Landowner tool for quantifying multiple environmental services of riparian vegetation buffers for use in water quality trading in Oregon Watersheds

Timeframe covered by the report: August 28, 2006- August 28, 2010

Deliverables:

1. Compilation of existing environmental service assessment tools into a single tool
2. Development of a monitoring protocol
3. 120 data sets collected (2 per year for each of 20 sites)
4. Report documenting usability and cost of monitoring protocol
5. 4 workshops delivered to teach agencies and landowners to use the new assessment tool
6. Written/graphic ‘portfolio’ package- available to agencies and landowners for assessment of riparian restoration values

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Executive Summary:

Landowners are unlikely to enter into ecosystem service markets without quantitative estimates of the natural capital they process. However, it has been difficult for landowners to quantity the ecosystem services provided by their land or the degree to which management decisions alter these services. Models that estimate ecosystem service values are complex, operate on institutional computing platforms, output results at spatially or temporally inappropriate scales, or report service values in units not tradable in the market. These roadblocks have hindered efforts to engage landowners in addressing priority resource concerns identified by the NRCS such as water quality and riparian zone integrity.

Our project developed a more accessible ecosystem service quantification tool using a distributed computing framework that makes use of the growing availability of spatially indexed bio-physical data and the increasing ability to link diverse computing platforms using web services. It addresses several NRCS priority areas (CIG FY11 Announcement for Program Funding) including: 1) integrated tools that facilitate the development of ecosystem markets; 2) cloud based computational analysis and modeling to link resource concerns, conservation systems/practices, and quantifiable outcome-based metrics; 3)demonstration of new or novel technology that can easily and inexpensively be adopted by small-scale producers in order to address concerns or problems of the farmers, producers, or landowners.

The specific goals of our project were to:

1. Develop a single practical tool to evaluate the potential ecological value of riparian restoration in units that relate directly to ecosystem services that have known or potential buyers.
2. Integrate the tool into a restoration monitoring protocol to assess the current and future ecological value of restoration sites in terms of these defined ecosystem services.
3. Test the usability, cost, and transferability of the new tool.

The project accomplished the following with respect to meeting these goals:

A web-bases Stream Shade Calculator
http://groups.hort.oregonstate.edu/content/stream-shade-tool
Our quantification tool provides landowners with estimates of solar heat loading along user defined sections of streams. Users can assess the degree to which management practices such as adding or removing riparian trees creates heat loading credits or deficits. The tool consists of four components that are linked through web services: 1) a graphical user interface; 2) geodatabases that store spatially indexed parameter values; 3) process models that calculate ecosystem service values; 4) a reporting interface the returns model outputs to the user. We believe that this general framework can produce more robust and accurate quantification systems as well as more accessible ecological information to individual landowners.

Field validated outputs
We validated the accuracy of the webtool outputs with field measured estimates of stream vegetation characteristics, shade conditions and temperature. Data were collected at 22 sites and

included 173 point data sets. In addition, we made use of current and potential shade data that were previously collected by Clean Water Services as part of their temperature trading requirements. Field collected data indicate that the webtool provides a robust estimate of current shade conditions.

A user guide and integrated monitoring protocol
We produced a detailed website and associated user guide explaining the purpose of the tool and how to use it.
http://groups.hort.oregonstate.edu/content/stream-shade-tool
(See also Appendix IV)

We also developed a field assessment and monitoring protocol to allow landowners to update the webtool estimates of current shade and to monitor the progress of restoration sites in terms of shade provisioning.

We evaluated the usability of the webtool through focus groups and feedback at workshops. We also evaluated the associated protocol in the field for ease of use and cost. An average user takes about 1 hour to complete the protocol for a 1500 ft. reach of stream. The cost of equipment and supplies is minimal ranging from no cost (excepting incidentals like wet boots etc) to a few hundred dollars. Overall, the webtool itself attempts to minimize costs. For many reaches there is no user override required to receive accurate results from the webtool. In these cases the user costs are only those related to the internet connection and the computer.

An Ecosystem Credit Worksheet
We developed a simple worksheet for landowners to compile a portfolio of potential ecosystem services credits (Appendix VI). The worksheet introduces landowners to our Stream Shade Calculator as well as the USDA's Nutrient Trading Tool (Lal 2010). These two new webtools allow landowners to estimate the potential ecosystem service benefits that could accrue by conducting riparian restoration and other conservation practices. Both tools report these potential benefits in units that are directly applicable to ecosystem service markets being developed in the Willamette Valley.

Outreach Workshops and meetings
We conducted four primary workshops that introduced the tool to conservation organizations, land managers, regulatory agencies, and private landowners. In addition to these four primary workshops, we also conducted several project meetings with cooperators and other groups doing similar work to elicit feedback on project direction and development, and to coordinate effort.

The project required a one year no cost extension. The delay was caused by a significant change to our original tool design that allowed us to take advantage of cutting edge developments in the design of web-services and the ability to integrate GIS databases into a distributed computing framework. We saw this as a vastly significant improvement over our original plan that justified the delay.

Our results demonstrate that the general design framework we developed for this project can produce more robust and accurate quantification systems for ecosystem services. Just as importantly, the user friendly and web based design make complex ecological information more accessible to individual landowners. This information can empower individual landowners to make more informed decisions about how to manage the ecological and conservation values of their property in addition to the market and commodity based values. This will likely produce more direct participation in conservation programs and improvements in priority resource concerns identified by the NRCS.

Our experience with this project identified some recommendations that would facilitate the widespread implementation of the technology to more regions and ecosystem service types:

1. Development of systems optimized for cellular based data portals such as smart phones and tablets that avoid issues with rural internet access and allow for use of the tool in the field.
2. Development of more robust distributed cyber infrastructure that coordinates the interoperability of data
3. Greater availability of spatial and temporally high resolution data of parameter values required for quantification of key ecosystem services.

