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Prairie and tree planting tool—PT^2 (1.0): a conservation decision support tool for Iowa, USA

John Tyndall

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Abstract This article overviews the prairie and tree planting tool or PT^2 (1.0), an online GIS-based decision support tool for landowners interested in exploring opportunities to plant prairie or trees in and around their farm fields for conservation or production purposes. PT^2 1.0 can be found online at: https://pt2.nrem.iastate.edu/. With the PT^2 (1.0) users locate farm fields of interest in an online aerial photograph and mapping geographic information system (GIS). Users explore areas they are considering for prairie or tree cover by examining different data layers: soil maps, 2-foot contour topography maps, LiDAR hillshade maps, and a map of current land values based on estimated land rent. Users then utilize scaled dimensional drawing tools to measure and delineate areas of interest for planting trees and or prairie. Once an area is delineated, users select from drop-down menus prairie seed mixes or woody species that are suitable for the soils present, and users can select basic long-term management options. PT^2 (1.0) estimates total annualized costs for tree or prairie establishment, long-term management, and opportunity costs (based on area weighted expected soil rent), and factors in the potential benefit of utilizing government cost-share programming, e.g., Environmental Quality Incentive Program or the Conservation Reserve Program. Key data layers are currently functional in Iowa, likewise the financial data underlying the cost analysis are specific to Iowa. PT^2 (1.0) is, however, open source and open code and guidance is provided regarding how to access and adapt the data for use in other states.

Keywords Prairie · Agroforestry · Decision support tool · GIS · Conservation · Financial analysis

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J. Tyndall (✉)
Iowa State University, Ames, IA, United States
e-mail: jtyndall@iastate.edu

Introduction

The US Corn Belt region is simultaneously one of the most productive and least diverse agricultural regions in the world (Guanter et al. 2014; Aguilar et al. 2015). 72 % of Corn Belt land area is dedicated to the production of corn and soybean commodities through a corn-soybean rotation or continuous corn planting (Green et al. 2018). This extensive row-crop orientation while highly valuable in terms of gross regional revenue is often challenged with annually volatile net revenue at field scales (Brandes et al. 2016). Likewise, the region is also known for various row-crop related environmental challenges such as chronic air and water quality impairments (Zimmerman et al. 2019; Domingo et al. 2021), and declining habitat for critical species such as pollinators (Dolezal et al. 2019). As such, in heavily modified and simplified agricultural regions such as the US Corn Belt, there have been increasing calls for restoring or otherwise integrating perennial vegetation into or around row crop systems as a way to: (1) restore biodiversity related ecosystem functionality including crop productivity (Thogmartin et al. 2017; Moore et al. 2019; Garibaldi et al. 2020; Tamburini et al. 2020; Nelson and Burchfield 2021), and (2) offer landowners land use alternatives for lower productivity areas that reduce overall farm costs (Brandes et al. 2016; Lovell et al. 2018) and provide other land owner benefits such as recreation, aesthetics, and alternative income streams (Mattia et al. 2018; Brandes et al. 2018).

There are many conservation-oriented practices that are based on prairie and tree cover. Likewise, both of these perennial vegetation systems have distinct production opportunities in the Corn Belt region particularly biomass for bioenergy or for use as fodder and bedding. Prairie systems are important as habitat for pollinators, game, and non-game wildlife particularly grassland bird species (Schulte et al. 2016). Strategically located prairie systems planted as strips of vegetation on the contours and or toeslopes of crop fields are increasingly being promoted and utilized in the Corn Belt region as a water quality best management practice that intercepts and slows runoff, increases infield infiltration and water storage due to deep root systems, with the combined effect of significantly reducing field-level nutrient and soil loss (Schulte et al. 2017). Prairie systems have also long been noted for their potential as bioenergy feedstock for myriad energy systems (e.g., liquid fuels, electricity and heat, biogas) due to high yield potential, as well as their concomitant field and landscape scale environmental contributions (Tillman et al. 2006; Mishra et al. 2019; Englund et al. 2021). For decades, trees have been planted in Corn Belt landscapes for windbreaks and shelterbelts to minimize wind erosion and protect fields, buildings, and livestock, or as forest buffers used to minimize pollen drift, mitigate livestock odor, or to protect surface water from field runoff (Jose 2009; Tyndall and Colletti 2007; Brandle et al. 2009; Groh et al. 2020). Tree plantings purposefully integrated into row crop systems are also used to generate local and regionally important ecosystem outcomes such as wildlife and pollinator habitat (e.g., Berges et al. 2010; Kay et al. 2020), as well as important outcomes at the biosphere scale such as greenhouse gas mitigation specifically via carbon storage and sequestration (Khaleel et al. 2020; Chenyang et al. 2021). Plantings of fast growing, high-yielding species are considered to be multifunctional biomass production systems suitable for myriad bioenergy outcomes as well as other wood products (Zalesny et al. 2011; Hand et al. 2019).

Landowners interested in exploring opportunities to diversify the land cover on their farmland by integrating prairie or trees are often challenged by a number of informational barriers. Farmer surveys denote that landowners and farmers often lack an initial knowledge base regarding how to utilize perennial land cover in managing environmental or agronomic quality of their row crop systems (Hand and Tyndall 2018). More pragmatically, interested landowners and their advisors often have limited knowledge about where specifically perennials should be established relative to specific ecosystem outcomes, what species should be planted, and how they should be established and managed over time (Tyndall and Randall 2018; Whitehair 2019).

Furthermore, financial information regarding costs or revenue potential related to perennial systems is often lacking, out of date, or too generically presented to be site-specifically informative (Tyndall and Roesch 2014). Financial information such as this is critical for landowners to understand the short- and long-term capital requirements involved with conservation or alternative cropping systems (Bravard et al. 2021). Meanwhile, federal and state conservation funding is available to landowners to help cost share establishment and management of perennial conservation practices and with some programs provide land rental payments, likewise, USDA loan programs open up opportunities for landowners to supplement investment capital for biomass systems (Carlisle et al. 2019). Yet, financial cost information is often required for landowners to properly weigh the potential use of conservation funding and to determine which programs are in their best interests (Tyndall et al. 2013).

In order to help landowners and their advisors consider integrating prairie or trees into their farm systems in ways that best suit their land use objectives, an easy-to-use online geo-spatial decision support tool called the prairie and tree planting tool or PT^2 (1.0) was created. PT^2 (1.0) is a geographic information system (GIS)-based tool that connects users to site-specific information aiding the design of prairie or woody conservation or production systems and enhances the financial planning process. Spatially, depending on the user's interests, the PT^2 (1.0) provides design and financial analysis of prairie or tree systems ranging from simple plantings of several square meters in size to larger planted systems at scales that can range to hundreds of hectares. This article provides an overview of this tool, the data that underlie its utility, and the context for its use. Decision support tools (DSTs) in agriculture are designed to assist users in making effective land use decisions by helping them evaluate complex data organized in relevant decision-making stages and by estimating outcomes associated with user choices (Rose et al. 2016).

