RESEARCH REPORT

ENVIRONMENT

Title: Vegetative Environmental Buffer Builder and Economic Review: A Decision Support Tool for the Pork Industry – **NPB #15-171**

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Date Submitted: May 30, 2017

Industry Summary: This project created a user-friendly online decision support tool for livestock producers (and their advisors) to design and plan for the use of Vegetative Environmental Buffers (VEB) for odor mitigation and improved site aesthetics. The tool, *VEB-econ,* allows users to locate facilities or future building sites within an online, high-resolution photo-mapping GIS (Google Earth). Users then utilize dimensional drawing tools to delineate property boundaries, roads, animal buildings and other structures, so as to parameterized idealized tree-row locations. Users specify number of desired tree rows, preferred tree-row protection zones, etc. Layered into the mapping tool is the NRCS SSURGO soil database linking tree species selection to soil-based tree suitability recommendations. *VEB-econ* estimates total annualized costs for tree establishment, long-term management, any opportunity costs and factors in the potential benefit of utilizing available NRCS EQIP cost-share programming for VEBs. Global Positioning System field location data points for all trees/ tree rows are downloadable for precision planting. *VEB-econ* can be found at: https://veb.nrem.iastate.edu/

Keywords: Odor, Vegetative Environmental Buffers, trees, decision support, internet

Scientific Abstract:
Vegetative Environmental Buffers or VEBs – purposefully planted trees and shrubs usually arranged in linear patterns near and around production sites - are a low-cost livestock odor mitigation technology. VEBs have been shown to be biophysically effective in intercepting, filtering and diluting odor-laden air streams associated with animal production sites. To aid livestock and poultry producers design the most appropriate VEB system for their production site, we've created a web-based Vegetative Environmental Buffer design program called *VEB-*

econ. *VEB-econ* allows users to locate facilities or future building sites within a high-resolution photo-mapping GIS (Google Earth). Users then utilize to-scale dimensional drawing tools to delineate property boundaries, roads, animal buildings and other structures, so as to parameterized idealized tree-row locations. Users specify number of desired tree rows, preferred tree-row protection zones, etc. Layered into the mapping tool is the NRCS SSURGO soil database linking tree species selection to soil-based tree suitability recommendations. Costs for VEB systems are highly variable and dependent upon site-specific VEB design. As such, *VEB-econ* estimates total annualized costs for tree establishment, long-term management, any opportunity costs and factors in the potential benefit of utilizing available NRCS EQIP cost-share programming for VEBs. Additionally, VEB-econ can be used to design field windbreaks and or shelterbelt systems for general conservation purposes. *VEB-Econ* is designed to be useful to producers, outreach professionals, farm/forest management consultants, tree nurseries and other key air quality stakeholders. Global Positioning System field location data points for all trees/ tree rows are downloadable for precision planting. *VEB-econ* can be found at: https://veb.nrem.iastate.edu/

Introduction: The management of odor emitted from animal production facilities continues to be a significant physical, social and economic challenge wherever confinement livestock production is prevalent (Ni, 2015). Recent research has demonstrated that tree barriers (windbreaks) called Vegetative Environmental Buffers (VEB) are a relatively low-cost and biophysically effective odor mitigation technology highly suitable for confinement production systems (Tyndall, & Colletti 2008; Liu, Powers, & Mukhtar, 2014). Vegetative Environmental Buffers are purposefully planted trees and/or shrubs usually arranged in linear patterns near and around production sites that intercept, filter and otherwise dilute odor laden air (Tyndall, & Larsen 2013). In order to help Midwest swine producers and their advisors design site-specific VEBs, this project facilitated the creation of the decision-support tool "*VEB-econ*", a user-friendly Geographic Information System (GIS) based planning tool. *VEB-econ* can be found at: https://veb.nrem.iastate.edu/.

VEB-econ bridges a common and challenging outreach knowledge gap when it comes to the deliberate integration of trees into agricultural production systems. Many land management professionals and Extension personnel have expertise in farm production systems or in trees and forestry but rarely expertise in both (Schaefer, 1989). Such gaps in experience or knowledge have led to inadequate planning and subsequent failure of VEB systems being appropriately established (leading to tree mortality or emergent site hazards such as undesirable snow deposition). Furthermore, effective VEB designs are based on site-level air-dynamics and tertiary odor mitigation principles which represent a degree of specialized planning knowledge (Tyndall, & Larsen 2013). Thus, *VEB-econ* identifies where trees should ideally be planted relative to the layout of the production system and relative to odor mitigation principles, matches appropriate tree species to soil conditions, and provides key tree establishment and management guidelines to maximize tree health and prevent unnecessary tree mortality.

