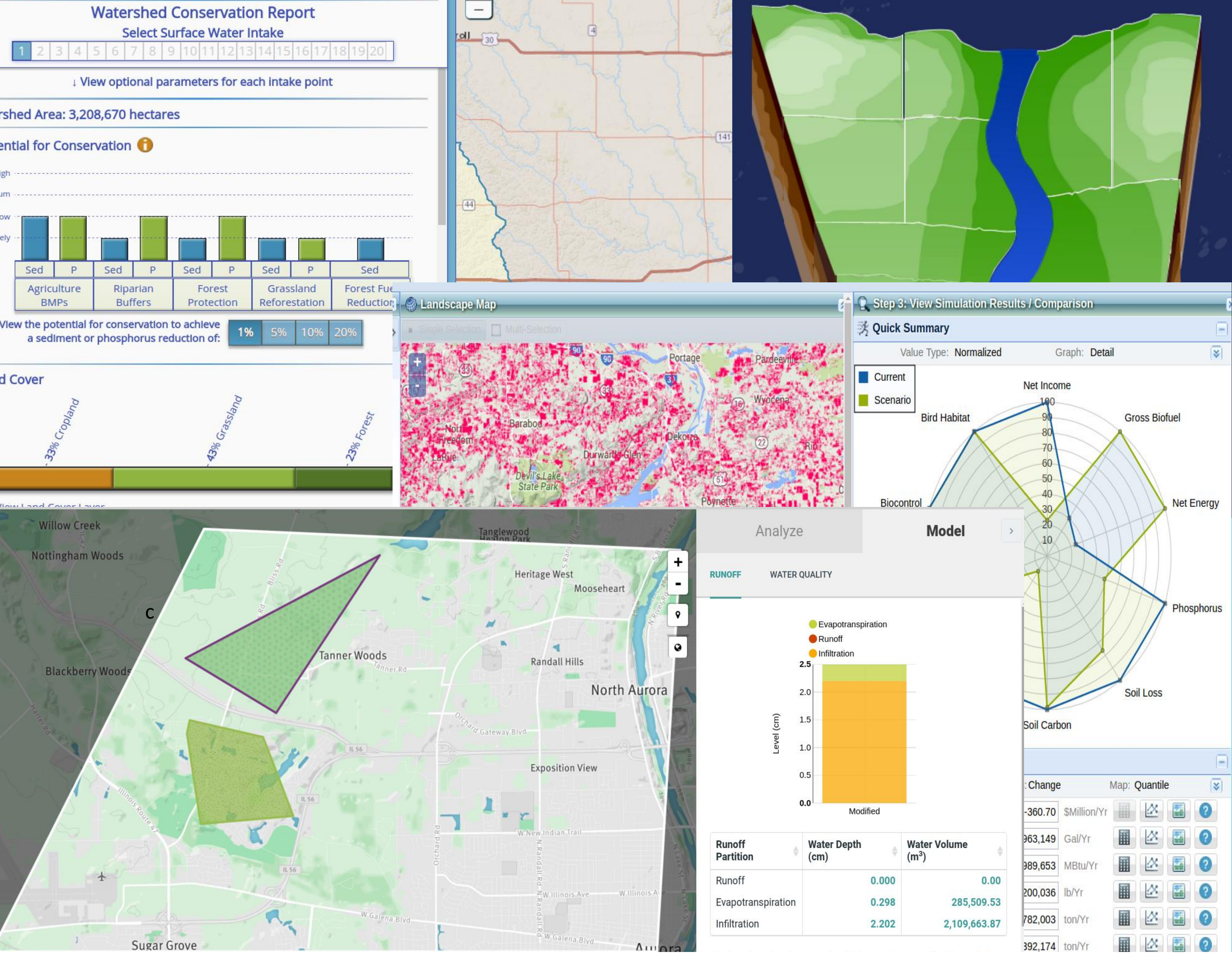


Watershed Tools Comparison White Paper

Noah Hagen

Landscape Ecology and Sustainable Ecosystems Management Lab

August 2016

Introduction

Introducing Watershed Educational Tools

Online learning experiences, including browser-delivered games, have the potential to stimulate student learning by providing instant feedback and evident goals.[1] Computer modeling, and not just games, can also create opportunities for student investigation of multidimensional systems.[2] Therefore, when it comes to communicating the complex interactions between land use and watershed ecosystems, computer utilities using one or both of these approaches have been of interest for students and education stakeholders. Agricultural professionals and policy formulators also stand to benefit from approachable tools grounded in solid scientific models.

A variety of such tools are already available, and they present a range of discretionary choices. Tools vary significantly in aspects including target audiences, ecosystem indicators, scientific buttressing, and complexity of usage. While some tools are notably more game-like than others, many are currently integrated into classrooms, and most have the potential to be.

Purpose

Information on these tools is being sought as part of the People in Ecosystems / Watershed Integration (PEWI) project, which is itself an educational tool for augmenting societal understandings of the impact of human choices in watershed ecosystems.[3] This research will be used in better understanding how PEWI compares to similar resources available today and will serve as an aid for future project direction.

---

[1] Kiili, Kristian. "Digital Game-based Learning: Towards an Experiential Gaming Model." The Internet and Higher Education 8, no. 1 (2005): 13-24. doi:10.1016/j.iheduc.2004.12.001.