Introduction

This four year project (three years with a one year extension) developed an innovative web-based tool for estimating effective shade potential and incident solar radiation, key ecosystem service s provided by riparian zones in the Willamette Basin of Oregon (http://groups.hort.oregonstate.edu/content/stream-shade-tool). The project was lead by Oregon State University in direct collaboration with the Sustainable Plant Research and Outreach Center (SPROut). In addition, the project collaborated with regional agencies and non-profit organizations to integrate the new tool with broader efforts to develop an ecosystem service marketplace for Oregon.

The tool allows users to estimate the potential shade credit they could receive for planting trees along streams. They can use the tool's map interface to identify a stretch of stream that they are interested in analyzing. The tool then uses LIDAR data to estimate the existing tree canopy along the defined stream. The tool uses this description of the canopy to calculate the amount of solar radiation currently reaching the stream (contributing to warmer water), and estimates how much the tree canopy could potentially be improved. The tool does this by using the stream's location, soil type, and the historic vegetation structure to construct a potential tree canopy for and then calculates the amount of solar radiation that would reach the stream under this potential tree canopy. The difference between the stream's current conditions and the potential conditions is the potential shade credit.

The project combined the diverse expertise of several key personnel, including a plant ecologist, a software engineer, a program coordinator, and an education and outreach specialist:

John Lambrinos (PI). Assistant Professor, Dept. of Horticulture, Oregon state University
Key expertise: plant ecology, landscape ecology
http://hort.oregonstate.edu/faculty-staff/lambrinos

Michael Guzy (programming and technical lead). Assistant Professor Senior Research, Department of Biological & Ecological Engineering, Oregon State University
Key expertise: software engineering, ecological modeling
http://bee.oregonstate.edu/Faculty/guzy/Guzy.htm

Lisa Gaines (project coordinator). Associate Director, Institute for Natural Resources, Oregon State University.
Key expertise: project management and facilitation
http://inr.oregonstate.edu/about_staff.html

Renee Stoops (outreach coordinator). Director, Sustainable Plant Research and Outreach Center (SPROut).
Key expertise: education and outreach

The goals and objectives of the project were to:

1. Compile existing assessment models into a single practical tool to evaluate the potential ecological value of riparian restoration in units that relate directly to ecosystem services that have known or potential buyers.
2. Implement a restoration monitoring protocol to assess the current and future ecological value of restoration sites in terms of these defined ecosystem services.
3. Test the usability, cost, and transferability of the monitoring tool.

To meet these goals the project had several key tasks divided across two distinct phases. During the first phase of development, the project team operationalized a prototype Web Shade Tool for quantification of potential shading along streams. The purpose of the phase 1 work was to establish initial requirements, designs, and implement draft architecture. Architectural components included developing a link between Google Maps and GIS software (ESRI, ArcGIS), various interfaces to the core physical process model (HeatSource 7), and a database scheme supporting accumulation of information. The first prototype version used pre-calculated results obtained from Clean Water Services that were created for their TMDL work in the Tualatin area.

In the second phase of the project, we fundamentally increased the usefulness of the tool by operationalizing it for most of the Willamette Basin. We also improved and enhanced the prototype design by developing an improved user interface, integrating an improved biophysical process model (HeatSource 8), developing an innovative and improved method for estimating current shade by making use of newly available remotely sensed data, and developing an improved method for estimating potential shade. We tested the accuracy and usability of the Shade Tool with ground truthed data. We integrated feedback on tool design and usability from project collaborators and stakeholders, and we demonstrated the final tool to stakeholder groups.

This project was facilitated by several key collaborations that helped facilitate project development and ensure that the resulting tool was responsive to stakeholder needs and requirements. These collaborators provided in-kind support to the project that included:

Clean Water Services (CWS). CWS Provided space for project meetings, restoration monitoring protocols developed for the Tualatin basin that we adapted for use in our ground truth protocol, calculated HeatSource output for the Tualatin basin that we used in an initial version of our tool.

Willamette Partnership (WP). WP facilitated contacts with the Oregon DEQ and CH2M Hill, who helped provide GIS data to the project, provided input and guidance on project design, scope, and integration with other related projects, provided feedback on usability and integration with the broader development of an ecosystem services market for Oregon.

The project was funded by an NRCS CIG grant for $175,097 and this was matched with $178,200 in direct and in kind contributions.

Background

Regulatory controls and technological mitigation measures have improved water quality, preserved wetlands and protected endangered species. But these approaches can be complicated, costly and contentious to implement--and they don't always produce broad environmental benefits. Water quality trading is an emerging approach to arrive at less expensive and more effective solutions to complex watershed problems. Implementing water quality trades hinges on scientifically valid, consistent, and user-friendly protocols to quantify environmental services provided by alternative mitigation measures such as riparian vegetation projects.

In 2005, the Oregon Department of Environmental Quality (DEQ) published recommendations regarding water quality trades between and among point and non-point sources. The document defines concepts, explains eligibility and describes specific trading scenarios that DEQ anticipates and generally supports. The DEQ noted the need for standardized protocols to quantify pollutant loads, load reductions, and credits to account for the generation and use of credits in permits and discharge monitoring reports in order to track the generation and use of credits between sources and to assess compliance.