To aid producers with a visual planning platform, *VEB-econ* provides a web-based graphic design interface that allows users to design site specific VEBs within a high-resolution photo-

mapping GIS (utilizing Google Earth; see figure 1 below for an example). Users navigate to find their production site or proposed site and with the tool's "VEB Builder" use scaled design tools to delineate general design parameters (e.g., scale of production system, building orientation, location of roads, property boundaries) and to select the dimensions of a site-specific idealized VEB (e.g., number of tree rows, orientation of plantings, etc.). Coupled to the mapping tool is a National soil database layering (the Natural Resource Conservation Service SSURGO soil mapping database) that automates tree species recommendations in accordance with Iowa Department of Natural Resources tree suitability recommendations based on soil types (IDNR, 2014). Once a VEB design plan is finalized, an economic analysis of that design and general management guidelines are provided.

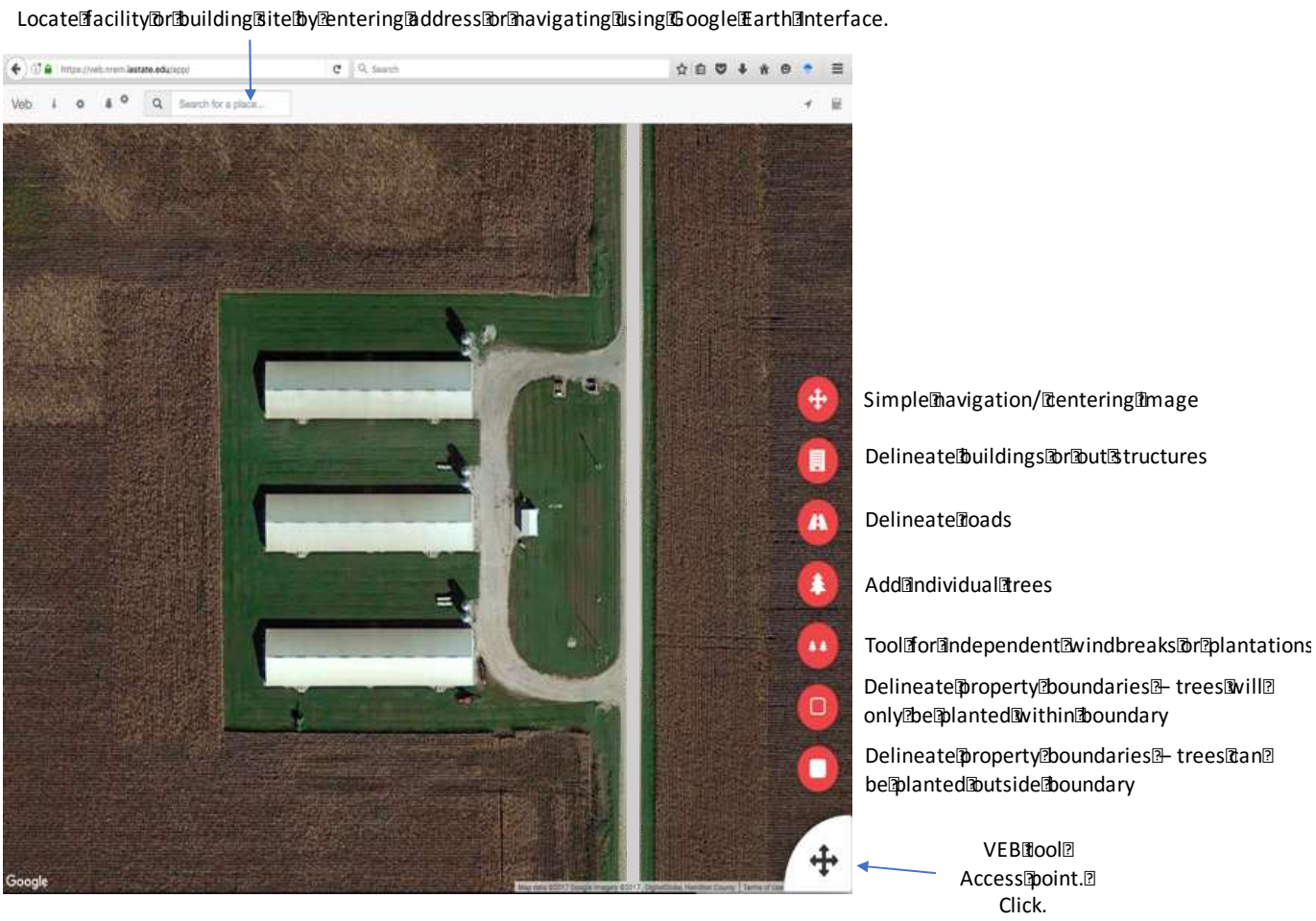


Figure 1. Description and example of the VEB-econ tool applications and online GIS interface.