[2] Wilensky, Uri, and Kenneth Reisman. "Thinking Like a Wolf, a Sheep, or a Firefly: Learning Biology Through Constructing and Testing Computational Theories—An Embodied Modeling Approach." Cognition and Instruction 24, no. 2 (2006): 171-209. doi:10.1207/s1532690xci2402_1.

[3] Schulte, L., J. Donahey, L. Gran, T. Isenhart, and J. Tyndall. "People in Ecosystems/Watershed Integration: A Dynamic Watershed Tool for Linking Agroecosystem Outputs to Land Use and Land Cover." Journal of Soil and Water Conservation 65, no. 2 (2010). doi:10.2489/jswc.65.2.33a.

Tools and Overviews

The breadth of educational ecosystem tools is wide,[4] even among those targeting watersheds. This paper does not offer a comprehensive overview of these tools, but rather presents a thorough discussion of a handful of software suites with marked similarity in purpose or utility to the PEWI project. The applications reviewed–SmartScape, Rock Your Watershed!, Watershed Screening Conservation Tool, Model My Watershed, and Pimp Your Landscape–are all free, web-delivered, watershed-oriented, and not so advanced as to limit their use by the general public.

In formulating the overview, considerable time was spent exploring the utilities and their features. Literature and web research was also performed. Particular areas of focus were input/output, user interface, underlying science, and educational value as a curriculum element.

[4] Bagstad, Kenneth J., Darius J. Semmens, Sissel Waage, and Robert Winthrop. "A Comparative Assessment of Decision-support Tools for Ecosystem Services Quantification and Valuation." Ecosystem Services 5 (2013): 27-39. doi:10.1016/j.ecoser.2013.07.004.

SmartScape

Wisconsin Energy Institute

https://dss.wei.wisc.edu

SmartScape Decision Support System is a utility designed and maintained as part of the Wisconsin Energy Institute by the Gratton Laboratory at University of Wisconsin-Madison.[5] Development for this tool began in 2013 with the last update occurring in May of 2015.[6] *SmartScape* was funded by a USDA grant.[5]

Usage is self-guided and potential stakeholders seem to be policy makers looking at decisions affecting a broad land area. The program gives users a good sense of how potential changes in land cover and management practices impact economic, energy, and ecosystem outputs. In addition to the online application, the program is available with documentation[7] for personal modification and deployment. The code implements server-side computations using the Java Play! framework.

The tool is straightforward with the default hiding of advanced elements and a tutorial video to assist new users[8] making the learning curve gentle. Users are greeted by three vertical panes with the center pane displaying a Google Maps interface available in both map and satellite views. By specifying one or more land use parameters, selection areas are created and overlaid in the central pane. Hypothetical changes made to these areas are modeled in a sortable results table and radar plot.

Tool features are numerous for both selecting land usage and overlaying modifications to it. Selection characteristics include land cover (corn, soy, grass, or alfalfa), proximity to streams or public land, slope, watershed membership, and estimated cropland capability. Changes in land cover, fertilization properties, conventional or no-till land management practices, cover crops, and contour farming are all potential modifications.

Outputs for both current land use and proposed changes consist of feedback on income, potential biofuel production, net energy, phosphorous, soil loss, soil carbon sequestration, nitrous oxide, pollinator habitat, biodiversity, and bird habitat. Each of the results can be

---

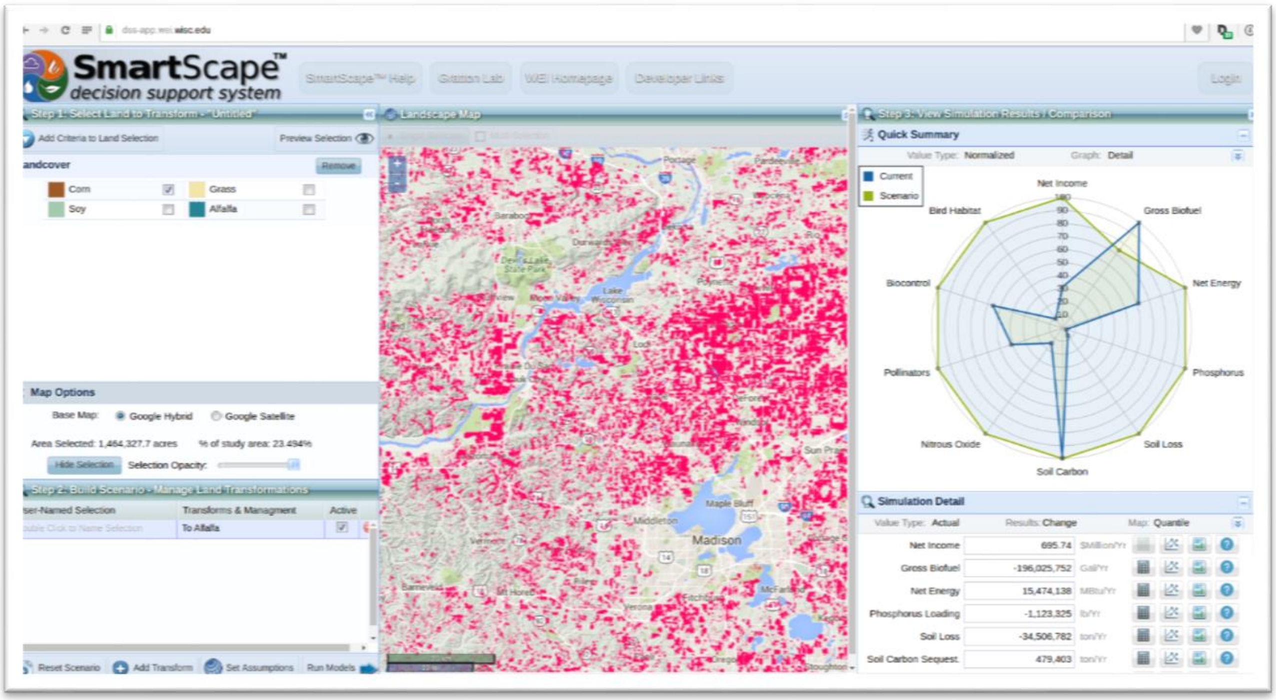
[5] "WEI Smartscape Decision Support System." University of Wisconsin Madison. 2015. Accessed July 25, 2016.