Landowners are unlikely to enter into ecosystem service markets without quantitative estimates of the natural capital they process. We have greatly improved our understanding of the benefits humans derive from natural systems, including improved frameworks for defining, classifying, and quantifying ecosystem services (cite Heinz report; Millennium Ecosystem assessment). However, it has still been difficult for landowners to quantity the ecosystem services provided by their land or the degree to which management decisions alter these services. Many ecosystem services (e.g. biodiversity) require enormous amounts of person hours and expert knowledge to assess accurately. Quantification is complicated by the fact that most services emerge from ecological and physical processes that interact in complex ways across space and time. Models that estimate ecosystem service values are complex, operate on institutional computing platforms, output results at spatially or temporally inappropriate scales, or report service values in units not tradable in the market.

The difficulty and expense of calculating ecosystem service values are significant roadblocks to the development of ecosystem service markets. While small and individual resource managers such as farmers provide the majority of potential ES capital (XXXX), they are often prohibited from entering markets because they have no inexpensive way of assessing the potential natural capital they posses or could create.

This project targeted this need by developing a more accessible quantification tool using a distributed computing framework that makes use of the growing availability of spatially indexed bio-physical data and the increasing ability to link diverse computing platforms using web services. Our quantification tool provides landowners with estimates of solar heat loading along user defined sections of streams. Users can assess the degree to which management practices such as adding or removing riparian trees creates heat loading credits or deficits. The tool consists of four components that are linked through web services: 1) a graphical user interface; 2) geodatabases that store spatially indexed parameter values; 3) process models that calculate ecosystem service values; 4) a reporting interface the returns model outputs to the user. We believe that this general framework can produce more robust and accurate quantification systems as well as more accessible ecological information to individual landowners.

Review of Methods

Rapidly evolving technology and a change in tool design.

Our original plan for developing a riparian restoration tool called for compiling existing evaluation and monitoring protocols into a low tech delivery mechanism such as an Excel spreadsheet or a handwritten worksheet. Early in the project development we realized that this actually was technically difficult and the resulting output was unsatisfactory in many ways. Instead, we realized that cutting edge developments in the design of web-services and integrating GIS databases into a distributed computing framework could allow the development of powerful, interactive, yet user friendly tool. We saw this as a vastly significant improvement over our original plan. During our annual reviews our grant officers (Todd Peplin and Kathryn Boyer) agreed that this represented a significant advance.

However, the shift in our design plan caused an initial delay in project development as we had to recruit a team member with the required high level programming and systems design skills. In addition because tool development now involved programming and sophisticated integration of GIS databases the pace of tool development progressed more slowly than originally planned. In our original plan we expected to have a working tool within the first year of the project. Because of delays in recruiting specialized personnel and in the slower pace of tool development we did not actually have a working prototype until well into the second year of the project. This delay pushed back execution of project elements that required a working tool prototype such as the design and implementation of field testing and grower outreach. This delay was the basis for our request of a no-cost one year extension of the project. The evolution of the project is described in detail in our semi-annual reports (Appendix II) and our request for a no cost extension (Appendix III).

An innovative approach to ecosystem service quantification

As described in the introduction, current methods for quantifying ecosystem service values are technically difficult, time consuming, and expensive. This is mostly because accurate quantification requires site and context specific information that is acquired through difficult field work or through multiple data repositories with their own interoperability and sharing requirements. This creates an enormous barrier to individual landowners to gain access to information needed to appropriately manage the ecosystem services on their land. Our innovative design overcomes this barrier by making use of increasingly available spatially explicit bio-physical data and models. It also incorporates recent advances in IT infrastructure and protocols to automate service quantification and to provide a non-technical interface and intuitive output.

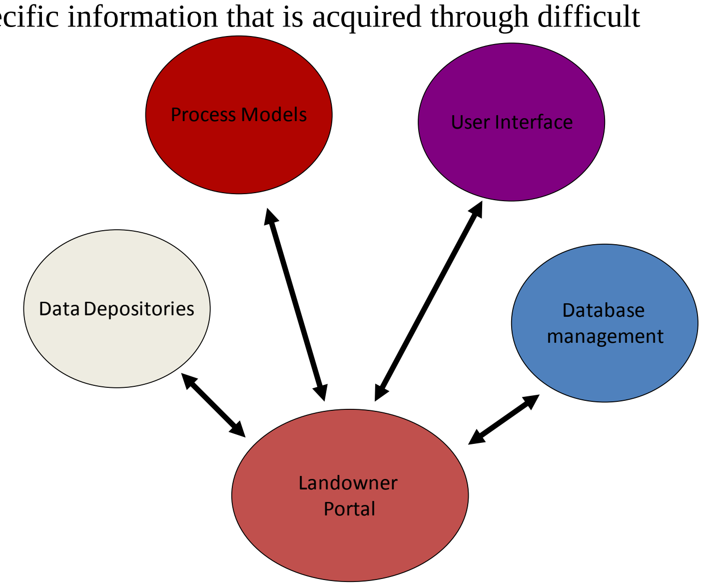

Figure 1. A distributed framework is a key design feature of the tool

Key innovations of tool architecture

A key design future of the tool is that it is built using a distributed architecture. Traditionally, ecosystem quantification and environmental assessments such as TMDLs and restoration assessments have been done as ad hoc projects. Each individual project entails the separate collection, compilation, analysis, and visualization of unique sets of data. This creates considerable redundancy in work (and cost) for each new project. It also means that project results and recommendations can easily become out of date as changes to the project components (such as new data or new methods) accrue. Our vision for the Web Shade Tool was for it to serve as an automated aggregator of information and analysis, rather than the repository of static ad hoc information. Each project component is linked and integrated via a web interface (Fig. 1). This distributed design allows for changes and updates to key components of the tool, and frees the end user (in this case the farmer) from having to directly administer each component of the complex process. For instance the Web Shade Tool can access soils data real time from the NRCS Web Soil Survey. This ensures that the most recent and updated soils information is used for the project.