Objectives:
Objective 1: Develop a web-GIS (Geographic Information System) based graphic Vegetative Environmental Buffer (VEB) design program that allows users to locate existing facilities or potential building sites within a high-resolution photo-mapping GIS (e.g., Google Earth) with automatic soil layering. Then utilizing scaled dimensional drawing tools (our "VEB Builder"), users draw/ locate tree rows and other plantings in and around the production site. Automatic tree species recommendations based on soil types are provided based on Natural Resource Conservation Service tree suitability recommendations and (when relevant) necessitated if a producer applies for Environmental Quality Incentive Payment programming. The tool is to be used by producers, technical service providers, engineers, etc., as a way to plan for the use of Vegetative Environmental Buffers for odor mitigation and assess the financial requirements of establishing and managing such a system over time. Alpha testing of the tool will begin summer 2014 (alpha testing is simulated or actual operational testing of the tool by potential users).

Objective 2: Develop dynamic (updateable/adjustable) financial spreadsheets that will be used to calculate cost information for user defined Vegetative Environmental Buffer designs. The financial costs of VEB systems in three states - Iowa, Illinois, and Missouri - will be accounted for.

Materials & Methods: Our technology team has created a fully functional beta version of the tool that operates across front and back-end technologies that run on modern browsers and on modern devices (e.g., Apple Ipad and Android -based tablet devices). The tool is coded via AngularJS, a JavaScript framework as the front-end technology and Drupal as the back-end technology. Drupal is an open source content management framework written in state of the art "server-side" scripting language called PHP which is designed particularly for web development). A mapping application programming interface (API; this specifies how our chosen software components will interact with each other) joined to create a unified and interactive interface.

Results*:* **Objective 1 Overview:** The tool is completed and is going through an extended testing phase (merged alpha and beta testing). **Objective 2 Overview**: The financial spreadsheets to calculate cost information for user defined Vegetative Environmental Buffer designs have been fully developed in Excel following standard engineering discounted cash-flow techniques. Spreadsheet calculations and information protocols have been fully coded for immediate online calculations.

VEB Design Parameters
In the context of tool usage, *VEB-econ* guides initial user created VEB designs to spatially observe general recommendations for location and arrangement of trees and/or shrubs relative to typical prevailing winds, minimum planting distances from roads, buildings, ventilation systems, etc. Using the application's drawing tools, the user identifies roads, delineates all buildings, and outlines the property boundaries. *VEB-Econ* then uses this information as parameters for site-specific guidance that covers the following specific VEB planning/design issues: 1) Relative to scale and orientation of animal buildings and/ or manure storage, *VEB-*

econ establishes idealized tree row location for odor plume interception/filtration and to enhance mechanical turbulence (caused when surface air encounters an obstruction like a row of trees); 2) In Iowa, winter winds largely come from the North/Northeast. Therefore, *VEB-econ* predetermines the planting distance north of buildings/roads tree rows so as to avoid problematic snow issues; and 3) Trees should not be planted too close to buildings where they prevent appropriate air flow into and out of the buildings. For naturally ventilated systems, a VEB should not impede necessary summer winds (which in Central Iowa tend to come from the South/South east) blowing into the buildings, thus *VEB-econ* locates minimum planting distances to the south of naturally ventilated buildings. For mechanically ventilated buildings, *VEB-econ* determines a distance of at least 40 feet away from fans as is typically recommended to prevent back pressure on the fans and to protect the trees from desiccation.

Initial VEB designs are subject to *VEB-econ*'s default settings in terms of distance of rows from buildings and spacing between trees within rows. Users can however adjust these default settings. Current default settings for tree row distance north of buildings, spacing between tree rows and distance between trees within rows are described in figure 2 and table # below.