[6] "Code Frequency." DSS Server Repository. https://github.com/jdischler/DSS_Server. Project Master Code Repository.

[7] Smartscape DSS. 2016. Accessed July 25. https://dss-app.wei.wisc.edu/app/file/DSS_Setup.pdf.

[8] WEI. 2014. Introduction to Smartscape. Video.

graphed as a histogram across the land subarea or converted into other units, including dollar amounts for simplified across-the-board comparisons of trade-offs.



In terms of the land change analysis, all models are documented, cited, and transparently presented in-game. Most, if not all, of the value judgments that were made in the development of the model (such as multipliers and costs) are easily changed in-application allowing individuals to tailor assumptions they disagree with. Results are calculated on a pixel basis and data is compiled from sources including satellite elevation mappings and the USDA SSURGO soil database.[9] Nevertheless, tool creators remark that users should set their expectations for ‘quick and dirty’ outputs that are roughly accurate.[10]

Curriculum use of the tool has not been an emphasis, although it has been used in undergraduate classrooms.[11] Notwithstanding, policy stakeholders have made use of the utility,[11] and it certainly seems to be geared more toward this audience. Overall, the tool strikes a balance between its scientific underpinnings and communication of interrelated outputs while maintaining an appealing and usable interface.

---

[9] Tayyebi, Amin, Amirhossein Tayyebi, Eric Vaz, Jamal Jokar Arsanjani, and Marco Helbich. "Analyzing Crop Change Scenario with the SmartScape™ Spatial Decision Support System." Land Use Policy 51 (2016): 41-53. doi:10.1016/j.landusepol.2015.11.002.
[10] "SmartScape." Gratton Lab. Accessed July 25, 2016. http://gratton.entomology.wisc.edu/smartscape/.
[11] Gratton, Claudio. Letter to Noah Hagen. "SmartScape Application Questions". Email.

Rock Your Watershed!

Iowa State University Extension and Outreach

http://www.waterrocks.org

Rock Your Watershed! is a browser-based game and educational tool. Originally developed in late 2012 and early 2013, a new version is scheduled for a Fall 2016 release.[12] The game was created by Entrepreneurial Technologies, an application development firm in Urbandale, Iowa.[13] Use by both individuals and classrooms is supported by the application, and it is one arm of a large suite of outreach programs including music and interactive visits administered by Iowa State University Extension and Outreach. As such, the *Rock Your Watershed!* utility is integrated into a largely content-focused website devised for students K-12.[14]

In the game, players attempt to find the best land use design for 10 customizable 40-acre sections. Gameplay is highly linear with little room for deviation, and users must select and customize all 10 sections before they can view the results of their actions upon the watershed. Graphically, the program presents the user with cartoon-like, 3d-style flat graphics. In experimenting with this tool, it was often unresponsive when calculating the results on successive plays of the game.

Player options for parcel cover type are a Corn/Soybeans Rotation, a Corn/Soybeans Rotation with buffer, a Corn/Soybeans Rotation with Wetland, and a Perennial Cover. Each land type apart from the Perennial Cover has further options regarding the rate of fertilization (low, medium, or high) and tillage practices (no till, strip till, mulch till, or no till with cover crops). Precipitation is determined randomly from low, medium, and high rainfall.

Upon completion of the customization, results are given for profit, nitrogen, phosphorous, and sediment measurements. These are qualitative indicators expressed essentially as a percentage. In addition, users receive an aggregate score which then ranks them in comparison with the quarterly leaderboards.

In terms of the science model, the utility presents limited cited research. Much of the modeling data stems from work done as part of the Iowa Nutrient Reduction Strategy.[15] It