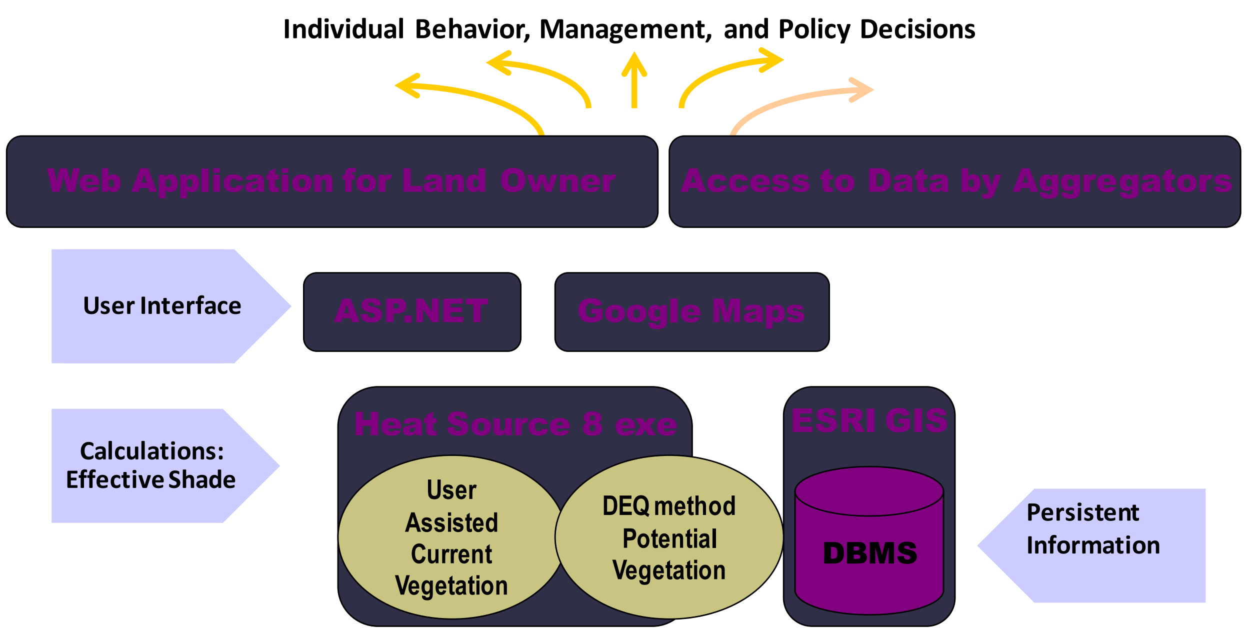

Fig. 2. Web Shade Tool design.

The Web Shade Tool integrates four components that are linked through web services (Fig. 2):

1. A graphical user interface.

The interface is based around Google Maps. This has two important advantages. First, it is an off the shelf well tested design. Second, it his highly intuitive and has a high level of familiarity across a range of users. The interface allows users to quickly identify a stretch of stream they are interested in analyzing (See Appendix IV).

2. Geodatabases that store spatially indexed parameter values

The tool uses a coupled assembly of an ESRI ArcSDE geodatabase associated with an ArcGIS server environment and a ASP.NET web service environment to store, manage, and distribute the parameter values needed by the process models as well as the calculated stream shading and incident solar radiation values themselves. Key features of this design include:

- Transactions Keyed to the USGS National Hydrological Data Set, which allows outputs to be associated with a wealth of other relevant spatial indexed data such as species incidence, stream flow data, and
- Secure Access Control
- Data source and date for each dataset and algorithm: provides for lineage tracking of each transaction.
- Scales to many users
- Dynamically links internet data sources

3. Process models that calculate ecosystem service values

The computational core of the tool is HeatSource 8.0, a bio-physical process model that estimates reach level shading and incident solar radiation (http://www.deq.state.or.us/wq/tmdls/tools.htm; Boyd and Kaspar 2003). The model uses input about physical relief (from a Digital Elevation Map) and vegetation characteristics (from a vegetation map linked to a look-up table of associated structural characteristics) to estimate the amount of solar radiation hitting the stream surface at a given location (spatial position, latitude). To predict potential shading following restoration along a section of an impaired stream, the same process is executed except using a model of potential vegetation instead of an existing vegetation map. The Oregon DEQ has developed a method for estimating potential vegetation for use in their TMDL obligations (http://www.deq.state.or.us/wq/tmdls/tools.htm). The potential vegetation model combines information about pre-settlement vegetation characteristics from an 1851 land survey with site specific geo-morphic characteristics that are known to influence vegetation type.

We made significant changes to this established methodology in order to make use of recently acquired remote sensing data and to better integrate the process model with the web-based architecture of the tool.

To estimate stream shading, HeatSource 8.0 requires estimates of reach scale vegetation structure, particularly height and canopy density. Previously this information has been acquired from GIS datasets of land use/landcover painstakingly developed through aerial photograph interpretation and ground truthing. Translating the land use/land cover layers into the appropriate input for HeatSource required a GIS analyst to sample a vegetation map using a specific sampling regime associated with the stream course. The resulting dataset describing stream vegetation is then converted into an estimate of vegetation characteristics using average values of height and canopy cover for specific vegetation types that are published by Oregon

DEQ (http://www.deq.state.or.us/wq/tmdls/tools.htm; Boyd and Kaspar 2003). This is a time consuming process that requires an expert GIS analyst to execute. For our tool we instead made use of recently acquired LIDAR data for the Willamette Valley. LIDAR is an optical remote sensing technology that can produce highly detailed three dimensional maps of tree canopy architecture. A key advantage of this new method to the previous technique is that LIDAR produces a vegetation model with a much higher degree of spatial precision (0.9) than the existing vegetation map (30 m). In addition, in the previous method the vegetation type information had to be converted to structure information (height, canopy density) using average values for particularly vegetation types. In contrast, by using the high resolution LIDAR data we can model vegetation characteristics directly for each stream reach.