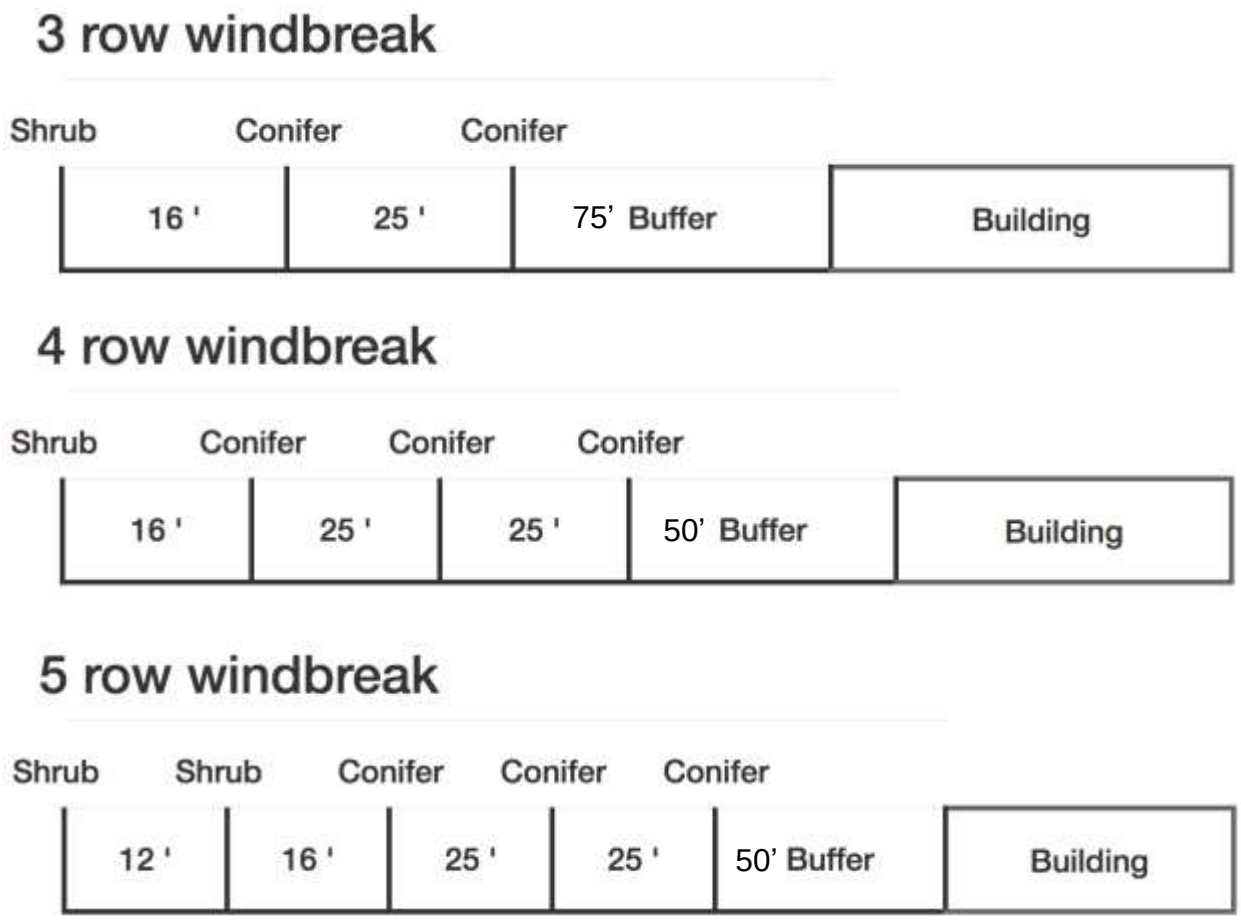


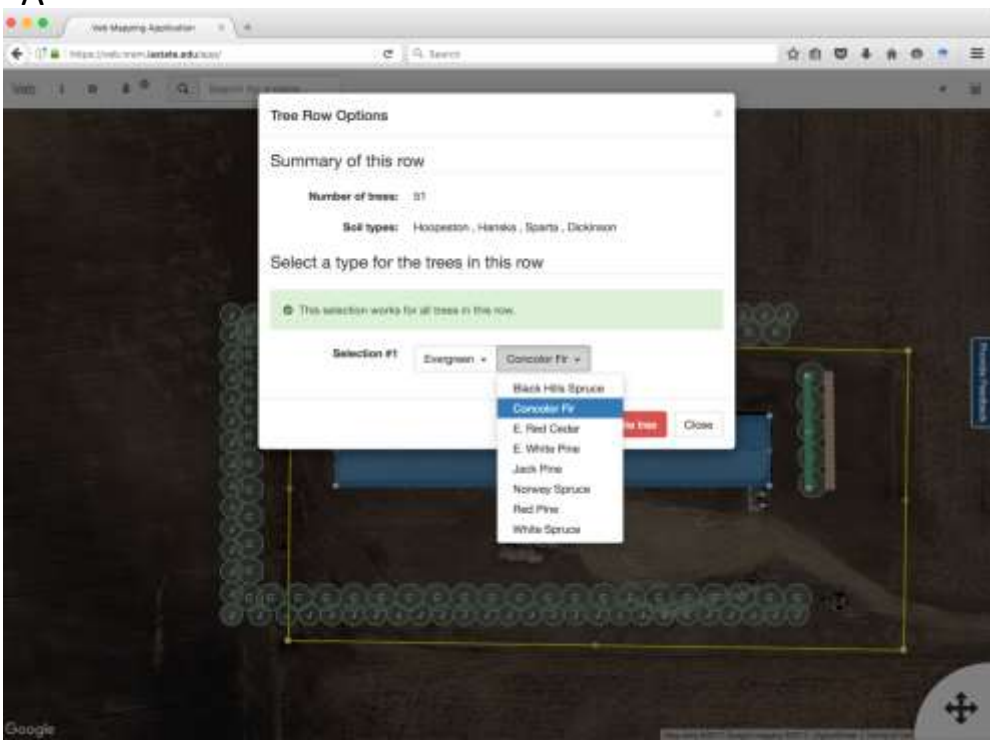
Figure 2. Current *VEB-econ* default settings for tree row distance north of buildings, and spacing between tree rows.

Table 1. *VEB-econ* default spacing between trees.

Planting stock size	Spacing (feet between trees)
Bareroot tree seedlings	20’
2-foot and larger containerized trees	30’
Shrubs	6’

Users determine the main site areas to be protected by a VEB (e.g., location of tree rows that will primarily intercept odor plumes or provide visual benefits; north, east, south or west of buildings/ roads) and the number of tree rows. Users then select desired tree or shrub species from drop-down menus that list species based on tree/shrub suitability recommendations as determined by a National soil database layer (GIS soil data: NRCS SSURGO, 2016). Tree