There are a number of GIS oriented DSTs that help farmers and their advisors explore spatial opportunities for integrating perennial vegetation into a farm or landscape. The utility of spatial DSTs can span topics such as determining suitable perennial species or land for planting or involve topics that use complex biophysical process models to explore hydrologic or ecological outcomes of land use scenarios (e.g., Ellis et al. 2004; Tomer et al. 2015; Saleh et al. 2015; Borucke et al. 2019; Lai et al. 2020). There are also GIS-based DSTs that are specific to certain agroforestry conservation or production practices such as vegetative environmental buffers for odor mitigation (Tyndall and Randall 2018), riparian forest buffers (Vermaat et al. 2018), and alley cropping (Tsonkova et al. 2014). Overall, DSTs can be quite variable in terms of the range of technical or content expertise required to operate the tool or interpret the output. DSTs also vary tremendously on the degree of input data required and the scale of analysis. PT^2 (1.0) appears unique among currently available perennial vegetation oriented DSTs in that it incorporates warm season grass and forb prairie as a perennial cover of interest along with trees, is easy to use yet features somewhat complex computational capacity, and features a site specific comprehensive financial analysis.

This paper first provides a general summary of the PT^2 (1.0) and its context for use. After, the data and computational procedures that underlie the PT^2 (1.0) are described. A step-by-step procedural example of its use in then provided. Finally, a brief overview is presented of how the software was developed, the specific software used, and how users can adapt this tool to suite their region or otherwise add value to its computational capacity.

Prairie and tree planting tool features and use

The PT^2 (1.0) can be found online at: https://pt2.nrem.iastate.edu/. There are no licensing or user fees associated with its use. Also important to note is that user or use data are not collected or archived in any way; this way users can be confident that their property information remains private. The tool features an easy to navigate online GIS interface with an OpenStreetMap (www.openstreetmap.org) address search engine, or users can navigate to field locations of interest via panning and zoom features (Fig. 1). While PT^2 (1.0) can navigate to anywhere in the USA, key data layers are currently functional only in Iowa, likewise the financial data underlying the prairie or tree cost analysis are specific to Iowa. PT^2 (1.0) is, however, open source and open code and guidance is provided regarding how to access and adapt the data for use in other states. As such, PT^2 (1.0) has the capacity to be adapted for use in multiple states.

Users do not need any background in GIS to use PT^2 (1.0), yet an ability to navigate PT^2 (1.0) itself and interpret aerial photographs and various other land feature images and maps is required in order to properly design different site-suitable perennial vegetation systems. For example, a user would need to be able to identify specific areas within fields based on vertical aerial photographs (satellite view), toggle between and interpret aerial photographs that display different seasonal vegetation conditions, use the zoom tool for desired scaling, and interpret any number of additional data layers such as a 0.6 m digital contour topography map. These user-based skills are demonstrated via an example later in this paper. Note that the PT^2 (1.0) does not model or otherwise demonstrate hydrologic processes or ecological outcomes. In its current form, the tool is an exploratory land use and financial planning tool where users select between prairie or the tree planting design applications. For both design tools, once the prairie or tree system of interest is determined, PT^2 (1.0) will calculate and present the estimated direct and opportunity costs of the planting, breaking costs down into the following categories: site preparation, establishment,

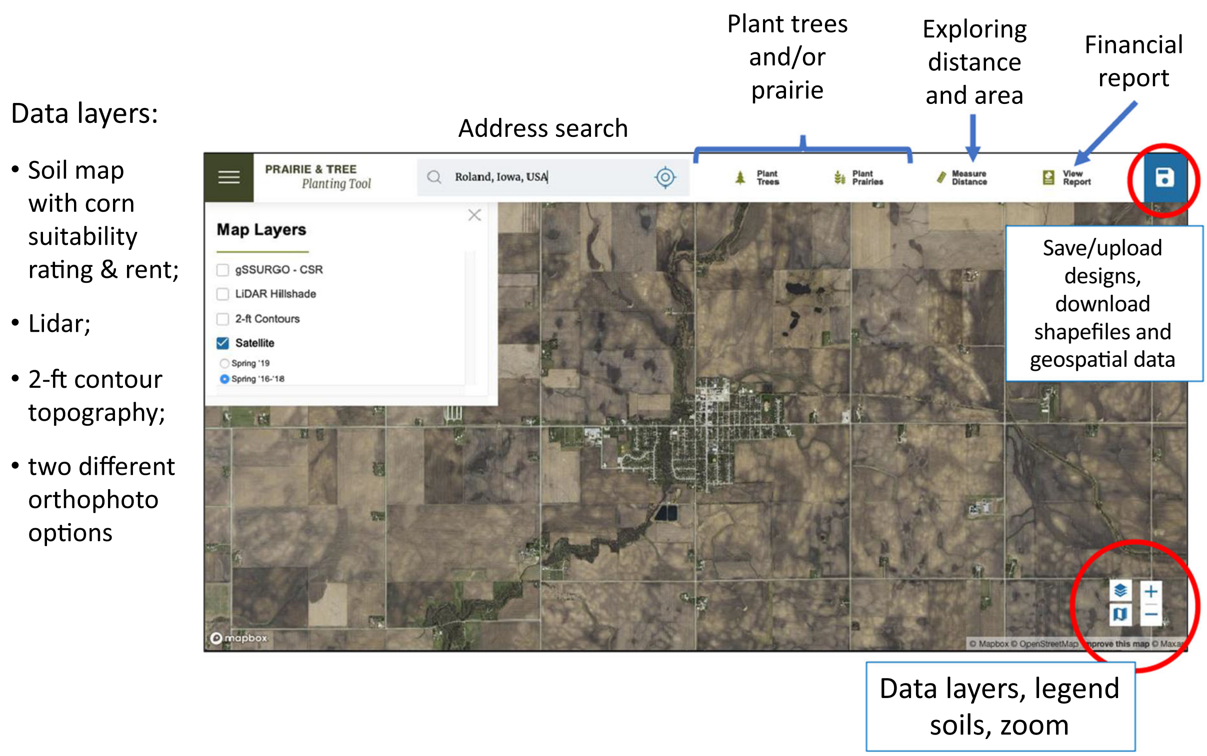


Fig. 1 Online GIS interface for PT^2 (1.0) and applications. PT^2 (1.0) can be found at: https://pt2.nrem.iastate.edu/

management, and opportunity costs. For prairie systems, users can review the financial effects of utilizing the 2020 Iowa Conservation Reserve Program for Pollinator Habitat (CP 42) or Prairie Strips (CP 43). For tree plantings, users can examine the financial effects of utilizing the 2020 Iowa EQIP program for establishing windbreak systems (Practice Codes 490-site preparation, 612 tree/shrub establishment, 380 windbreak tree stock). These conservation program parameters will be updated in the PT^2 (1.0) in accordance to any future changes in program payment schedules.