---

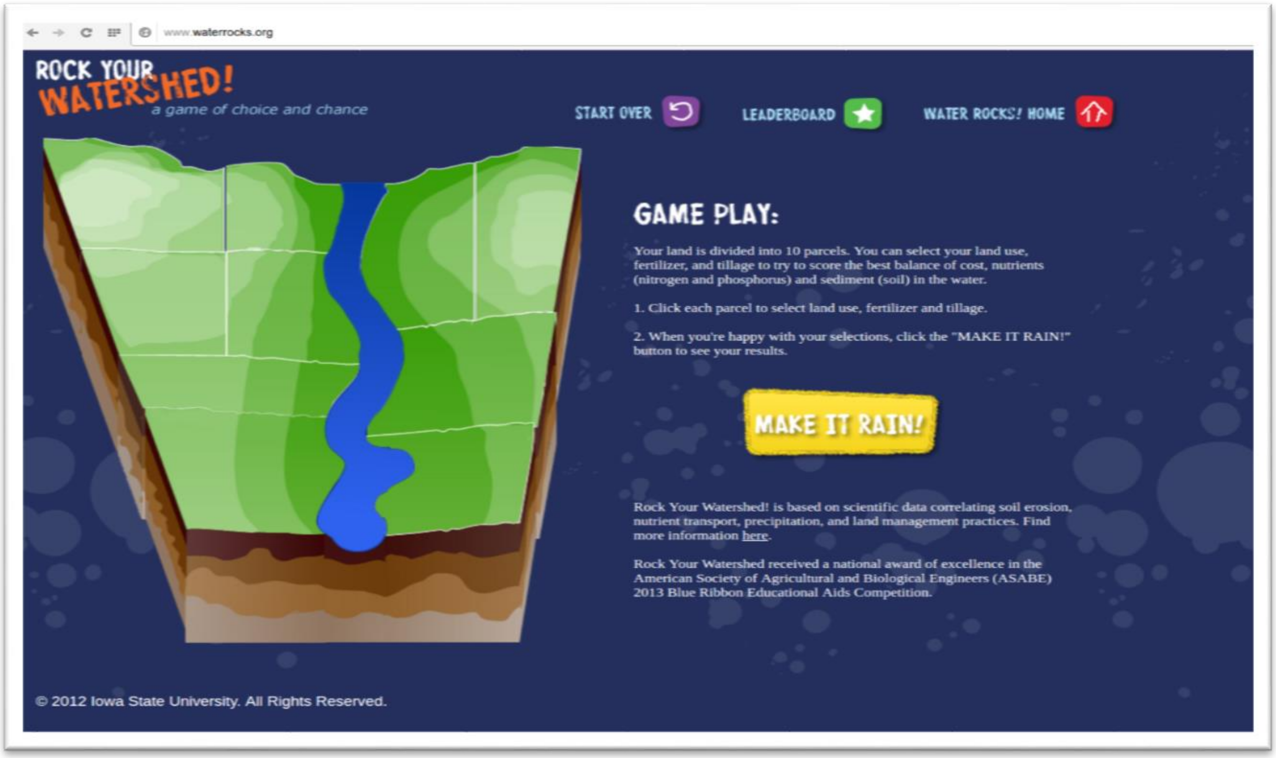
[12] Comito, Jacqueline. Letter to Noah Hagen. "Water Rocks Software Inquiry". Email.

[13] Water Rocks!. 2013. Interview with Erin Rollenhagen - Water Rocks! Creative Team. Video.

[14] Iowa State University. "Water Rocks! Ready to Inspire Kids Across Iowa." News release, September 03, 2013. Extension and Outreach. Accessed July 25, 2016.

[15] "Resources Cited." Water Rocks! 2012. http://water-rocks.herokuapp.com/resources-cited.

seems that land placement has minimal impact on the results, and while the map has a contoured look, it is unclear if topography is taken into account.



As an educational tool, the game is intuitive and can easily be learned from in a self-guided fashion. Numerous in-game information buttons give relevant details and factoids about the elements, and some rough, relative cost measurements are given as in-game feedback when users are considering land choices. Since its inception, the game has been accessed over 15,000 times.[16] In 2013, the utility won an Educational Blue Ribbon in the category of Electronic and Web-based Delivery from the American Society of Agricultural and Biosystems Engineers.[17]

[16] "Rock Your Watershed!" Water Rocks! Accessed July 25, 2016. http://water-rocks.herokuapp.com/game/index. Game play statistics are available via id number in results screen.

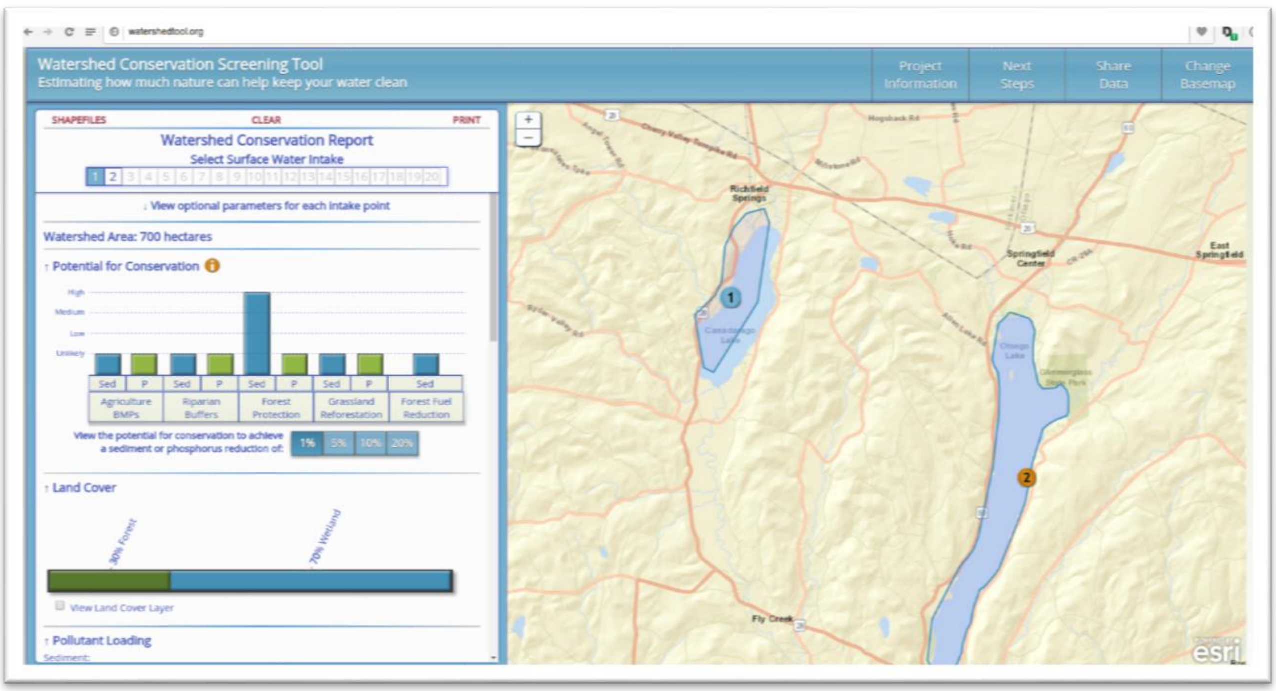
[17] "Educational Aids Blue Ribbon Awards Competition." ASABE. 2015. http://www.asabe.org/awards-landmarks/awards/educational-aids-blue-ribbon-awards-competition.aspx.