and shrub species recommendations based on soil groups are in accordance with the Iowa Department of Natural Resources (IDNR), Woodland Suitability Recommendations (IDNR, 2014). The species database also notes when non-native species are selected or when there are known pest and/or pathogen susceptibilities. Compliance with IDNR species recommendations is required if landowners wish to participate in the Environmental Quality Incentive Program (EQIP) and receive cost share support. All VEB designs are fully modifiable in terms of planting locations, number of rows and species selected. Users can save and then change a design at any time. See figure # for an example of species selection based on soils present and an example VEB design.

A



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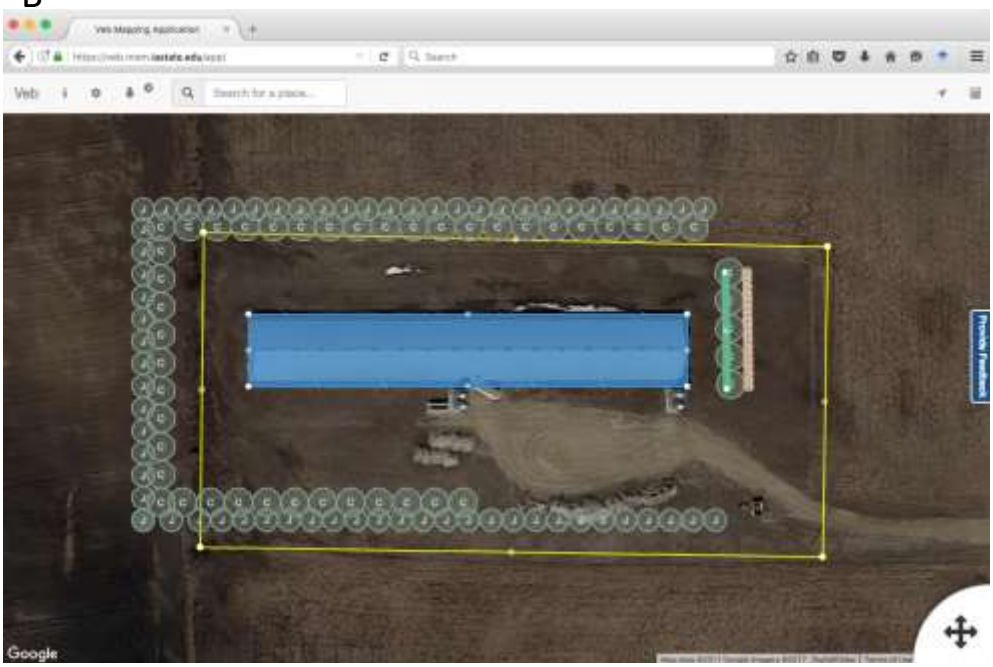