Procedurally, the PT^2 (1.0) guides users through a basic decision-making framework that is based on navigating to farm fields of interest and then allowing users to explore different geospatial data singularly or layered to help them seek out areas within farm fields that might benefit from prairie or tree plantings for conservation or alternative crop purposes or both (Fig. 2). PT^2 (1.0) then offers users planting design options that are based on site-level soil conditions, and various management options. A comprehensive financial analysis completes the analysis. Users can plan for single plantings or multiple plantings on multiple fields. Users can save designs and reupload into PT^2 (1.0) for continued analysis, and download shapefiles for use with ArcGIS for additional GIS modeling.

Methods and materials

There are several primary data layers that singularly or in combination help landowners and their advisors explore field level opportunities for planting trees and or prairie. Topography, soil type, landscape position (e.g., hilltop/summit/ridge, shoulder slopes, backslope, toe and foot slopes), aspect, proximity to water all can provide guidance on site-level vulnerabilities to erosion, overland flow of water, and the movement of nutrients and sediment. Or to explore alternatives for low yielding crop land. The PT^2 (1.0) includes different aerial orthophoto data sets, a soil map, 0.6-meter elevation contour layer, a LiDAR hillshade, layer, and a layer that displays the measure of crop productivity for the state of Iowa, the Corn Suitability Rating (CSR2) and concomitant estimated land rent

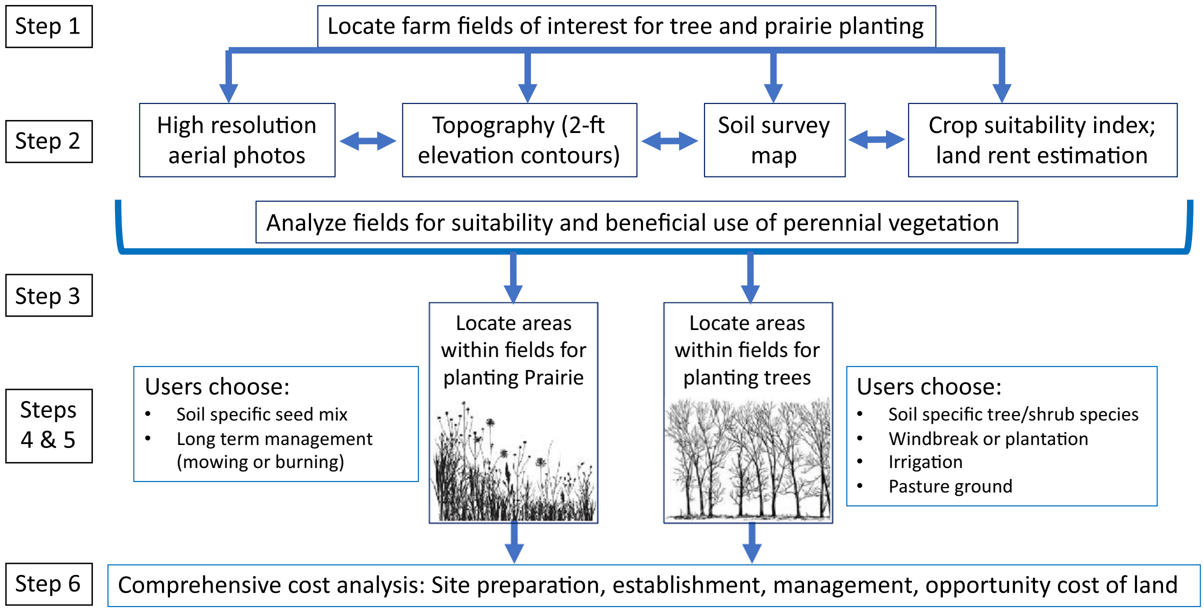


Fig. 2 Basic land use decision analysis and making framework of PT^2 (1.0)

value per soil type. Specific data layers are all publicly available for download and use and include:

- OpenStreetMap.org mapping platform from Mapbox (www.mapbox.com) that includes streets, buildings, administrative areas, water, and land data. This platform has an address or geographic coordinates search engine, and manual navigation tools including zoom.
- Iowa 2019 USDA National Agriculture Imagery Program (NAIP) Orthophotos, captured July-October 2019 (ISU GIS, undated a). These data are the latest geo-rectified orthophotos with a 1-meter resolution, summer flown so as to capture "leaf-on" conditions. NAIP data are acquired on a 3-year cycle, and is due for updates in 2022–2023. When available, PT^2 will be updated with this new data layer.
- Iowa 2016–2018 Spring Orthophotos (ISU GIS, undated b). These 1-meter resolution photographs allow for more ground level land view featuring the open canopy phenophase of deciduous vegetation.
- Iowa LiDAR hillshade from 2007 to 2010 statewide collection. Hillshade is a black-and-white high-resolution image showing elevation changes in the landscape. The Iowa data set is derived from a 1-meter digital elevation surface model that helps users determine potential flow patterns of precipitation run off, areas vulnerable to erosion, and aspect which is useful in determining site conditions for selecting and establishing site appropriate tree or prairie vegetation. This data layer was created by the state of Iowa in May 2017 (Iowa Geospatial Data 2020). The state of Iowa is currently in process of updating LiDAR-derived hillshade data and full state-wide coverage is expected in 2022 (Iowa Geospatial Data 2020). When available, PT^2 will be updated with this new data layer.
- 0.6 m elevation contour data are derived from and complements the LiDAR data layer (Iowa Geospatial Data 2020) and helps guide precision land positioning, determining field contours, and determining flow patterns of precipitation run off and areas vulnerable to erosion.
- NRCS SSURGO Soils web map service provides the soil mapping and CSR2 data layer (NRCS Soil Survey Staff 2015). The soil mapping data are used to determine the site suitability of various prairie seed mixes or tree species. This data layer also includes a measure of crop productivity, the Corn Suitability Rating (CSR2), which in turn is converted to estimated land rent value so that users can explore areas on their farms with lower opportunity costs of land.

Financial analysis methods and data

To provide the cost analysis that landowners require to make capital budgeting decisions the PT^2 (1.0) uses comprehensive baseline enterprise budgets (2020$ USD) specific to establishing prairie or planting trees in Iowa. Accounted for are: upfront site preparation and establishment costs, annual or periodic management costs, annual land use costs (opportunity cost of land), annual overhead costs, and practice relevant federal conservation program funding. Standard discounted cashflow analysis is conducted to calculate the total present value costs of either prairie or tree planting over a 15-year planning horizon with a 2 % real discount rate. Total present value costs are then annualized using a capital recovery procedure (e.g., Tyndall et al. 2013); annualizing costs is done to allow for comparative analysis with other farm-level production costs.