Watershed Conservation Screening Tool

The Nature Conservancy

http://watershedtool.org

Released in 2015 by The Nature Conservancy,[18] the *Watershed Conservation Screening Tool* is currently available for public online access. This utility gives users feedback on the potential water supply impacts for each of five major watershed conservation actions. In practice, users need foundational knowledge of intake water sources and inter-basin transfers that occur in the water supply, and as such, the tool is targeted toward large-volume water users with decision making interests in increasing water quality, especially municipal utilities.



The tool provides a self-led process for selecting up to 20 surface water input sources, which include high-volume water transfer points, on one of three ESRI mapping interfaces (topography, satellite, or streets). Next, the program performs an analysis on sediment and phosphorus, giving likelihood ratings for achieving 1, 5, 10, and 20% reductions across 5 conservation practices. These practices—Land Protection, Reforestation, Riparian Restoration, Agricultural Best Practices, and Forest Fuel Reduction—represent general

[18] Dating deduced from research dates and archival information from the Internet Archive.

categories of conservation methodology. Output is given in dynamic bar graphs and numerical form, and the data can be saved or shared in multiple formats.

The scientific model underlying the program is well documented[19] and fully developed for the entire globe.[20] Most of the application methodologies come from research done by The Nature Conservancy first released in November of 2014.[21] Data for land use coverage comes from the GlobCover 2009 dataset and mappings for watersheds stem from the HydroSHEDS project.[19] A limited number of assumptions in the program regarding the relative costs of conservation practices are in-application mutable.

On the topic of education, the tool appears to have a low probability of being used as a curriculum tool targeting land use or conservation practices. Factors such as prerequisite knowledge, limited scope, and minimal feedback wedge the tool into the small category explicit in its name: screening by stakeholders to see whether future exploration of one or multiple conservation options makes sense. Nevertheless, the tool could be helpful in exploring concepts such as returns on investment and the relative value of conservation methods across distinct watersheds. Current audience reach appears to be limited, with less than 50 views[22] of the getting started video thus far.

---

[19] Watershed Conservation Screening Tool: Methodology. 2016. Accessed July 20. http://www.urbanwater.org.s3-website-us-west-1.amazonaws.com/assets/MethodologyV1.pdf.

[20] McDonald, Robert. September 17, 2015. Screening Tool Briefing. Video.

[21] McDonald, R. I., and D. Shemie. Urban Water Blueprint: Mapping Conservation Solutions to the Global Water Challenge. Publication. 2014.

[22] McDonald, Robert. September 17, 2015. Screening Tool Walkthrough. Video. Accessed July 23, 2016.

Model My Watershed

Stroud Water Research Center

http://wikiwatershed.org/model/

Model My Watershed began development after receiving a National Science Foundation grant in fall of 2009 for its creation.[23] The tool was built by Azavea, Inc[24] and is maintained by the Stroud Water Research Center as one of a suite of web-based tools for exploring water and ecosystem impacts. Application users can explore current land modeling and results of hypothetical changes to the area.

Graphically, the main content window is powered by Leaflet (a JavaScript framework) and OpenStreet Maps. These maps are available in 4 views, including satellite and terrain, and users may overlay one of the land partitioning borders (congressional districts, watersheds, and more) to the map. In-game tools float above this map display, and a rightmost results pane features data visualization and sortable tables. The program was found to be very responsive, although model calculations sometimes took upwards of 10 seconds.

User areas for modeling are selected via free form drawing from anywhere across the United States. Scenario based modifications can be applied to these areas in the form of land cover changes and conservation practices. Areas are convertible into open water, developed area (4 intensities), barren land, forest, shrub, grassland, pasture, crop, or wetland. Rain gardens, vegetation basins, porous pavement, green roofs, no-till agriculture, and cluster housing are the conservation practices able to be implemented.