Figure 3. Example of species selection based on soils present and an example VEB design. Design displays a simple two-row VEB located around the south, west and north sides of the single, naturally ventilated animal building; species selected based on soils include Jack pine (*Pinus banksiana*) and Concolor fir (*Abies concolor*). An independent two-row windbreak is to the west of the building; species selected include Concolor fir and hybrid poplar (*Populous spp.).*

VEB-econ Economic Analysis

Establishment and management costs for VEB systems can be highly variable and are dependent upon site-specific VEB design as well as implementation context, e.g., a retrofitted VEB planted around existing production sites or a planned planting as part of pre-construction site plans. Therefore, to aid producers determine capital requirements *VEB-econ* estimates total present value and annualized costs for: 1) Site-preparation costs; 2) tree establishment costs which includes purchasing tree stock and planting costs; 3) long-term maintenance costs which include weed control and periodic site mowing; 4) any land purchase costs or opportunity costs such as forgone land rent; and 5) the estimated financial cost-share effects of the Environmental Quality Incentive Payment (EQIP) programming which in Iowa, payments vary depending upon the number of rows and the tree/shrub planting stock used (NRCS,). All costs are scaled by the dimensions of the whole VEB system as designed.

Financial Model

All key dimensional aspects of the VEB as designed are accounted for (e.g., total area of site preparation, total number of trees/shrubs, total area of land occupied by trees, total estimated area between tree rows to be mowed, etc.) and assigned current market prices (costs) and when they occur (see table 2 below). All costs are discounted using standard discounting formulation following the general VEB cost model from Tyndall and Grala (2009) displayed below:

$$\text{Present value of total VEB costs} = PV^{VEBSPrep} + PV^{VEBest} + PV^{VEBmgt} + PV^{VEBoppcost} \quad [1]$$

$$\text{Annualized VEB costs} = \text{Present value of total VEB costs} * [i(1+i)^n]/[(1+i)^n - 1] \quad [2]$$

Following equation 1, $PV^{VEBSPrep}$ is the present value of VEB site preparation costs (includes tilling, disking, herbicide application and other activities needed to prepare land for tree planting); these costs generally occur in year zero. The PV^{VEBest} term stands for the present value of VEB establishment (includes purchase price of all planting stock and planting, and other activities such as mulch and installing irrigation equipment); these costs generally occur in years 0 or 1. The PV^{VEBmgt} represents the present value of VEB maintenance needs (includes activities such as: mowing between tree rows, tree/shrub replacement, drip irrigation); these are periodic and or annual costs. Finally, $PV^{VEBoppcost}$ represents any upfront or annual opportunity costs of land (if additional land is required for the VEB); this is an upfront cost if it involves land purchase, annual if land was/is rented. Total discounted costs for each design are then annualized using a capital recovery factor (equation 2), which transforms the present value into equal annual payments over a planning horizon (n) at a specified discount rate (i) (Sullivan, Kulonda, & White, 2005). A twenty-year analysis is the default planning horizon, as the average life span of typical animal production facility ownership has been estimated to be between 15 and 20 years (ISU, 1998). *VEB-econ* uses a 2% real discount rate following the EPAs recommended discount rate for environmental quality projects that involve only costs (Tyndall and Roesch, 2014).

The data assembled for *VEB-econ*'s default cost assessment include current custom rate input prices covering costs for typical site preparation, tree planting, long-term management costs, and average Iowa land rental rates (table 1). There is a database of current (2016/2017) regional nursery prices for various sizes of tree and shrub stock, e.g., bare root stock to containerized(table 2). The 2017 Iowa EQIP payment schedule for VEBs is also included and automatically aligns with the type of VEB designed (table 3). The current launch version of *VEB-econ* is largely calibrated to Iowa market conditions for nursery stock, custom rates and land values yet input prices can easily be modified by the user and subsequent versions of the software will allow users to select different states (e.g., Iowa, Minnesota, Missouri, Illinois, and Indiana) thus accessing a cost database unique to that state.