For the PT^2 (1.0) default cost data, the enterprise budgets for the direct costs of prairie and tree plantings were developed using a combination of custom rates and regional dealer transaction surveys as recommended by Tyndall and Roesch (2014). These budgets will be updated on an annual basis. See SI Tables 1 and 2 for comprehensive prairie and tree enterprise budgets.

Opportunity costs of land use

With regard to land use opportunity costs, when crop land is removed from production and used for prairie or tree plantings, PT^2 (1.0) calculates a weighted proxy measure for forgone revenue relevant to the state of Iowa (as per Zimmerman et al. 2019). An area weighted land rent calculation uses the Corn Suitability Rating index data layer (CSR2) provided by the NRCS gSSURGO database (NRCS Soil Survey Staff 2015) and average county level cash rental rate for cropland or pasture per CSR2 point data (Plastina et al. 2019). Land rent by CSR2 data is published annually by Iowa State University Extension & Outreach (Plastina et al. 2019; these data are presented in Bravard et al. 2021).

PT^2 (1.0) users are cautioned that while the tool captures variability in potential opportunity costs, the tool assumes a degree of uniformity in biophysical conditions and likewise the direct costs of establishment and management within any planting design. In reality the direct, management, and opportunity costs of planting prairie and or trees can vary considerably within a single planting, from one site to another and across time. Site-level costs depend on initial site conditions (such as hydrology, soil, cropping history), weather, practice design (including variable tree stock and seed mix costs), management choices, farmer/landowner experience, availability of technical or custom farm services, and the possibility of specific cost-lowering deals for materials and labor. As with all cost assessments of this type, the cost estimates provided by PT^2 (1.0) serve as baseline numbers and are meant to be informative rather than prescriptive.

Tree, shrub, and prairie seed mix cost

PT^2 (1.0) offers the user a drop-down menu for prairie seed mixes or tree/ shrub species selections based on the soils present in the areas of interest. Tree and prairie seed costs then are based on user selections. For prairie plantings, we created a database that categorized Iowa soils based on soil moisture categories (e.g., wet, wet-mesic, mesic, dry-mesic, dry); pre-made seed mix options are based on these classifications. If the mix of soils present in a defined area of interest overlap across two different moisture classifications, seed mix options for both soil moisture conditions are shown. Likewise, the 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: http://publications.iowa.gov/17411/). Compliance with IDNR species recommendations is required if landowners wish to participate in the Environmental Quality Incentive Program (EQIP) and receive cost share support. Depending on the purpose of the tree planting, it is possible that landowners would purchase older, larger tree stock so as to "get a jump start" on the practice (Tyndall and Randall 2018). As such, users can also select an initial planting stock size ranging from bareroot seedlings up to containerized tree stock over 1.52 m tall and the PT^2 (1.0) will account for differences in plant stock costs.

The default costs for pre-made prairie seed mixes across different soil conditions and conservation goals are based on a survey of regional seed company catalog prices (2019/2020$ USD). The default costs for tree planting stock are based on a database of regional nursery prices (2020$ USD) for various sizes of all tree and shrub stock (e.g., bare root stock to containerized stock). See SI Tables 3 and 4 to review the prairie seed mix and tree stock option costs.

Conservation program parameters and payment schedules for 2020

There are a number of different federal, state, or non-governmental organization conservation programs that landowners can utilize to obtain catered technical planning assistance and help offset direct and opportunity costs of planting trees and or prairie. For prairie systems, as part of the overall financial assessment, the PT^2 (1.0) includes the financial effects of two USDA Conservation Reserve Program options, one is the CP 42 Pollinator Habitat, the other is the new CP 43 Prairie Strips program. The CP-42 is designed to provide habitat for native pollinator species and honey bees. The CP-43 is designed to facilitate the use of strips of prairie panted on the contours or toe slopes of crop fields to intercept run off, increase infiltration and water storage, and create pollinator habitat. Both of these programs are paid by the USDA Farm Service Agency and facilitated by the USDA NRCS. For either program landowners receive: (1) Sign-up Incentive Payment (SIP) equal to 32.5% of first full year's annual rental payment, plus a 5% Practice Incentive Payment (PIP); (2) Annual 90% rental payments based on weighted rental rates; and (3) Cost share payment covering up to 50% of the eligible cost of establishing the practice. PT^2 (1.0) assumes a 15-year contracted period as part of the continuous signup program (as such, this would account for one and a half ten-year contracts).

For tree systems, as part of the overall financial assessment the PT^2 (1.0) includes the financial effects of two Environmental Quality Incentive Program (EQIP) options. EQIP is a working lands program administered and paid for by the USDA NRCS. These are one-time payments that occur in the first year of the practice. PT^2 (1.0) chooses and combines the program and payment parameters that best approximates the user designed tree planting. A process factors into the analysis the number of tree rows, species selected, and size of planting stock. PT^2 (1.0) assumes that landowner would at minimum receive payments for site preparation (CP 490; $341 per hectare) and some payment for nursery stock (CP 612 for tree plantations—payments range from $914 to $1502 per hectare, or CP 380 if the user designates the tree planting as a windbreak system with payments ranging from $1.18 to $11.25 per linear meter of windbreak). Optional irrigation program payments can be selected by user. Users are informed that other EQIP payments may be available for weed management, planting, mulching, and various other establishment considerations but are currently outside the scope of PT^2 (1.0), and that actual NRCS tree planting plans and payment schedules will vary from project to project.

Demonstration and discussion

To demonstrate the analytical and planning steps (presented in Fig. 2), as well as data and output of the PT^2 (1.0), the following case study example explores steps involved in designing a simple multi-species riparian buffer that features two rows of trees planted adjacent to a stream and a 6-meter-wide pollinator habitat prairie buffer between the trees and upland crop fields. The example site is located in Story County, Iowa (Central Iowa) along a tributary to the South Skunk River. The exact location of the site is confidential.

Step 1 The user in this case has located a field of interest for surveying planting options for both prairie and trees. The quick way to do this is to use the PT^2 (1.0) mapping tool address search engine and then the panning and zoom navigation features to locate the field(s) of interest.