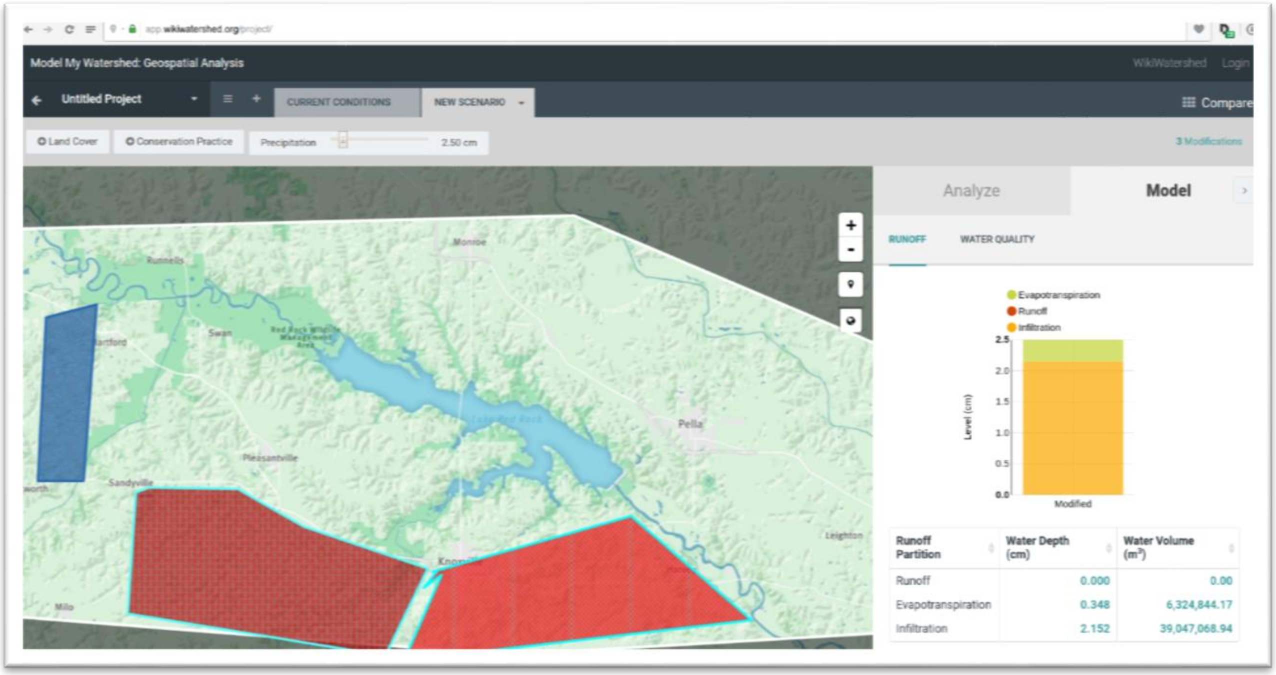
Output and a comparison display option allow the relation between current levels and scenario modifications to be easily discerned. The storm-site modeling gives a detailed analysis of a 24-hour rainfall[25] with configurable precipitation amounts. Two output categories are expressed: displaced water partitioned across infiltration, evapotranspiration, and runoff, and water quality given in terms of nitrogen, phosphorus, suspended solids, and biochemical oxygen demand. Output can also be created for rainfall events across an entire year using average precipitation for the area.

---

[23] "Award Abstract #0929763." National Science Foundation.

[24] Stroud Water Research Center. "Stroud™ Educators at Work." News release, Fall 2011. http://www.stroudcenter.org/newsletters/2011Fall/model.shtm.

[25] Model My Watershed Walkthrough: Site Storm Model. 2016. Accessed July 23. http://3zlpu231e6hebptt888geo1b.wpengine.netdna-cdn.com/wp-content/uploads/WalkthroughforSiteStormModel-v2-1.pdf.



The science for the application comes from 2 main models[25] with limited additional literature cited by the program. Runoff measurements are based on the TR-55 USDA report *Urban Hydrology for Small Watersheds*. Likewise, water quality analysis finds its basis in the STEPL Model for nutrient and sediment load fashioned by the US EPA. Data for land coverage and soil hydrology respectively comes from the USDA and USGS.

Educationally, the tool allows for both classroom-guided and self-directed learning, though it seems mostly tailored toward the latter. The tool is already used in classrooms by 75 teachers across the nation, with an expansion to 100 for the Fall 2016 academic year.[26] *Model My Watershed* has noteworthy research supporting statistically significant increases in watershed knowledge for students when used in a classroom setting.[27]

---

[26] Stroud Water Research Center. "Students Nationwide Model Their Watersheds, Solve Environmental Challenges." News release, June 2016. http://www.stroudcenter.org/newsletters/2016/issue3/modeling-app-goes-nationwide.shtm.