4. A reporting interface returns model outputs to the user

The reporting interface has several key advantages over the existing way in which HeatSource output is presented. First, output is delivered real time for any stream section within the study area. Previously, detailed GIS analysis had to be accomplished for each new region. Second, output is user friendly and in units (% shade and heat flux before and after a restoration) that are relevant to actual management decisions. Third, users can override tool derived estimates of current vegetation and receive HeatSource output for the revised inputs in real time.

Project schedule and milestones

A detailed chronological description of project activities and milestones is provided in the biannual reports (Appendix II).

We list key milestones below:

Phase I

1. Consultation with collaborators and stakeholders about tool design, integration with other ongoing work, and integration with developing ecosystem service marketplace for Oregon/
Time frame: year 1

2. Development of a prototype tool with a working version of the user interface. Prototype used pre-calculated HeatSource outputs provided by Clean Water Services.
Time frame: years 1-2

3. Demonstrated the prototype to project collaborators and stakeholders; received feedback on tool design and future development.
Time frame: year 2

Phase II

4. Development of a final version of the tool from the prototype. This involved incorporating feedback from stakeholders, implementing the HeatSource 8 codes in the business logic layer of the web application, and implementing the associated dependencies including the DEQ method for potential vegetation calculation.

Time frame: years 3-4
5. Ground truthed and assessed the accuracy of the tool outputs. Outputs from the Web Shade Tool were compared with field collected information from streams in the Willamette Valley.
Time frame: year 3-4

6. Development of ecosystem service portfolio worksheet and protocols for implementing the Web Sade Tool and associated ground based restoration monitoring.
Time frame: year 4

7. Outreach and feedback from landowners and other stakeholders.
Time frame: year 4

What worked and what didn't

Our tool demonstrates the feasibility of automating some portions of ecosystem service quantification. This automation relies on several elements: sufficient high resolution (both in space and in time) spatial data for important parameter values, a robust process model, new software techniques and infrastructure that allow for data sharing and manipulation over the web. While integrating these elements was technically challenging, the outcome was a fully automated too that any user can use.

One aspect of our design concept that was not fully realized was a truly distributed design. Ideally, our tool would function as an aggregator of information and other tools (e.g. models) that are constantly being updated and maintained by their respective owners. While we demonstrated the feasibility of this concept with our tool, the infrastructure to fully realize this design goal in practice does not currently exit. For instance, the LIDAR data used by the Web Shade Calculator is collected and maintained by the Oregon Department of Geology and Mineral Industries. Ideally, the Web Shade Tool would be able to access these data sources via web services and would have access to the most up to date LIDAR coverages as they are progressively being developed for the state of Oregon. However, the LIDAR coverages are currently not maintained in a form that is directly usable by the Web Shade Tool. This required us to download the files to a local server. As these technologies developed, better frameworks for facilitating the interoperability of data will be needed. While there has been considerable progress in making the IT infrastructure and protocols more interoperable, more work is needed to make the underlying data themselves more accessible. One potential model would be to have a centralized repository for core earth systems data. Google has been one pioneer in this area with their development of Google Earth and the newly released Google Earth Engine.

Discussion of Quality Assurance

Study sites

We validated the accuracy of the webtool outputs by comparing them to field measured estimates of stream vegetation characteristics and shade conditions. Data were collected at 16 sites over two years (Appendix V). The number of sites used for field testing was slightly less than the estimate stated in the deliverables because data gaps in the remotely sensed data required that some sample locations be dropped from analysis. The total of sites surveyed during the study was 22, but only 16 of these were subsequently used for analysis. The resulting data consisted of a total of 173 individual data sets.

The study sites were stream reaches in the Willamette Valley. Sites were chosen to represent a range of site conditions, histories, and restoration status. Sites were also chosen to encompass uniform reach sections. Streams flowed through both agricultural and urban landscapes. The vegetation along all streams was typical of riparian zones in the Willamette Valley. Dominant emergent trees included big leaf maple (*Acer macrophyllum*), Oregon Ash (*Fraxinus latifolia*), Oregon white oak (*Quercus garryana*), alder (*Alnus rhombifolia*), and cottonwood (*Populus trichocarpa*). Understories were typically dominated by Himalayan blackberry (*Rubus armeniacus*) with other shrubs e.g. hawthorne (*Crataegus douglasii*), snowberry (*Symphoricarpos alba*), willow (*Salix* sp.), hazelnuts (Corylus *cornuta*), and ocean spray (*Holodiscus discolor*).

Sampling Design

We measured vegetation characteristics approximately every 100 ft. along each stream reach (Fig. XX). This corresponds to the sample spacing used by the Web Shade Calculator. It's perfectly fine to adjust the sample spacing slightly to avoid obstacles like intense blackberry thickets or poison oak. You may also need to reduce the spacing if your stream reach is short. You want to take an average of at least three points for each reach. Here is a diagram of a typical stream sample design, with the stream section of interest divided into two reaches:

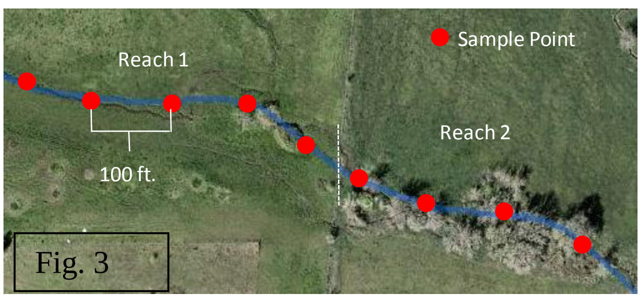

Fig. 3

At each sample point we measured the near stream canopy height in each of seven cardinal directions relative to the stream (NE, E, SE, S, SW, W, and NW) using a laser rangefinder. Canopy height values were average for each sample point. Also at each sample point we measured the vegetation overhang on opposite banks of the stream and the wetted width.

