinacea* |
| Trumpet creeper | *Campsis radicans* |
| Winged burning bush | *Euonymous alatus* |
| Winter Creeper | *Eonymus fortunei* |