Step 2 The user goes on to explore field-level opportunities for planting trees or prairie by selecting from drop-down menus singular and overlaid combinations of high-resolution data layers: aerial photographs, digital elevation (0.6 m contour lines), LiDAR hillshade, soil and soil rent data (Figs. 3 and 4). There is also a 2-dimesional measurement tool that can be used to measure area and distance for area and scale estimation purposes. In this example, the user is studying a currently unbuffered stream segment by examining a spring-flown aerial photograph with a 0.6 m contour map overlay. Examining the contours of the adjacent fields helps to determine potential

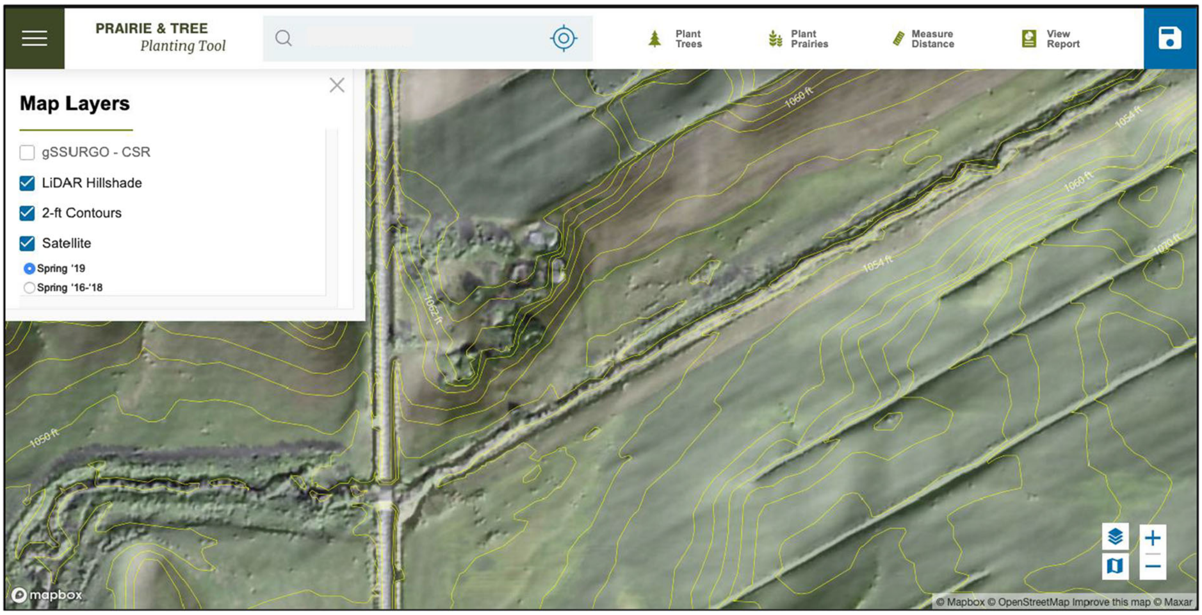


Fig. 3 Data display of PT^2 (1.0) showing spring flown 2019 aerial photograph with overlaid 0.6 m contour lines and LiDAR hillshade layers

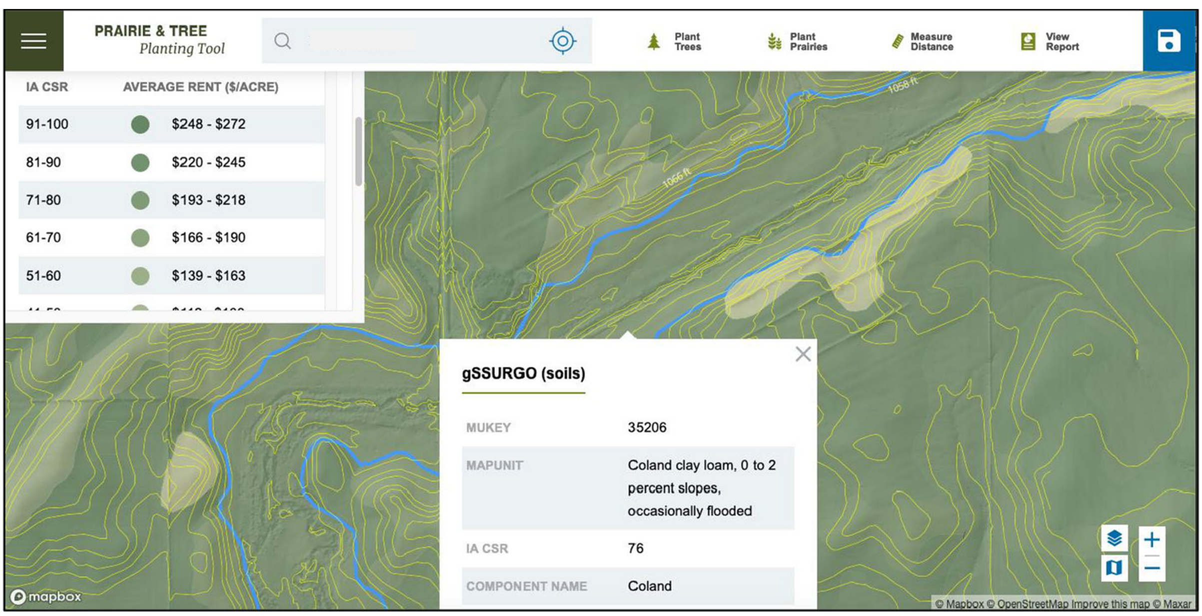


Fig. 4 Data display of PT^2 (1.0) showing gSUURGO soil survey data with overlaid Iowa Corn Suitability Rating based land rent data

patterns of run off and pre-existing features of the field such as linear terraces by interpreting topographic data and using their own knowledge of the field in question (Fig. 3). The soil map allows the user to understand general soil characteristics and explore the long-term opportunity costs of land that might be removed from production to make way for prairie or trees (Fig. 4). In this example, the primary soil adjacent to the stream is Coland, a poorly drained alluvial soil. PT^2 (1.0) displays the Corn Suitability Rating (CSR2) for Iowa soils. The CSR2 indexes the inherent soil productivity of each soil series relative to corn production in Iowa and is scaled from 5 to 100 for the least to most productive soils, respectively (Burras et al. 2015). The lower the CSR2, the lower the land use cost is for prairie or tree systems. In this example, the CSR for Coland soils is 76, which translates to moderate corn or soybean yields (Fig. 5). The average Iowa land rent for this soil type is in the $494 per hectare range (2020$).

Step 3 The user then selects the plant community of interest, either (a) prairie or (b) trees (Fig. 5). For the prairie design application, the user outlines an area of interest on the aerial photograph with a polygon drawing tool. Likewise, the tree planting tool allows users to select an area of interest for planting trees with a linear selection tool. PT^2 (1.0) will then arrange the desired number of rows of trees (representing idealized planting design for windbreaks or plantations). In this example, the user has first selected the tree planting design tool and designs a simple two row linear tree buffer that runs adjacent to the stream system. The user then selects the prairie design tool and uses the prairie polygon drawing tool to locate prairie, in this case a 6-meter-wide linear strip planted adjacent to the tree rows. Thus, it creates a multi-species riparian buffer system; shown in Fig. 5.