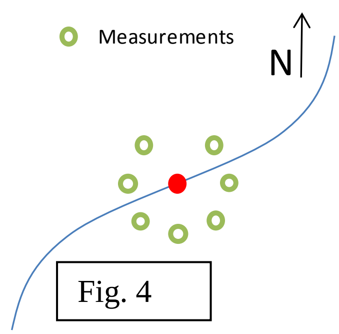

Fig. 4

We measured Angular Canopy Density (ACD) at each sample point using a spherical ACD meter (Beschta et al. 1987). They argued that for purposes of summertime stream heating, shade is most important between 10 AM and 2 PM in mid- to late-summer and that this should be the reference parameter for the exposure of streams to sunlight. At a given point on a stream, ACD is the percentage of time that it will be shaded between 10 AM to 2 PM local solar time (http://www.acdmeter.com/). The ACD meter was calibrated for the month of August and latitude of 44˚. We averaged ACD of each sample point over a stream reach.

The resulting data consists of vegetation characteristics at173 points along 22 stream reaches (Appendix V)

Analysis and results
To test the ability of the Web Shade Tool to accurately estimate actual current shade values along streams we compared the field measured ACD estimates with the web tool calculated stream shade values. There was a strong correlation between the field measures of stream shade and the web tool estimates based on the LIDAR data. The relationship was stronger when data points were averaged over a stream reach (Fig. 5). There were no differences in the relative strength of the correlation between field and web tool estimates across streams with different land use status or restoration history. These results indicate that the Web Shade Tool produces robust and highly accurate estimates of stream shading.

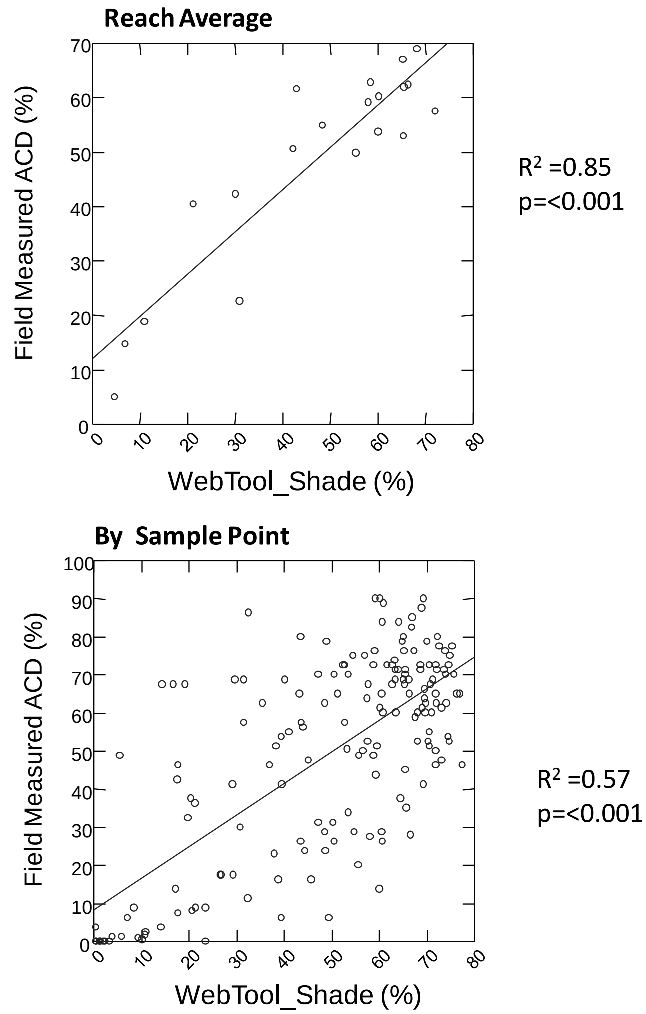

Fig. 5. Relationship between field measured and webtool calculated % current shade.

Findings

Our findings relative to the project goals and deliverables are as follows:

Web-based ecosystem service tools are feasible and potentially powerful (Goal 1, deliverable 1)
Our principal goal was to develop a more accessible quantification tool using a distributed computing framework that makes use of the growing availability of spatially indexed bio-physical data and the increasing ability to link diverse computing platforms using web services.

We accomplished this goal with an easily web accessible tool that is user friendly and provides accurate and high resolution results:
http://groups.hort.oregonstate.edu/content/stream-shade-tool

Our quantification tool provides landowners with estimates of solar heat loading along user defined sections of streams. Users can assess the degree to which management practices such as adding or removing riparian trees creates heat loading credits or deficits. The tool consists of four components that are linked through web services: 1) a graphical user interface; 2) geodatabases that store spatially indexed parameter values; 3) process models that calculate ecosystem service values; 4) a reporting interface the returns model outputs to the user. We believe that this general framework can produce more robust and accurate quantification systems as well as more accessible ecological information to individual landowners.

Web-based tools can provide highly accurate information (Goals 1, 2; deliverables 1, 3)
We validated the accuracy of the webtool outputs with field measured estimates of stream vegetation characteristics and shade conditions. Data were collected at 22 sites representing 173. The field collected data indicate that the webtool provides a robust estimate of current shade conditions at a very high spatial resolution (reach and even single point scales).

