J. For. 116(6):573–580
doi: 10.1093/jofore/fvy051

economics

VEB-Econ: A Vegetative Environmental Buffer Decision-Support Tool for Environmental Quality Management

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Purposefully planted tree and shrub systems called Vegetative Environmental Buffers (VEBs) have been shown to be biophysically effective in intercepting, filtering, and diluting odor-laden air streams associated with animal production sites. This article overviews the web-based VEB planning and design program called *VEB-Econ*. *VEB-Econ* allows users to locate the site of current or planned animal production facilities within a high-resolution photomapping GIS (Google Earth). Users use to-scale drawing tools to delineate boundaries, roads, animal buildings, and other structures, so as to parameterize idealized tree-row locations. Users specify the number of desired tree rows, preferred tree-row protection zones, etc. Layered into the mapping tool is a soil database linking tree species to soil-based tree suitability recommendations. *VEB-Econ* estimates the total annualized costs for tree establishment, long-term management, any opportunity costs, and factors in available Natural Resources Conservation Service Environmental Quality Incentive Program cost-share programming for VEBs. Additionally, *VEB-Econ* can be used to design field and homestead windbreaks or small plantations.

Keywords: windbreaks, geographic information systems, odor management, software

Odor management in agricultural regions has long been a pressing concern, and access to and guidance regarding low-cost biophysically effective odor-mitigation technology are in demand (Ni 2015, Maurer et al. 2016). Recent research has demonstrated that tree barriers called VEBs are a relatively low-cost and biophysically effective odor-mitigation technology suitable for most confinement production systems in the Midwest (Tyndall and Colletti 2007, Liu et al. 2014). VEBs are purposefully planted trees and/or shrubs usually arranged in linear patterns near and around animal production sites that intercept, filter, and otherwise reduce the concentration of odor-laden air (Tyndall and Larsen 2013). This article overviews the decision-support tool "*VEB-Econ*," a user-friendly Geographic Information System (GIS)-based planning tool to aid in the design of site-specific VEBs. Computerized and broadly usable decision-support tools such as *VEB-Econ* have been noted for their potential to be among the most critical of management tools for producers to assess complex agricultural issues (Fernandez and Trolinger 2007, Watermolen et al. 2009). *VEB-Econ* bridges a common and challenging outreach knowledge gap when it comes to the deliberate integration of trees into agricultural production systems. A fully functional beta version of *VEB-Econ* can be found online and used for free at: https://veb.nrem.iastate.edu/. Although *VEB-Econ* is usable as a basic VEB or windbreak design tool for properties located anywhere in the United States, the current version of *VEB-Econ* in terms of tree selection and financial data is specific to the state of Iowa (the nation's leader in hog and egg production). Subsequent versions of the software, however, will include more state-specific financial data (new iterations of the software are planned for summer 2019).

Many land-management professionals and Extension personnel have expertise in farm production systems or in trees and forestry but rarely expertise in both (Tyndall and Colletti 2007). Such gaps in experience or knowledge have led to inadequate planning and either a disregard of the technology altogether or subsequent failure of an established VEB system because of poor establishment and management techniques (that can lead to extensive tree mortality, higher costs, or creation of emergent site

Received May 16, 2018; accepted September 11, 2018.

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Acknowledgments: *This project was supported by funding from the Iowa Pork Producers Association and the National Pork Board. Project # NPB 13-243 (a Pork Checkoff-funded research grant). We would also like to thank John VanDyk and Ann Greazel with Iowa State University Biology Information and Technology, and web application engineer Ryan Frahm.*