Step 4 To further design the chosen buffer system, the user selects from a dropdown menu prairie seed mixes of interest or tree nursery stock that are suitable for the soils present, Figs. 6 and 7. Choosing a plant community that suits the hyper-local site-level soil conditions will in theory increase establishment success and lower long-term maintenance costs. The user then selects various design and management parameters. For the tree planting, the user in this example has selected a fast growing willow species (*Salix spp.)* suitable for Coland soil conditions for one row and the slower growing swamp white oak (*Quercus bicolor*) for the other row (Fig. 6). The user then indicates if the site is a pasture or not. If the site is a pasture PT^2 (1.0) will account for slightly higher site preparation costs associated with terminating pasture sod compared to planting trees into crop ground as well as the land rent for pasture. In this example, the site has been in use for corn and soybean production and the appropriate weighted soil rent for crop ground is applied to the design. The user then selects the desired planting dimensions—spacing between trees in a row and spacing between tree rows, and size of planting stock with choices that range from bare root seedlings to containerized tree stock > 1.5 m tall. These dimensional features are not shown here.

For the prairie planting, the user selects from a menu of site appropriate pre-made warm season grass and forb seed mixes. In this example, a CP-42 pollinator mix suitable for hydric Coland soils has bene chosen (Fig. 7); CP-42 is the pollinator habitat

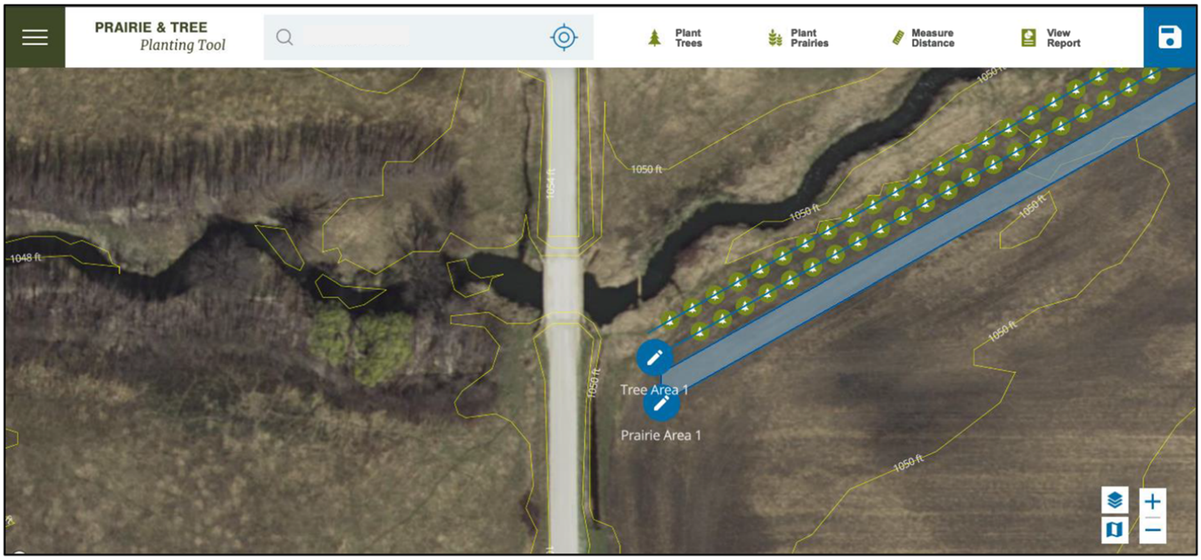


Fig. 5 Data display of PT^2 (1.0) displaying a view of the final user designed 2 row riparian tree buffer, with 6-meter-wide strip of prairie

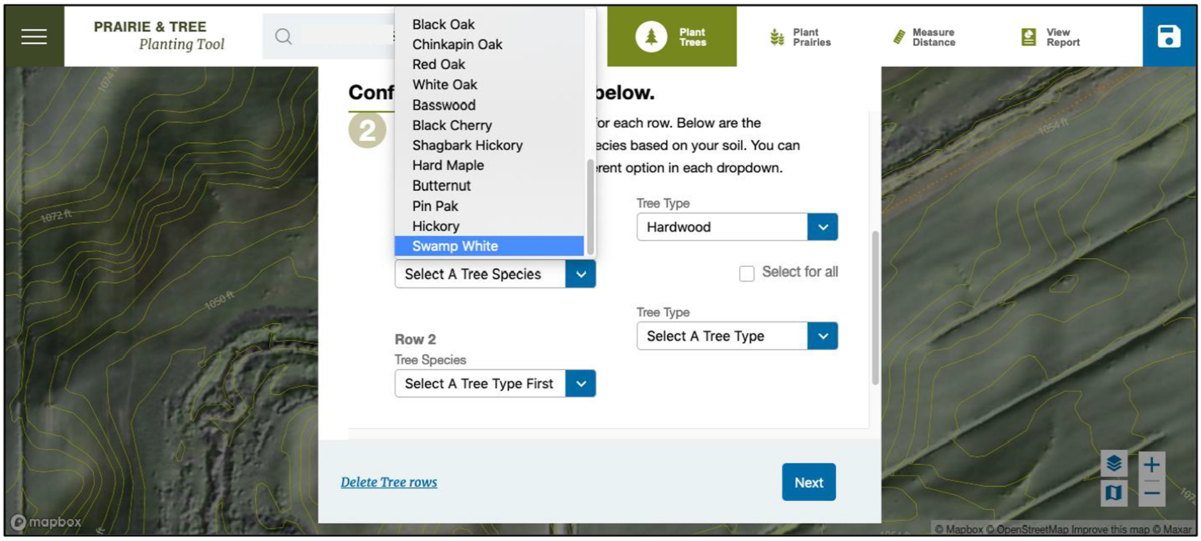


Fig. 6 Data display of PT^2 (1.0) showing species selection tool for a two-row tree buffer near a stream. PT^2 (1.0) only displays species that would be suitable for the soils present