Table 1. Default transaction cost data and year(s) in which they occur used by *VEB-econ* to estimate the total long-term costs of a designed Vegetative Environmental Buffer. All costs are in 2017 dollars US.

Action	Year(s)	Price/ Unit (US 2017 $)
Site Prep if planting in grass [1]		
Plowing (Chisel) - fall	0	$19.15/ acre
Spraying - Fall	0	$7.00/ acre
Spray (roundup)	0	$32.00/ acre
Disking - Spring	0	$15.15/ acre
Site Prep if planting in cropland [1]		
Disking - Spring	0	$15.15/ acre
Spraying - Fall	0	$7.00/ acre
Spray (roundup)	0	$32.00/ acre
Shelterbelt Establishment		
Tree purchase costs	0	Variable; See table 2 below
Shrubs purchase cost	0	Variable; See table 2 below
Tree planting cost	0	$1.00/ tree
Shrub planting cost	0	$1.00/ shrub
Permeable plastic mulch and installation	0	$74.00/ 1000 ft
Drip Irrigation and Installation	0	$700/ acre
Long Term Maintenance		
Tree replanting [2]	3	Variable; 10% of initial planting
Shrub replanting [2]	3	Variable; 10% of initial planting
Tree planting cost	3	$1.00/ tree
Shrub planting cost	3	$1.00/ shrub
Weed control (e.g. mowing)	Annual	$45.00/ hour; mow ~1.3 acres/ hour
Other relevant costs		
Overhead/management [3]	Annual	2% of year 0 costs
Land rent/ or land purchase [4]	Annual or 0	Variable; proxy is land rent. Land purchase price is also possible.

[1] Site preparation will vary across sites. In many cases, the grounds of a confinement livestock facility - the area where trees are to be planted – feature highly compacted soils, subsurface soil piling, poor drainage, etc. Appropriate site preparation is critical for the long-term health of tree plantings and will contribute toward lower tree mortality, faster tree growth and, ultimately, lower time, money and effort in managing the system over life of the operation. [2] Some tree and shrub mortality should be expected. In Iowa, about 10% mortality of initial planting is typical in otherwise healthy windbreaks; [3] A general rule of thumb for overhead cost is that it is equal to 2% of all year 0 costs; Includes insurance, energy requirements, monitoring time, etc; [4] If land is taken out of production for permanent VEB use, land rent or land purchase should be factored in. The average rental rate for the state of Iowa in 2016 was $230/acre (county level averages can be found here: https://www.extension.iastate.edu/agdm/wholefarm/html/c2-10.html.

Nursery Tree and Shrub Stock Pricing

The default costs for planting stock are based on a database of current (2016/2017) regional nursery prices for various sizes of all tree and shrub stock (e.g., bare root stock to containerized). Table 2 below summarizes these costs.

Table 2. VEB-econ default tree and shrub nursery stock pricing. Data is a compilation of prices from five Iowa based tree nurseries; all prices per tree/shrub are based on 2017 pricing catalogs.

Tree/Shrub	Bareroot	Container (18"-24")	Container (2'- 3')	Container (3' - 4')	Container (4" - 5')	Container > 5'
Hybrid willow	$1.03	$6.50	$7.57	$8.65	$11.00	$11.00
Eastern Red Cedar	$3.25	$16.75	$25.00	$35.00	$45.00	$60.00
Conifers (average price across species)	$2.11	$21.00	$25.00	$35.00	$54.00	$65.00
Hardwoods (average price across species)	$1.35	$8.50	$32.50	$35.00	$45.00	$60.00
Shrubs (average price across species)	$1.33	$8.00	$12.00	$14.00	n/a	n/a

Note regarding price data: The cost of nursery stock of any size can vary significantly from this pricing guide due to sales, scale of purchase, timing of purchase, availability, shipping/ transportation costs, etc. The tree and shrub prices used by *VEB-econ* are meant to serve as general baselines. Baseline nursery prices will be updated annually.