hazards such as undesirable snow deposition). Furthermore, effective VEB designs are based on site-level air-dynamics, tertiary odor-mitigation principles, and, in cold regions, snow management, which all represent a degree of specialized planning knowledge regarding localized air movement (Tyndall and Larsen 2013). Thus, *VEB-Econ* identifies where trees should ideally be planted relative to the layout of the animal production system, general prevailing wind patterns, and odor-mitigation principles. The tool also matches appropriate tree species to soil conditions and provides up-to-date 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 photomapping GIS (utilizing Google Earth; see Figure 1). Users navigate to find their production site or proposed site and use scaled application tools to delineate property boundaries and other key design parameters (e.g., scale of production system, building orientation, ventilation systems in use, location of roads) and to select the dimensions of a site-specific idealized VEB (e.g., number of tree rows, orientation of plantings, species selection, 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). Tree recommendation/selection in states other than Iowa is not automated, so users will need to consider the characteristics of the soils present and make their own researched determination of appropriate species. Once a VEB design plan is finalized, a basic economic analysis of that design and general management guidelines are provided.

Vegetative Environmental Buffer Biodynamics and Odor Mitigation

Before describing *VEB-Econ* in detail, an overview of how VEBs function regarding odor mitigation is instructive. As an odor-management technology, VEBs have been shown to aid in the mitigation of odors, particulates, and ammonia associated with animal production through a complex of biophysical and social dynamics (Tyndall and Colletti 2007, Liu et al. 2014, Willis et al. 2017). As comprehensively overviewed in Tyndall and Colletti (2007), the biophysical VEB dynamics of note are: (1) enhanced dilution/dispersion of odor into the lower atmosphere via vertical atmospheric mixing caused by air being pushed upward via forced mechanical turbulence (windbreak dynamics); (2) odor filtration through particulate interception and retention (livestock production odors, e.g., volatile organic compounds, adhere to particulates, and tertiary odor management is largely about controlling the movement of particulates); (3) odor/particulate fallout because of reduced wind speeds; (4) adsorption and absorption of ammonia onto and into the plant because of a chemical affinity that ammonia has to the waxy coating on tree leaves. Regarding more social-oriented outcomes of this technology, VEBs have been noted to help subjectively improve site-level aesthetics and soften the visual cues of negative responses to confinement animal production and odor. Anecdotally, VEBs have aided in improved producer/community relations because of their visibility as an odor-management technology (Maulsby 2012).

The biophysical effectiveness of a VEB in mitigating odor will vary considerably from site to site because of variation in VEB design, production scale, on-site manure management, topography around site, and overall airshed conditions (Tyndall and Larsen 2013). The effect of a VEB on odor will also vary across time as the trees and shrubs grow larger and more morphologically complex, thus enhancing the VEB/odor interaction dynamics. Depending upon the growth rates of individual tree and shrub species, the biophysical response to the presence of trees may take 1–3 years (or longer) to fully manifest; yet aesthetic and/or social benefits may present themselves immediately after planting (Tyndall and Colletti 2017). With regard to specific biophysical effects of VEBs on livestock odor, a number of regional field, laboratory (e.g., wind tunnel), and computer-simulation studies have quantified reductions in both particulates and odorous volatile organic compounds. For example, a recent research review from Liu et al. (2014) summarized five studies noting that VEBs of various configurations (e.g., one to five rows of trees) have been shown to reduce downwind concentrations of: ammonia and dust by up to 50%; hydrogen sulfide (H_2S) by up to 85%; and odorous volatile organic compounds by up to 66%. These reductions in the physico-chemical aspects of odor in turn contribute to odor mitigation by variously reducing the frequency, intensity, duration, and subjective offensiveness of odor events (Lin et al. 2006, Tyndall and Colletti 2007).

According to a 2008 Iowa-wide swine producer survey, 21% of Iowa producers use VEBs for odor management, and 75% expressed a willingness to try them with existing facilities (Tyndall 2009). Despite the demand for VEBs, the lack of comprehensive VEB design, cost, and management information has been identified as one of the