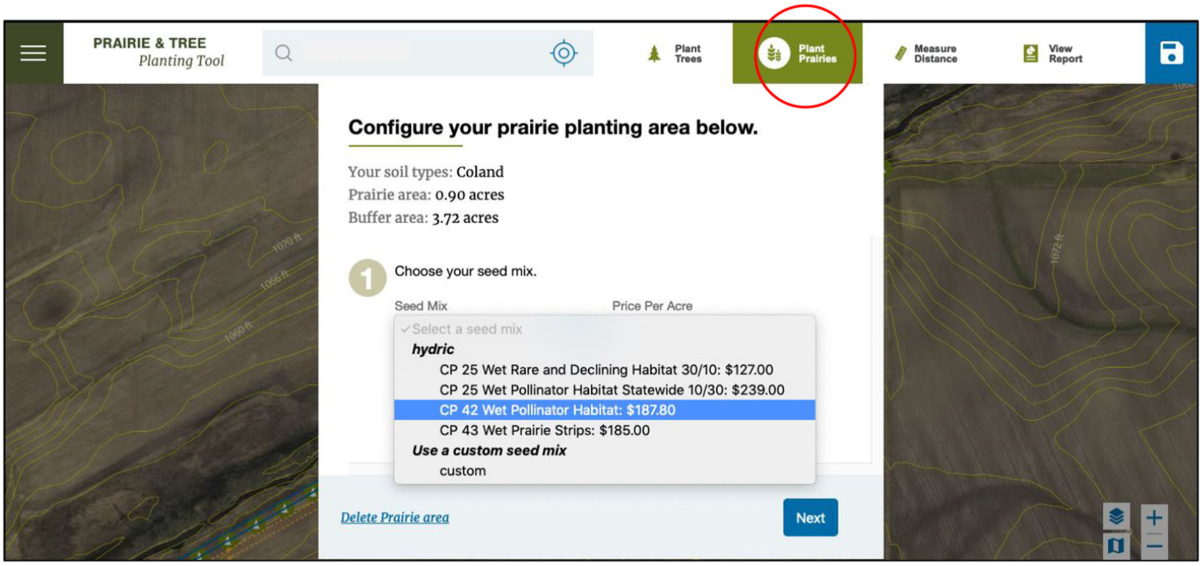


Fig. 7 Data display of PT^2 (1.0) showing prairie seed mix options suitable for the soils present on the site (in this example the primary soil is Coland, a poorly drained alluvial soil). A polygon tool has been used to plant a 6-meter-wide prairie buffer between the row crop field and the two-row tree buffer

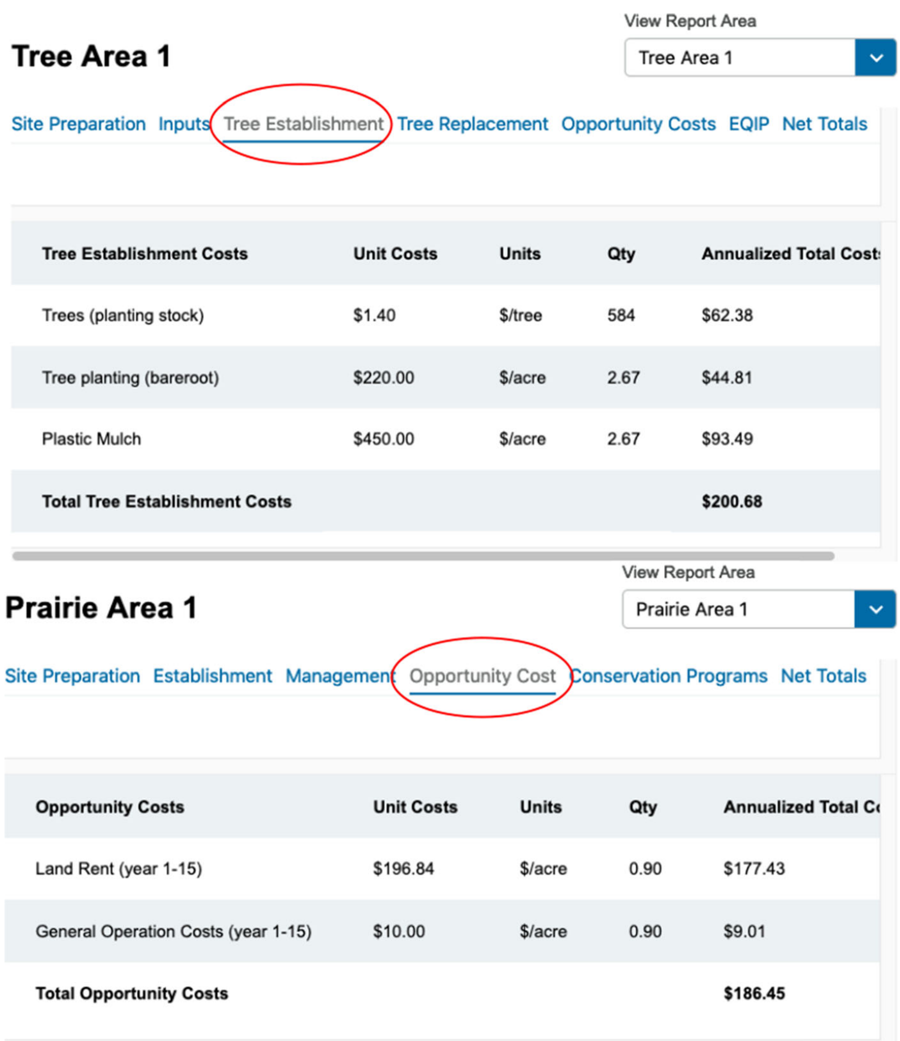
conservation practice designation (CP) for the USDA Conservation Reserve Program. The prairie planting tool has also calculated the area of a 15.25 m buffer around the planting to represent the area that a crop farmer might consider for utilizing an Integrated Pest Management protocol to best protect pollinators and other beneficial insects that might utilize the habitat.

Step 5 The user then needs to choose a basic long-term management protocol for the plantings. For the designed tree system, the users indicate if the planting will need irrigation (it does not in this case). If the site does need irrigation the PT^2 (1.0) will account for the cost of a drip irrigation system. For the prairie system, the user can select if the prairie will be periodically burned on a 3-year burn cycle, which is the choice for this example design, or if the site will be mowed and the biomass baled. Depending on the choices, PT^2 (1.0) will account for the appropriate management costs.

Step 6 Finally, the user selects the cost analysis report for the design and reviews the comprehensive financial analysis, and reviews the design map (Fig. 8). As part of the financial analysis, different cost components of the tree or prairie systems as designed are presented singularly and as part of a total analysis. Demonstrated in Fig. 8 are tree establishment costs for the example design, and the opportunity cost of land for the prairie.

User centered PT^2 (1.0) design approach

When PT^2 (1.0) was designed and developed, to the degree possible the software team utilized a user centered design approach. Research regarding the development of computer-based decision support tools (DSTs) in agriculture routinely note that the majority of DSTs have short lifespans and often go largely unused (e.g., Matthews et al. 2008; Rose et al.



Tree Establishment Costs	Unit Costs	Units	Qty	Annualized Total Cost:
Trees (planting stock)	$1.40	$/tree	584	$62.38
Tree planting (bareroot)	$220.00	$/acre	2.67	$44.81
Plastic Mulch	$450.00	$/acre	2.67	$93.49
Total Tree Establishment Costs				$200.68

Opportunity Costs	Unit Costs	Units	Qty	Annualized Total C
Land Rent (year 1-15)	$196.84	$/acre	0.90	$177.43
General Operation Costs (year 1-15)	$10.00	$/acre	0.90	$9.01
Total Opportunity Costs				$186.45

Fig. 8 Data display of PT^2 (1.0) showing components of the financial analysis report

2016; Lindblom et al. 2017). When considering reasons for low adoption rates of agricultural DSTs by farmers, Lindblom et al. (2016) identified a number of software related factors that DST developers should account for: perceived complexity, tedious data input requirements, poor user interface design, low adaptation to specific farm situations, and lack of frequent information updates. Regarding the latter two points, PT^2 (1.0) is explicitly site specific, and developers have a data management plan that includes updating geo-spatial data as it becomes available and annually updating the financial data. Regarding the software related factors, during several points within the development phase of the software, the PT^2 (1.0) was beta tested by farmers ($n = 5$) as well as graduate students ($n = 5$) who specialize in conservation land use and modeling. Specifically, our beta testers provided formative feedback on accessibility of the tool on a variety of browsers and home computers, navigability within the tool itself, review of and comprehensibility of data presented, and usability of the prairie and tree planting design data and cost estimation information. The developers made user interface adjustments to the PT^2 (1.0) based on this feedback.