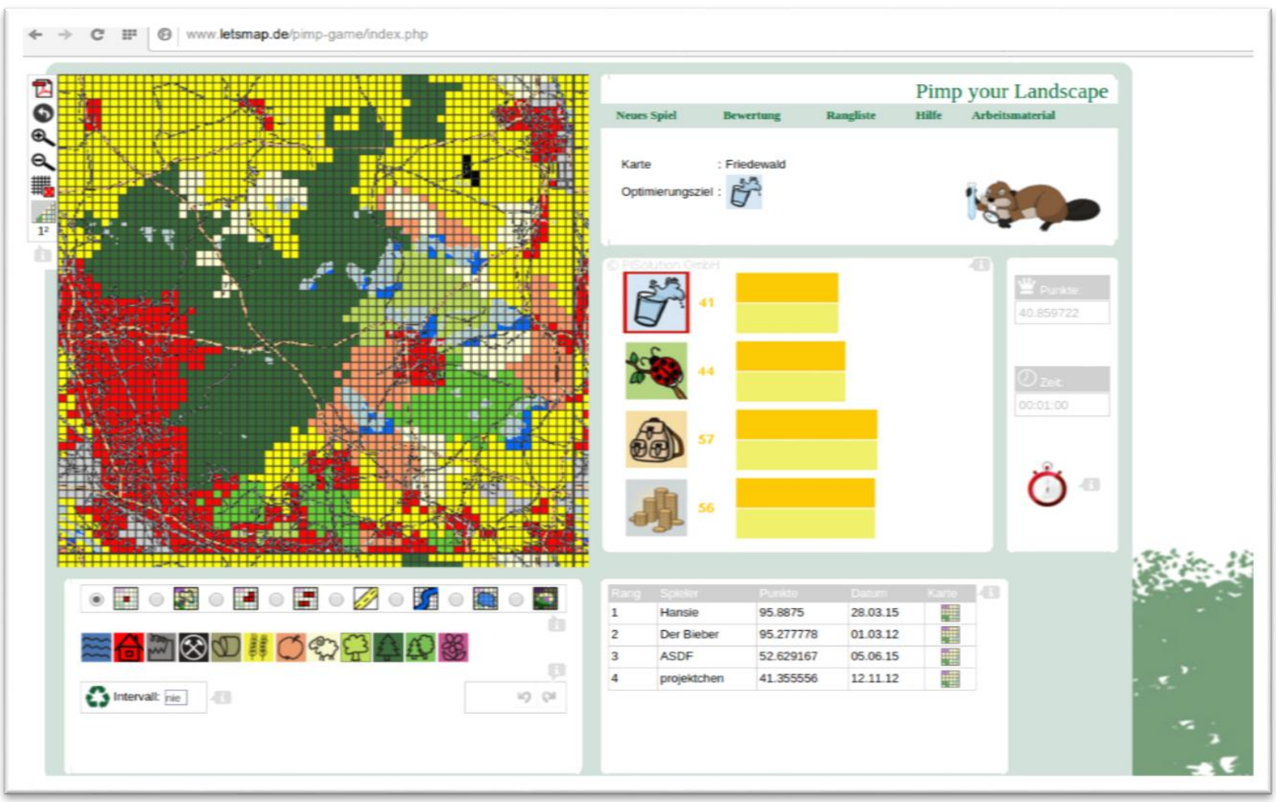
[27] Gill, Susan E., Nanette Marcum-Dietrich, and Rachel Becker-Klein. "Model My Watershed: Connecting Students' Conceptual Understanding of Watersheds to Real-World Decision Making." Journal of Geoscience Education 62, no. 1 (2014): 61-73. doi:10.5408/12-395.1.

Pimp Your Landscape

GISCAME

http://www.letsmap.de

Pimp Your Landscape is an application for evaluating trade-offs and qualitative effects of land use changes. The tool was developed originally through collaboration with the Dresden University of Technology.[28] As a whole, it is geared toward European users and has unlikely usage as an education tool in the United States. Nevertheless, the tool is one of interest as a result of its many variants maintained by stakeholders, including a paid version, some of which are designed to target specific regions of the world.[29]



[28] Fürst, C., C. Davidsson, K. Pietzsch, M. Abiy, M. Volk, C. Lorz, and F. Makeschin. "“Pimp Your Landscape” – an Interactive Land-use Planning Support Tool." Geo-Environment and Landscape Evolution III, 2008. doi:10.2495/geo080221.

[29] "Software Tool for Planning, Economy, Science, and Education." GISCAME. Accessed July 28, 2016. http://www.giscame.com/giscame/english_home.html.

Users of the tool are greeted by a colored 50 by 50 grid with each cell representing a 1 hectare area. [30] The game offers a number of tools for changing land cover and output information is continually updated in the neighboring pane. Land changes are allowed until time runs out, and a beaver mascot cheers players on at various points along the way. The browser program forces the page to reload on all land changes larger than one cell, making its use somewhat haphazard.

Land uses include water, housing, industry, mining, landfill, crop land, fruit and viniculture, forestry (three variants), and gardens. Outputs from land changes consist of water quality, ecology, aesthetics, and economic quality. Feedback is given to users as scores from 0 to 100 with no absolute measurements available in the program.

One potential issue with the tool results from its German roots. Although the application is available in multiple languages, none of the English variants are fully translated, posing a potential challenge for many users here. Additionally, while much of the scientific literature is in English, game-use documentation is not.

Modeling for the land types comes from European research effort CLC 2000.[28] Overall, the indicators seem to be based on very simple models with water quality synonymous with nitrogen load, and economic output based solely on land types. The aesthetics indicator comes from somewhat arbitrary decisions regarding land-types.

In terms of educational value, factors such as the language issues, minimal documentation, and low-quality game responsiveness probably limit it from many classrooms in the United States. The online leaderboard for the application indicates minimal usage of the game application. Even so, the program has been used in actual policy decisions and has been used as coursework in educating land management professionals.[30]

[30] Fürst, Christine, Martin Volk, Katrin Pietzsch, and Franz Makeschin. "Pimp Your Landscape: A Tool for Qualitative Evaluation of the Effects of Regional Planning Measures on Ecosystem Services." Environmental Management 46, no. 6 (2010): 953-68. doi:10.1007/s00267-010-9570-7.