Management and Policy Implications

Vegetative environmental buffers (VEBs) are a tree-based animal odor-mitigation technology increasingly being used in agricultural landscapes. *VEB-Econ* is a web-based tool designed to aid the planning process, increase the accuracy of tree/shrub selections based on soil suitability, provide users with a visual of the offset distance from buildings while selecting the number of rows and species, and provide current cost estimates for VEB establishment and management with and without current Natural Resources Conservation Service (NRCS) cost-share funding (via the Environmental Quality Incentive Program). Adoption of VEBs by producers relies heavily on the interaction between the producer and NRCS personnel. In many states, access to cost-share assistance for VEBs is not mandated to be reviewed by the local District (or public) Forester's office. As a result, when VEBs fail to establish, this is most often caused by improper species selection given the soil types around the facility, as well as rows being placed too close to the facility creating issues during the summer cooling season and winter months with unwanted snow drifting across access roads. *VEB-Econ* provides the necessary guidance in a user-friendly online format beneficial to animal producers, outreach professionals, farm- and forest-management consultants, tree nurseries, and other key environmental quality stakeholders.

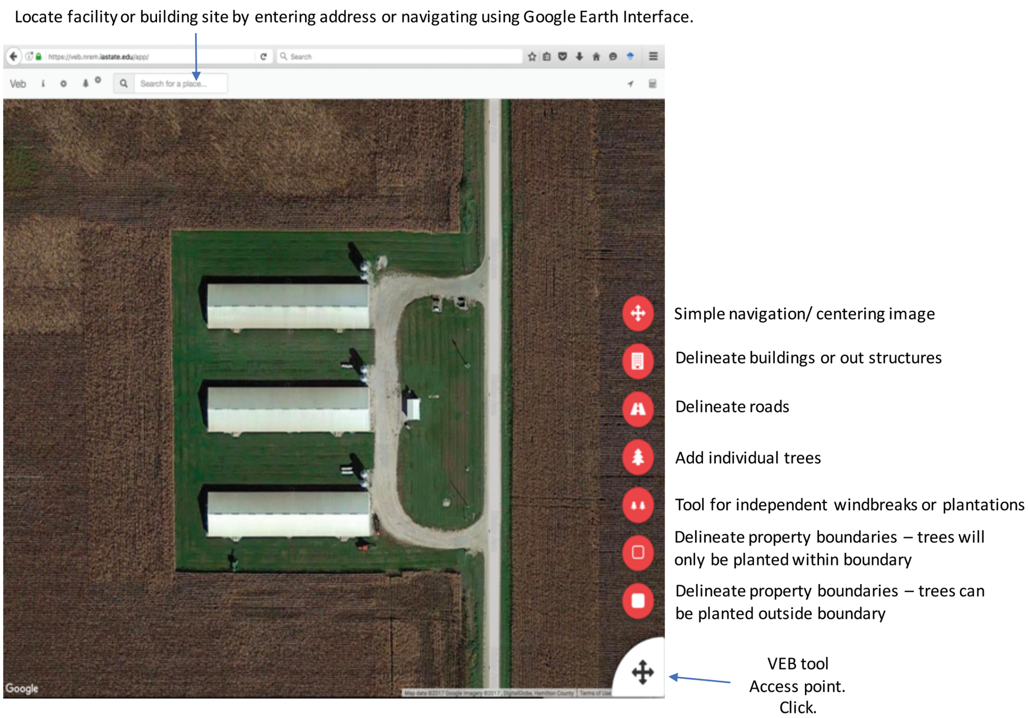

Figure 1. Description and example of the *VEB-Econ* tool applications and online GIS interface.

chief barriers to swine producer adoption of this air-quality technology (Tyndall 2009). The use of a VEB is ultimately contingent upon the financial feasibility of the technology at the farm level, because it represents an "out of pocket" expense for most producers. Comprehensive financial analysis of VEBs used in the context of confined hog production and hog producer survey data suggest that VEBs are comparatively affordable relative to producer willingness to pay (WTP) for odor management. In Iowa, Tyndall and Grala (2009) and Tyndall (2009) estimate that average costs of VEB establishment and management over a 20-year period come in between 35% and 71% below Iowa swine producers' WTP on average for odor-mitigation technology; suggesting available monies for multiple odor-management technologies/approaches per farm. In the context of financial planning, it is important that animal producers can estimate the direct upfront and longer-term management costs of various approaches to managing environmental quality to make the most efficient use of available capital. It has long been noted that a lack of planning capacity and lack of cost assessment (particularly in retrofit situations) are considerable barriers to cost-effective odor mitigation (Tyndall 2009, Williams 2009).