Focusing more on the context for DST use, a central critique of many agricultural DSTs has been that approaches to system development have often been top-down from experts who, because they themselves were not the target audience of the tool, demonstrated limited understanding of decision making in practice or the nuances in how farmers might weigh choices (Rose et al. 2018). In an effort to initially counteract this potential disconnect between DST developers and users, PT^2 (1.0) developers adopted an indirect User Centered Design (UCD) approach to DST development that accounted for the information needs of key stakeholders—those who serve as advisors to farmers: technical service providers (TSPs; entities outside of the USDA who help agricultural producers apply conservation practices), certified crop advisors (CCAs), and contractors who are tasked with providing on the ground design advice and labor regarding the types of perennial systems the PT^2 (1.0) designs. In 2017, members of the Iowa State University Prairie Strip Project Team (https://www.nrem.iastate.edu/research/STRIPS/) conducted five training workshops involving 91 TSPs, CCAs, or contractors from five different US Corn Belt states. The purpose of these training workshops was twofold: (1) to share research-based findings and experiences regarding the use of prairie strips for water quality management and other ecosystem service outcomes, and (2) to learn from stakeholders and partners what their information needs were regarding prairie in general and prairie strips specifically. The day-long trainings covered site mapping and geospatial data, siting of prairie strips, prairie plant identification, seed mixtures, maintenance, determining costs, and more (Whitehair 2019). The tree planting side of the PT^2 (1.0) was informed by the process utilized in the making of a similar tree-based online GIS tool for vegetative environmental buffers planted around livestock facilities (Tyndall and Randall 2018), which was guided by feedback from livestock producer workshops and the experience of Iowa State University's Extension Forester.

Future user centered design plans with the PT^2 (1.0) will involve in-person training sessions that will feature focused discussions regarding the current utility of the tool and suggestions for future advancements. These were planned as part of the original beta testing process, but all suitable in-person venues (e.g., farmer-oriented conferences, workshops, tradeshows, etc.) were cancelled or postponed due to Covid-19.

About the software and future applications of PT^2 (1.0)

PT^2 (1.0) runs on modern browsers and devices (e.g., desktops and tablets; Apple or Android operating systems). The PT^2 (1.0) website includes access to the application, a step-by-step illustrated user's guide, and comprehensive documentation regarding the default PT^2 (1.0) design parameters, financial data used and sources, and guidance on modifying default data. The website also archives downloadable relevant peer-reviewed publications as well as outreach materials.

PT^2 (1.0) is built with front-end tools such as React and Mapbox (https://www.mapbox.com/). The design of the tool focused on ease-of-use and portability. Mapbox's mapbox-gl-js library was used to build all interactive map features, and the Mapbox service free-tier was used to host and serve SSURGO soil data. All other data layers are served from Iowa State University Geographic Information Systems endpoints (https://www.gis.iastate.edu/). The application is also backend-less, meaning all assets are static and there are no servers or databases to secure and maintain, and no user privacy considerations. All data are retained on the front-end on the user's device, and not saved on any hosted servers and databases. To share data, users simply download a JSON file and email it to the recipient who can then load it into the app on their device. To port this application for other use, simply fork the Github repository and make changes to the Planting Forms and Report logic as needed.

PT^2 (1.0) is open source and open coded so that it can be adapted for use in other states, or advanced to include different vegetation cover oriented conservation or production options such as cover crops, grass waterways, bioenergy cropping systems, filter strips, and so on. Financial data for these other perennial land covers are available at Bravard et al. (2021); financial data are available for IA, IL, and MN. To customize this project for your own use, simply download a zip file of the codebase, or use the git command line tool to clone the repository. Adaptors can also fork the repository for personal use by clicking the "Fork" icon in the Github interface when viewing the repo. Adaptors will have to provide their own Mapbox-hosted data layers. To develop your own project with the PT^2 (1.0) as the platform, working knowledge of the following is required:

- HTML.
- CSS.
- CSS precompilers such as SASS.
- JavaScript.
- React.js (a JavaScript framework).
- Mapbox-gl-js (a JavaScript library for working with interactive maps using Mapbox).
- Webpack (for compiling and building the project).

Conclusion

Farmer surveys and workshops with various technical support professionals who aide farmers in making conservation decision have noted decision makers often lack the biophysical knowledge needed to make site appropriate decisions regarding prairie or tree-based conservation practices. Similarly, lack of up-to-date, and complete information regarding the financial aspects of perennial conservation is a chronic issue in agricultural regions. As such, the PT^2 (1.0) was created using user centered design techniques and the latest in high-resolution spatial data to help Iowa landowners and their advisors make more informed land use decisions regarding prairie and or tree plantings based on site-specific biophysical information and project specific financial data. This DST features open source and code software thus offering opportunities for it to be adapted for use in states beyond Iowa; project developers are also actively seeking collaborators interested in advancing the tool's analytical capacity beyond prairie and tree plantings.

Public and private conservation entities in the US Corn Belt region are poised to earnestly take advantage of a new era of publicly available, high-resolution data to guide private landowners in making conservation decisions (Tyndall 2020; Ranjan et al. in review). There are sophisticated spatial or process-based DSTs relevant to the state of Iowa and other states that are currently leading the way in helping public and private conservation professionals guide conservation plans at watershed scales (e.g., the Agricultural Conservation Planning Framework; Tomer et al. 2015), and are contributing to developing and testing innovative ways to finance conservation efforts via nutrient trading (e.g., the Nutrient Tracking Tool; Saleh et al. 2015). These DSTs, however, require a significant amount of skill and experience with geographic information systems or hydrologic modeling and are not particularly assessible to farmers, or many farm advisors. Nor do these DSTs allow users to explore low cost opportunities for prairie or tree plantings at relatively fine field-level scales. PT^2 (1.0) therefore strongly complements the suite of DSTs that are empowering landowners to make specifically informed perennial conservation or production land use decisions that suit landowners goals.

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Data availability All data are cited or provided as supplemental information.

Code availability All code used in the prairie and tree planting tool—PT2 (1.0)—is open source and is available at: https://pt2.nrem.iastate.edu/ . Specific instructions on how to access the code is provided in the manuscript.

Declaration

Conflict of interest The author does not have a conflict of interest associated with the research presented or with this journal.

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