Discussion

The applications fall into two distinct categories: namely, those based on a Google Maps-like interface (group A) and those with home-built graphics (group B). PEWI clearly falls into the latter category. While all of the applications allow for self-guided land modification followed by results feedback, distinctions between the groups are present.

Group A applications are lent instant credibility through their map interfaces, whether warranted or not. Land modifications feel as if they translate back to real-world changes much more so than with group B programs. As such, programs from group A have a clearer appeal to policy makers, agricultural professionals, and utility corporations. Group A applications also have a broader ability to compare results across distinct hypothetical changes.

On the other hand, tools from group B communicate a more game-like environment and offer map customizability that is not possible in the previous group. These applications may hold more appeal in an educational setting, and they present a more interactive approach to the watersheds. Their gentle learning curve makes them good introductory utilities to build intuition and confidence before users explore more advanced tools. Among applications in this group, PEWI presents the most compelling and responsive interface, and it has the deepest evident scientific foundations.

Apart from these groupings, PEWI offers a wider variety of land type changes than the other tools, but lacks the conservation practice resolution of tools that allow custom fertilization rates and a wide range of tillage options. PEWI is also lacking the urban options integrated into two of the tools. Generally powerful in its quantitative output and its range of indicators, PEWI is either on par with or ahead of each explored application in this respect. Nevertheless, pollinator information and water runoff appeared in the set yet are not represented in PEWI. Additionally, economic tradeoffs, while not present in PEWI, are addressed at least lightly in 4 of the 5 tools.

PEWI is certainly comparable for its basis in scientific literature. Moving forward, ease of access to this documentation should be a point of interest. In-application documentation, as in *SmartScape*, lends itself well to investigation and credibility.

Overall, there are currently two programs that most compete with PEWI. First, while *SmartScape* offers limited land use changes, it considers conservation parameters and offers the most output indicators. Second, *Model My Watershed* offers less output than PEWI but similar levels of input, and it has by far the most aggressive educational outreach. Certainly, none of the discussed limitations are insurmountable.

Supplement A1 – Summative Table

	SmartScape Decision Support System	Rock Your Watershed!	Watershed Conservation Screening Tool	Model My Watershed	Pimp Your Landscape	PEWI
Organization	Wisconsin Energy Institute at University of Wisconsin-Madison	Iowa State University Extension and Outreach	The Nature Conservancy	Stroud Water Research Center	Dresden University of Technology and PiSolution GmbH	Iowa State University
Public Release	2013	2012-13	2014	2009	2008	2010
Graphics	Realistic	Fictional	Realistic	Realistic	Fictional	Fictional
Estimated Minutes to Learn Tool*	45	5	30	30	20	20
Estimated Educational Target Level	High-School and above	Middle School and below	Upper Undergraduate and above	Middle School and above	Middle School and below	Upper Elementary and above
Available Land Change Categories	4	4	0	12	12	15
Conservation Practice Resolution†	High	High	Medium	Medium	None	Low
Precipitation Parameter	Not integrated	Non-adjustable, Random	Not integrated	Non-adjustable, From data	Not integrated	User settable, Multiple choice
Board Scale	Configurable within Dane County (0.32 Million ha)	~516 ha	Global	United States	2,500 ha	~2,428 ha
Editing Resolution	Map$^{\alpha}$	~100 ha	N/A	Pixel	1 ha	~4 ha
Output Indicators	10	4	2	7	4	9
Output Style (qualitative/quantitative)	Both	Qualitative	Quantitative	Quantitative	Qualitative	Both
Economic Indicators	Yes, Quantitative	Yes, Qualitative	Yes, Quantitative	No	Yes, Qualitative	No
Online Science Documentation	High	Low	Medium	Medium	Low	Low
User settable model constants	Yes, Most	No	Yes, Some	No	No	No

* Estimated Minutes to Learn is based on the time the average user would need to investigate all the utility's core functionality.
† Describes the user's ability to define parameters such as fertilization rates, tillage categories, contour farming practices, etc.
α Resolution limits imposed by dataset for area selection. Resolution estimated higher than within 1 ac.

Supplement A2 – Related Further Tools

Tool	Location	Comments
InVEST	http://www.naturalcapitalproject.org/invest/	Maintained by the Natural Capital Project, InVEST is a map based tool that gives ecosystem and economic feedback on hypothetical land decisions. Outputs from the program are wide and include Carbon Sequestration, Crop Pollination, Sediment Retention and Scenic Qualities. The tool is not included here as it is tailored to advanced audiences.
iTree	https://landscape.itreetools.org	This tool originates from the US Forest Service and has as its emphasis the ecological impacts of changes in land forest cover, but it still has pertinent similarities to the other watershed tools. Feedback from the tool includes effects on carbon, air pollution, and water runoff, and the tool prioritizes areas for conservation practices based on specified criteria. It was not included because of its distinct forestry focus.
Missouri River Basin Balancer	http://mobb.usace.army.mil/basin_balancer.swf	Created by the US Army Corps of Engineers, this is a highly game-oriented tool, complete with quality graphics and interactive sounds. While helpful for considering the needs of diverse stakeholders and showcasing a game oriented program, it was not included in this overview because of its narrow input focus on waterway operations.

Watershed Planning Tool: ACPF	http://northcentralwater.org/acpf/	This tool, part of a development led by Mark Tomer allows for the analyzing of land use, conservation practices, and soils, and gives users feedback on conservation decisions. The tool requires dataset handling and has a sharp learning curve, and as such, it was not included in this overview.