All this considered, *VEB-Econ* is a decision-support tool that connects livestock and poultry producers and their advisors to up-to-date, science-based information designed to enhance the financial planning process and to aid in the design of a VEB system that best suits individual animal production systems.

VEB-Econ Design Applications

The following describes the functional use of *VEB-Econ* and overviews the data underlying the application. For a VEB to be biophysically effective in mitigating odors and ultimately inexpensive to manage, tree rows need to be located strategically to maximize mitigation dynamics and prevent on-site management hazards, and trees must grow in a healthy manner. As such, there are a number of general design parameters that *VEB-Econ* considers as part of the planning and establishment phase.

Once a user finds their production site in the mapping application, *VEB-Econ* guides initial 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. First, 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). Second, in Iowa, winter winds largely come from the north/northeast. Therefore, *VEB-Econ* predetermines the planting distance of tree rows north of building and roads to avoid problematic snow issues. Third, 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/southeast) 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 50 feet away from fans, as typically recommended to prevent back-pressure on the fans and to protect the trees from desiccation and/or ammonia burn on tree leaves (Malone et al. 2006). With these considerations, 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 1.

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 the 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). Woodland Suitability Recommendations also note 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. Global Positioning System data are downloadable to aid establishment actions. Designs and financial reports are printable.

See Figures 3 and 4 for examples of species selection based on soils present and an example of a VEB design.

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 preconstruction site plans. Therefore, to help producers determine capital requirements, *VEB-Econ* estimates total present value and annualized costs for: (1) site preparation; (2) tree establishment, which includes purchasing tree stock and planting costs; (3) long-term maintenance, which includes weed control and periodic site mowing; (4) any land purchase costs or opportunity costs using forgone land rent as the proxy; and (5) the estimated financial cost-share effects of the USDA Natural Resource Conservation Service's EQIP programming.

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.), assigned current market prices (costs), and tracked as to when they occur (see Table 2 below). All costs are discounted using a standard discounting formulation following the general VEB cost model from Tyndall and Grala (2009) as shown below:

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

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

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 denotes 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} denotes the present value of VEB maintenance requirements (includes activities such as: mowing between tree rows, tree/shrub replacement, drip irrigation, and followup herbicide); these are periodic and/or annual costs. Finally, $PV^{VEBoppcost}$ denotes 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 or annual if land was/is rented. The 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