Of course, tool accuracy is ultimately dependent on the accuracy of the underlying data and biophysical models. In our case, we made use of newly developed LIDAR data and an existing well validated bio-physical model. However, the power of the distributed and web enabled design of our tool is the relative ease with which the most up to date data and models can be integrated. This general result suggests that future data and models should be organized and designed in ways that facilitate incorporation into a distributed web environment.

Web tools can facilitate restoration monitoring (Goal 2, 3; deliverables 2-4).
In our original proposal, we conceived of compiling existing models into a spreadsheet style tool that would facilitate compiling data and organizing the ecosystem outputs of a restoration. This type of tool still requires extensive field monitoring to acquire the data to parameterize the underlying ecosystem service models. However, as we developed our web-based tool we realized that the new design could automate much of the actual field monitoring. Our field testing confirmed that our tool produces results comparable to actual field measurements.

This new type of monitoring protocol is intuitive and easy to use. We produced a detailed website and associated user guide explaining the purpose of the tool and how to use it.
http://groups.hort.oregonstate.edu/content/stream-shade-tool

In addition, the web tool allows for data storage, updating, and user overrides of existing values. This can greatly facilitate tracking and monitoring restoration success. We developed a field assessment and monitoring protocol to allow landowners to update the webtool estimates of current shade and to monitor the progress of restoration sites in terms of shade provisioning (Appendix VI).

We evaluated the protocol in the field for ease of use and cost. An average user takes about 1 hour to complete the protocol for a 1500 ft. reach of stream. The cost of equipment and supplies is minimal ranging from no cost (excepting incidentals like wet boots etc) to a few hundred dollars. Overall, the webtool itself attempts to minimize costs. For many reaches there is no user override required to receive accurate results from the webtool. In these cases the user costs are only those related to the internet connection and the computer.

Web tools facilitate developing portfolios of ecosystem service values (deliverable 6).
The ability to automate ecosystem service calculation through easy to use and intuitive interfaces creates the ability to develop individualized portfolios of ecosystem service values for landowners. One of the key limiting restrictions to creating such portfolios currently is that ecosystem service quantification requires site and context specific evaluation and manipulation of complex models. Our tool demonstrates that these roadblocks can be overcome for estimating current and potential stream shade and thermal benefits. Other similar web tools are being developed that calculate other ecosystem service values and how they respond to varying management. One of these is the Nutrient Trading Tool developed by the NRCS West National Technology Support Center (Lal 2010). In our original project proposal, we envisioned integrating stream shade provisioning and nutrient buffering capacity calculations into a single tool. As we outline in our semi-annual reports (Appendix II), we realized that the WTSC was embarking on a similar web-based design for nutrient trading. For various technical and practical reason we agreed that the best approach would be to keep the software infrastructure for the two tools separate. Instead, we decided to integrate the tool outputs suing an easy to use worksheet that a landowner can use to compile a portfolio of values for the various services.

We developed a simple worksheet for landowners to compile a portfolio of potential ecosystem services credits (Appendix VII). The worksheet introduces landowners to our Stream Shade Calculator as well as the USDA's Nutrient Trading Tool. These two new webtools allow landowners to estimate the potential ecosystem service benefits that could accrue by conducting riparian restoration and other conservation practices. Both tools report these potential benefits in units that are directly applicable to ecosystem service markets being developed in the Willamette Valley.

Users from a range of stakeholder groups found the tool useful and easy to use (Goal 3; deliverable 5)
We conducted four primary workshops that introduced the tool to conservation organizations, land managers, regulatory agencies, and private landowners:

- 9/15/08. Workshop held at Clean Water Services. At the workshop we demonstrated a version of the tool to agencies and received feedback on gathered feedback on the tool design and directions for future development.
- 1/25/09. Workshop held as part of the Oregon Processed Vegetable Growers Meeting, Albany, OR. At the workshop we covered the importance of improving and conserving riparian habitat on farms, demonstrated the tool, and covered resources available to landowners for doing restoration.
- 8/19/10. Workshop held at the Oregon Garden. The workshop introduced the latest version of the tool, covered resources available for doing restoration and improving ecosystem services, and discussed emerging market based programs in Oregon. Workshop participants included representatives from local and regional agencies, city governments, and private landowners.
- 8/24/10. A second workshop same as above.

In addition to these four primary workshops, we also conducted several project meetings with cooperators and other groups doing similar work to elicit feedback on project direction and development, and to coordinate effort. These are outlined in the semi-annual reports.

We prepared information packets for participants that included general information about ecosystem services, developing marketplaces for them, the value and importance of riparian habitats, and technical information about restoration. The packet also contained a summary of the Stream Shade Tool functions and uses (Appendix VIII)
Participants of the four public workshops were generally enthusiastic about the tool. Values that they highlighted included:

- Ease of use
- Quick return of outputs
- High spatial resolution
- Ability to override initial values
- Clear reporting output

The main general concern expressed by participants was the limited working extent of the tool. There was great demand for the tool to work outside of its current coverage area in the Willamette Valley.

While individual landowners were interested in the idea that they could readily calculate stream shading values, they ultimately were more interested in how these values could be translated into incentives and payments to carry out restoration. At our workshops we had representatives from both the Willamette Partnership (http://willamettepartnership.org/) and the Freshwater Trust (http://www.thefreshwatertrust.org/) present to provide information about efforts to develop a functioning ecosystem service market that would facilitate restoration and conservation activities. While full engagement of private landowners awaits the development of these broader efforts, we think that tools like our Stream Shade Calculator are powerful ways of engaging individual landowners in the process. The ability to provide landowners with quick and explicit estimates of current and potential conditions on their property empowers landowners to integrate conservation and restoration into their site and farming plans.