Environmental Quality Incentive Program:
Practice Code 380 (Windbreak/ Shelterbelt Establishment)

The Environmental Quality Incentive Program (EQIP; administered by the Natural Resource Conservation Service) provides cost share funding for eligible farmers, for the establishment of Vegetative Environmental Buffers. The program utilizes Practice Code 380 for windbreak/ shelterbelt establishment for, "...any area where woody plants are desired and can be grown and where wind, noise, air quality, or visual problems are a concern." Table 3 presents the Iowa EQIP 2017 Payment Schedule for Practice Code 380.

Table 3. Iowa EQIP 2017 Payment Schedule for Practice Code 380*

Variant	Variant Description	Payment ($/foot)
380-1	3 row windbreak, containerized planting stock	$3.05
380-3	3 row windbreak, bareroot seedling planting stock	$0.90
380-5	1 row windbreak, containerized tree planting stock	$0.60
380-7	1 row windbreak, containerized shrub planting stock	$1.91
380-9	1 row windbreak, bareroot tree seedling planting stock	$0.28
380-11	1 row windbreak, bareroot shrub seedling planting stock	$0.40

*Practice must be maintained for at least 15 years; Payment rate is based on 50% of the estimated incurred costs and foregone income (if applicable) associated with practice implementation. For Historically Underserved producers, which Includes, Beginning Farmers/Ranchers, Limited Resource Farmers/Ranchers, Socially Disadvantaged Farmers/Ranchers, Tribal Farmers/Ranchers and Veteran Farmers/Ranchers, the payments per unit are 25% to 40% higher.

Final VEB costs are then presented in the following forms to best aid the financial planning process: annualized total cost so as to assess VEB costs relative to typical annual livestock or poultry production costs, total upfront costs which represents the money needed to cover the costs of establishing the VEB (in most cases the majority of a VEBs total cost - upwards of 70% - occurs in the establishment phase and is tied to the cost of the initial planting stock), total costs on a per animal produced basis which is a common way that producers consider environmental management costs, and finally total annualized costs with and without the Iowa EQIP cost share payment.

Discussion: This project facilitated the creation of "*VEB-econ*", a user-friendly Geographic Information System (GIS) based planning tool designed to help Midwest swine producers and their advisors design site-specific Vegetative Environmental Buffers. Vegetative Environmental Buffers or VEBs are purposefully planted trees and shrubs near and around production sites that intercept, filter and aid in the dilution of odor-laden air streams associated with animal production sites. Decision-support tools such as *VEB-econ* link producers to sound, science-based information and can be critical to facilitate the implementation of bio-physical and cost effective environmental stewardship. Odor management continues to be a complex social, economic, and biophysical challenge for livestock and poultry producers. Computerized and broadly usable DSTs have been noted for their potential to be among the most critical of management tools for producers to assess complex agricultural issues. However, in order for DSTs to be used at all and used effectively to aid land-use decisions, these tools must be broadly accessible, user-friendly, and provide germane and up-to-date information. Specifically in the context of VEB based odor management, a VEB oriented DST must provide site-defined technical information that can be readily and directly used in a producer's planning process.

As a planning tool, *VEB-econ* bridges a common and challenging outreach knowledge gap when it comes to the deliberate integration of trees into agricultural production systems. Many land management professionals and Extension personnel have expertise in farm production systems

or in trees and forestry but rarely expertise in both. Such gaps in experience or knowledge have led to inadequate planning and subsequent failure of VEB systems being appropriately established (leading to tree mortality or emergent site hazards such as undesirable snow deposition). Furthermore, effective VEB designs are based on site-level air-dynamics and tertiary odor mitigation principles, which represent a degree of specialized planning knowledge. Thus, *VEB-econ* identifies where trees should ideally be planted relative to the layout of the animal production system and relative to odor mitigation principles, matches appropriate tree species to soil conditions, and provides key tree establishment and management guidelines to maximize tree health and prevent unnecessary tree mortality. We anticipate that *VEB-econ* will be an important planning tool strengthening the Iowa pork industry's ability to tackle important air quality management issues. The use of trees for odor management has been on the upswing in Iowa over the past few years and has been a focus of at least one significant Industry support organization in Iowa, the Coalition to Support Iowa's Farmers via their Green Farmstead Partner program (http://www.supportfarmers.com/programs/green-farmstead-partner-program). The use of VEBs also factors into the Iowa Master Matrix scoring protocol used to evaluate new production sites. If VEBs are going to continue to be planted and utilized, it is critical that they are planned in accordance to general odor mitigation principles and conform to site-level characteristics. To date, *VEB-econ* is the best available tool for the VEB planning process. *VEB-econ* can be found at: https://veb.nrem.iastate.edu/

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