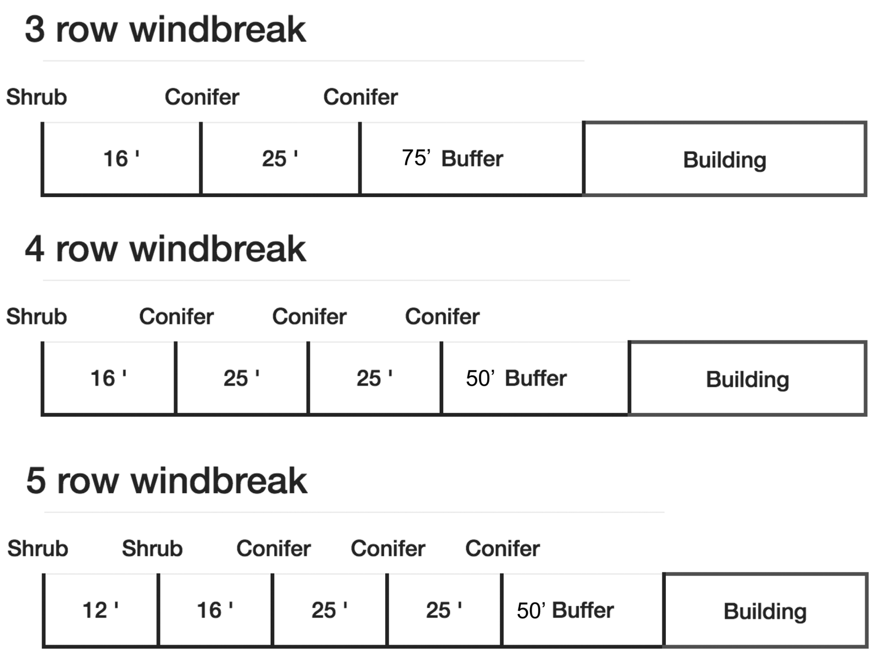

Figure 2. Current *VEB-Econ* default settings for tree row distance north of buildings and spacing between tree rows.

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	20–30*
Shrubs	6

* White spruce (*Picea glauca*) and Black Hills spruce (*Picea glauca* var. *dens.*) are 20 feet; all other conifers are 30 feet.

planning horizon (n) at a specified discount rate (i) (Sullivan et al. 2005). An equal annual cost basis allows producers to consider the costs of a long-term management endeavor in the same time frame that they do typical farm production costs, thus providing important capital planning context (Jacobson 2003). A 20-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 US Environmental Protection Agency's recommended discount rate for environmental quality projects that involve only costs (Tyndall and Roesch 2014). For additional context, users can enter the total number of animals produced annually, and *VEB-Econ* will calculate the cost of the VEB on a per-animal basis (dividing annualized VEB cost by the total annual animal production). Specific to hog production, cost per pig/hog is one of the preferred ways that swine producers consider their costs for environmental management actions (Tyndall 2009).

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 2). 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 3). The 2018 Iowa EQIP payment schedule for VEBs is also included and automatically aligns with the type of VEB designed (Table 4). All financial data will be updated annually.

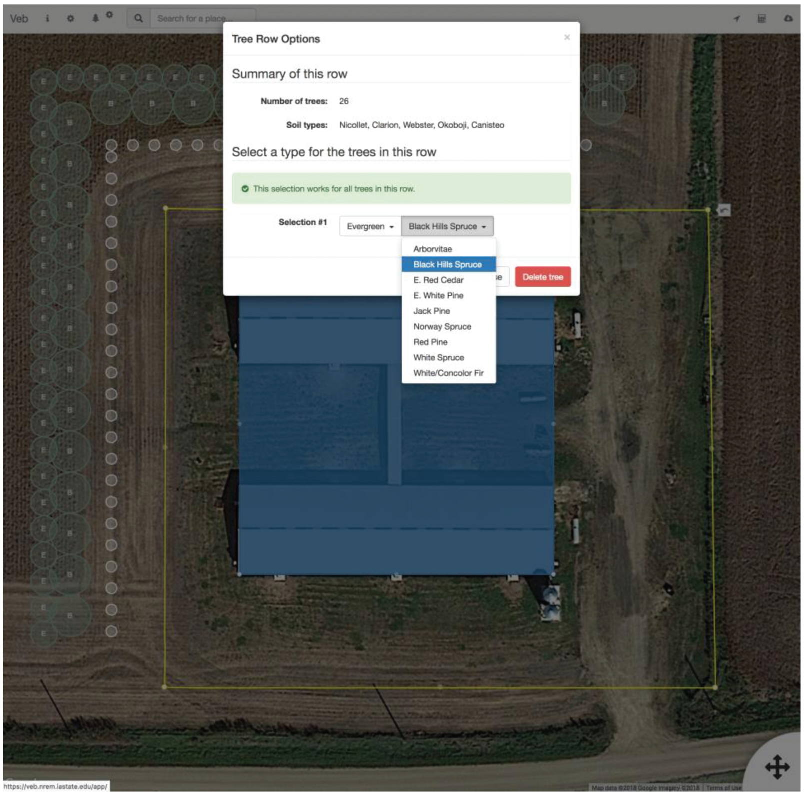

Figure 3. Example of a VEB design around a three-building confined animal facility and the species-selection process based on soils present.