Many of the participants of the workshops were from local and regional municipalities that have permitting requirements with respect to Oregon DEQ and the Clean Water Act. These participants were interested in how the tool could be used in their planning and reporting efforts. These stakeholders were most interested in the final outputs of the tool (current and potential shading) since these were among the primary metrics that they had to report to Oregon DEQ and mitigate for. Consequently, they were very receptive to the tool design that allowed very quick, yet accurate estimates of these values for particular stream reaches. One of the principal desires they expressed was for tools that would similarly calculate other service values such as bacteria loading.

Representatives of regional agencies such as Oregon DEQ were also present at the workshop. They largely had a desire for a tool that would fulfill specific regulatory requirements such as developing TMDL’s. They offered feedback on aspects of tool design that would help them in these tasks. These included elements such as the ability to evaluate the vegetation on different banks of the stream separately and the ability to implement full temperature modeling. Some of the deficiencies in this regard were intentional design decisions on our part. There are always tradeoffs between tool/model functionality and ease of use. Because our tool was targeted at landowners we made a conscious effort to design for ease of use. As a consequence, we purposely omitted some functionalities that are only really important for higher end users such as those developing TMDL's for a watershed.

These varying comments among groups highlight the fact that different stakeholder and user groups vary in their requirements and needs. Web tools, like any other tool need to be designed with these potentially conflicting requirements in mind and with explicit users identified. However, the distributed design of our web tool likely facilitates the ability to design user specific tools. Much of the underlying infrastructure required to integrate data and calculate results is shared or similar, even if the specific functionalities are different. One design approach would be to vary the user interface of ecosystem services calculators for each particular user group. These interfaces could function like webpages (e.g. Amazon.com), that vary the information they display depending on the particular user.

Conclusions and Recommendations

We believe that the general design framework we developed for this project can produce more robust and accurate quantification systems for ecosystem services. Just as importantly, the user friendly and web based design make complex ecological information more accessible to individual landowners. This information can empower individual landowners to make more informed decisions about how to manage the ecological and conservation values of their property in addition to the market and commodity based values. This will likely produce more direct participation in conservation programs and improvements in priority resource concerns identified by the NRCS.

However, there are several obstacles that potentially hinder the widespread adoption of this technology. These obstacles apply both to the specific case of the Stream Shade Calculator as well as the more general applicability of web based ecosystem calculators. We outline these and offer recommendations to overcome them below:

Rural internet access
The most basic infrastructure needed to implement web based tools is a high speed internet connection. While there are still significant gaps in internet service (particularly in terms of affordability) in rural areas, affordable coverage is expanding rapidly. The expansion is partly a result of the development of cellar based data infrastructures. Web based ecosystem service tools should be designed with this in mind. While we did not have the resources to develop n smart phone "app" based on the Stream Shade Tool in this project, we would like to develop a version optimized for mobile devices in the future. This would allow users to get instant estimates of shade using their smartphone or tablet device while they are in the field over. The ability to get estimates of current and potential ecosystem service credits while actually looking at a project site would greatly help in planning and in visualizing the impact of a restoration.

Distributed computing cyber infrastructure
One of the main design goals of our project was to demonstrate the utility of a distributed design for integrating the myriad components needed to derive ecosystem service estimates. While we

successfully demonstrated the concept, fully implementing our distributed vision was not possible. This is because many of the data needed to do calculations were not stored in ways that made them directly accessible and usable by our tool. To have truly distributed information networks there needs to be greater coordination of data collection and management standards, as well as other aspects of interoperability. Many important ecosystem services such as nitrogen filtration or stream shading are derived from a finite set of underlying parameters. We need regional or national level plans to identify these data needs and to develop unified data collection and repository infrastructures. Greater coordination would greatly facilitate the development of truly distributed ecosystem service calculators.

These systems are increasingly being developed. The NRCS web soil survey (http://websoilsurvey.nrcs.usda.gov/app/HomePage.htm) is a good example. Interestingly, the private sector led by Google has also been a leader in developing unified data storage and distribution for environmental and earth science data. Google Earth and the recently released Google Earth Engine (http://earthengine.googlelabs.com/#intro) are good examples. In the words of Google: "Google Earth Engine brings together the world's satellite imagery—trillions of scientific measurements dating back more than 25 years—and makes it available online with tools for scientists, independent researchers, and nations to mine this massive warehouse of data to detect changes, map trends and quantify differences to the earth's surface."

More data

One of the most frequent requests at our workshops was for the Stream Shade Tool to be operationally for more areas in Oregon. Our experience developing the tool exemplifies the general opportunities and challenges surrounding the basic data needed to make ecosystem service calculations. There has been a great increase in the availability of remotely sensed and field collected data. In particular, the increasing availability of data at high temporal and spatial resolutions has made it possible to quickly access site and time specific data. The Web Soil Survey (mentioned above) as well as Agrimet (http://www.usbr.gov/pn/agrimet/wxdata.html) are good examples. In our case, we made use of LIDAR data recently developed for the state of Oregon by the Oregon Department of Mines and Industry (http://www.oregongeology.org/sub/default.htm). These data allowed us to create highly detailed estimates of current stream shade at the reach scale.

Despite the explosion in availability of data, the absolute amount of it relative to potential needs and questions is still small. In the case of the Stream Shade Calculator, the LIDAR data it requires does not exist for much of Oregon, although fortunately the agricultural intensive Willamette Valley is a coverage focus. In addition to spatial coverage, temporal coverage can be important for many ecosystem services, if for no other reason than to track trends in service creation with respect to changing management practices, restoration, or climate change. We think that there should be a concerted effort to target parameters for data collection that have specific relevance to ecosystem service estimation.