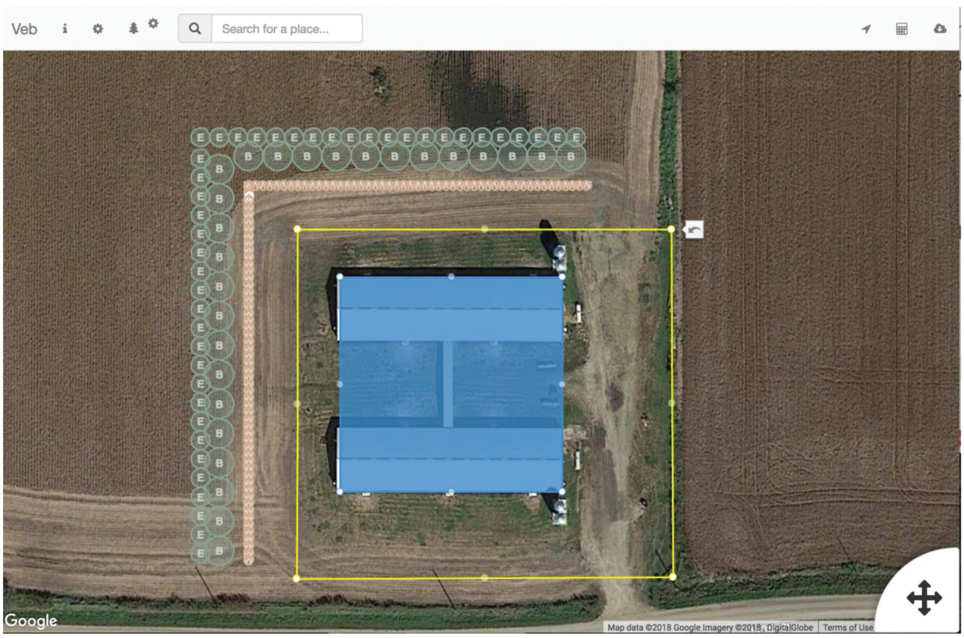

Figure 4. Design displaying a simple three-row VEB located around the west and north sides of a three-building, naturally ventilated animal building; tree species were selected based on soils include Eastern red cedar (*Juniperus virginiana*) in the outside row, hybrid willow (*Salix spp.*) in the middle row and Ninebark (*Physocarpus opulifolius*) on the inside.

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 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 and cost-share program database unique to that state.

EQIP: Practice Code 380 (Windbreak/Shelterbelt Establishment)

The EQIP (administered by the Natural Resource Conservation Service) provides cost-share funding for eligible farmers, for the establishment of VEBs. The program uses 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 4 presents the Iowa EQIP 2018 Payment Schedule for Practice Code 380. Cost-share funding through the USDA NRCS for the establishment of VEBs and windbreaks is available in all US midwestern states.

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 represent the money needed to cover the costs of establishing the VEB (in most cases, the majority of a VEB's 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; and finally, total annualized costs with and without the EQIP cost-share payment.

Other *VEB-Econ* Applications

Importantly, *VEB-Econ* has applications beyond the livestock production odor-management context. *VEB-Econ* has an independent windbreak function so that it can be used to design and assess the costs of establishing and managing field or homestead windbreaks and/or simple tree plantations. In US midwestern agricultural landscapes (and other regions), windbreaks have long been used for both crop and livestock production as well as for conservation benefits (Brandle et al. 2009). Lowered wind speeds can reduce leaf damage and root lodging, enhance pollination in both row and higher-value food-crop systems (e.g., fruits and vegetables), and reduce wind erosion, which

Table 2. 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.

Action	Year(s)	Price/unit (2017 US$)
Site Prep if planting in grass*		
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*		
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 3 below
Shrubs purchase cost	0	Variable; see Table 3 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†	3	Variable; 10% of initial planting
Shrub replanting†	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/h; mow ~1.3 acres/h
Other relevant costs		
Overhead/management‡	Annual	2% of year 0 costs
Land rent/or land purchase§	Annual or 0	Variable; proxy is land rent; land purchase price is also possible

Note: All costs are in 2017 US$. Updated from Tyndall and Grala (2009). Budgets will be updated annually

* 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 the life of the operation.

† Some tree and shrub mortality should be expected. In Iowa, about 10% mortality of initial planting is typical in otherwise healthy windbreaks.

‡ 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.

§ 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 2018 was $222/acre (Plastina and Johanns 2018a, b).

Table 3. VEB-Econ default tree and shrub nursery stock pricing*.

Tree/shrub	Bareroot (US$)	Container (18" to 24") (US$)	Container (2' to 3') (US$)	Container (3' to 4') (US$)	Container (4' – 5') (US$)	Container (>5') (US$)
Hybrid willow	1.03	6.50	7.57	8.65	11.00	11.00
Eastern red cedar	1.40	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: Data are a compilation of prices from five Iowa-based tree nurseries; all prices per tree/shrub are based on 2018 pricing catalogs.

* The cost of nursery stock of any size can vary significantly from this pricing guide because of 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.

Table 4. Iowa EQIP 2018 Payment Schedule for Practice Code 380*.

Variant	Variant description	Payment ($/foot)	Payment with temporary irrigation ($/foot)
380-1	3 row windbreak, containerized planting stock	3.20	6.19
380-3	3 row windbreak, bareroot seedling planting stock	1.04	4.03
380-5	1 row windbreak, containerized tree planting stock	0.57	0.88
380-7	1 row windbreak, containerized shrub planting stock	1.27	1.68
380-9	1 row windbreak, bareroot tree seedling planting stock	0.33	0.46
380-11	1 row windbreak, bareroot shrub seedling planting stock	0.45	0.57

* Practice must be maintained for at least 15 years; payment rate is based on 50% of the estimated incurred costs and forgone 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 25–40% higher.

protects soil fertility. Windbreaks also aid in managing spring-time soil moisture conditions during planting, which can be important in drier climates or during drought events, and, under certain conditions, can enhance plant water-use efficiency by mediating micro-climates and evapotranspiration. All of these are outcomes that can in various ways enhance yields or otherwise protect crop attributes and quality. In the context of livestock production, windbreaks have been shown to reduce animal stress and improve weight gain efficiency by mediating winter temperatures. In terms of habitat, windbreaks are known to provide critical habitat (e.g., food, shelter, tree nesting sites) in agricultural landscapes for a variety of songbirds and game mammals (particularly cottontail rabbits and white-tailed deer). Broader ecosystem services such as carbon sequestration, improved landscape aesthetics, snow management, and recreational opportunities as well as ecosystem goods such as biomass are also associated with windbreaks.

Conclusion

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. Tree-based VEBs have been shown to be a low-cost odor-mitigation technology suitable for both retrofit and preconstruction confinement animal production situations. The lack of comprehensive VEB design, cost, and management information has been identified as one of the chief barriers to producer adoption of this air-quality technology (Tyndall 2009). To that end, *VEB-Econ* is designed to aid in the adoption of VEBs and be useful to animal producers, outreach professionals, farm and/or forest management consultants, contractors, tree nurseries, and/or those simply seeking to enhance ecosystem functionality and outcomes by planting trees and shrubs.

VEB-Econ runs on modern browsers and devices (e.g., Apple iPad and Android -based tablet devices). The website includes access to the software, a step-by-step illustrated user's guide, and comprehensive documentation regarding the default VEB design parameters, financial data used and sources, and guidance on modifying default data. We also provide downloadable peer-reviewed publications and other materials produced by our team that overview the biophysical dynamics of VEB-based odor mitigation, various economic factors involved, and general establishment and tree-management considerations for VEBs and general windbreak use.

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