A LANDSCAPE APPROACH TO ECOSYSTEM SERVICES

IN

OREGON'S SOUTHERN WILLAMETTE VALLEY AGRICULTURAL LANDSCAPE

by

CHRISTIANNE ENRIGHT

A DISSERTATION

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Student: Christianne Enright

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This dissertation has been accepted and approved in partial fulfillment of the requirements for the Doctor of Philosophy degree in the Department of Landscape Architecture by:

David Hulse	Chairperson
Bart Johnson	Member
Thomas Oles	Member
Stanley V. Gregory	Member
Susan W. Hardwick	Outside Member

and

Kimberly Andrews Espy	Vice President for Research & Innovation/ Dean of the Graduate School

Original approval signatures are on file with the University of Oregon Graduate School.

Degree awarded March 2013

DISSERTATION ABSTRACT

Christianne Enright

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Title: A Landscape Approach to Ecosystem Services in Oregon's Southern Willamette Valley Agricultural Landscape

Over the past decade, ecosystem services has become a familiar term. Definitions vary but the central idea is that society depends on and is enhanced by earth's resources. Concerns about natural resource depletion and degradation have motivated researchers to move from concept to operation and real-world change. Since the late 1990s, attention has been directed at characterizing the monetary value of ecosystem services to influence decision-making processes. This research has been dominated by the disciplines of ecology and economics with the underlying assumption that the integration of these disciplinary approaches will provide the necessary operational pathways forward. The perspectives of ecology and economics are crucial but the unique qualities of ecosystem services suggest the need to consider other approaches and a willingness to look beyond existing models and disciplinary boundaries.

I propose a landscape approach to ecosystem services in which they play a role in the intentional coevolution of social/ ecological systems. I apply this approach to explore the potential for floodplain agricultural landscapes to provide ecosystem services in a 65,000 acre study area located in Oregon's agriculturally-dominated southern Willamette Valley. The landscape's biophysical processes are represented by three ecosystem services: non-structural flood storage, carbon sequestration and floodplain forest. These are quantitatively evaluated using a geographic information system. One aspect of

the landscape's sociocultural processes is explored through qualitative interviews with farmers and profiles of the crops they commonly grow. The biophysical and sociocultural research components are integrated through an alternative futures framework to compare the ca. 2000 landscape with a 2050 future landscape in which agricultural production includes ecosystem services.

In the 2050 landscape, the synthesis results show where all three ecosystem services are simultaneously provided on 2,981 acres and where increases in carbon sequestration and floodplain forest are simultaneously provided on an additional 4,841 acres. For the identified acres, the annual income from present-day conventional crop production is provided as a first approximation of the monetary income that farmers would consider for producing ecosystem services.

CURRICULUM VITAE

NAME OF AUTHOR: Christianne Enright

GRADUATE AND UNDERGRADUATE SCHOOLS ATTENDED:

University of Oregon, Eugene
University of California Santa Barbara

DEGREES AWARDED:

Doctor of Philosophy, Landscape Architecture, 2013, University of Oregon
Master of Landscape Architecture, 2006, University of Oregon
Bachelor of Landscape Architecture, 2003, University of Oregon
Bachelor of Arts, Botany, 1984, University of California Santa Barbara

PROFESSIONAL EXPERIENCE:

Graduate Research and Teaching Fellow 2002 - 2013, Institute for a Sustainable Environment and Department of Landscape Architecture, University of Oregon

PUBLICATIONS:

Hulse, D., A. Branscomb, C. Enright and J. Bolte. 2009. Anticipating floodplain trajectories through alternative futures analysis. *Landscape Ecology* 24(8): 1067-1090.

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CHAPTER I

INTRODUCTION

Background and introduction

Ecosystem services has become an increasingly familiar term over the past decade. The concept is intended to make explicit the ways in which people's lives depend on and are enhanced by the earth's resources. This is not a new idea but increasing concerns about the rates of natural resource depletion have propelled efforts to move from concept to operational pathways for better protecting and restoring these services that nature provides. At present, many ecosystem services are used as public goods; their use is unrestricted and there is no monetary cost to an individual user. The discourse surrounding ecosystem services was elevated in the late 1990s and since that time a research agenda has developed rapidly. There is a common motivation to develop the concept of ecosystem services in effective ways for the purpose of maintaining, restoring and planning into the future for a sufficient supply of natural resources. Although multiple academic disciplines are involved, the primary approach to ecosystem services research is to characterize their monetary value through the integration of ecology and economics. While this is key, I argue that a research agenda limited to this approach omits fundamental aspects of ecosystem services and narrows the range of pathways to address the problem. I present what I refer to as a landscape approach to ecosystem services in which the coevolving relationship between people and the land is central. The intention is to offer a pathway that is holistic and encompasses a landscape's particular ecological and social systems. My research explores this approach to ecosystem services in the agricultural landscape of the southern Willamette Valley, Oregon.

The study area

Ecosystem services can be approached from multiple perspectives and the focus of attention varies with different disciplines. Economists tend to focus on identifying and characterizing benefits to people from ecosystem services; ecologists tend to focus on characterizing and quantifying ecological functions and processes as they relate to ecosystem services. My focus is on landscapes which evolve through the interaction of people and the land. Bounded territories of land have been central units of inquiry in expanding the body of knowledge in landscape architecture, and this effort builds on that tradition. In my approach to ecosystem services, the particulars of place are especially relevant and so I begin with a brief introduction to the study area. Additional descriptions of the study area's qualities, for example historic vegetation and agriculture, are provided in subsequent chapters.

The study area is in Oregon's Willamette Valley Ecoregion (Figure 1a) which is bounded on the east by the Cascade Range and on the west by the Coast Range. The Valley (Figure 1b) contains the state's largest urban centers and is home to approximately 68% of the state's population (Oregon Department of Fish and Wildlife 2006). The central spine of the Valley is the Willamette River which flows northward from its origin in the southern part of the Valley to its confluence with the Columbia River north of Portland. On the Valley floor, the Willamette River and its tributaries form a network within a broad alluvial floodplain that was formed by the Missoula Floods approximately 15,000 years ago (Lee 2009). Since the mid-nineteenth century, people have taken advantage of the fertile deposits left by the Missoula Floods to develop the Willamette Valley's diverse agricultural landscape.

The 65,000 acre study area is in the southern Willamette Valley between the communities of Harrisburg in the south and Albany in the north (Figure 1b, 1c). The east/west boundaries are centered on the Willamette River and extend across the floodplain to major roads. Agriculture is the primary land use (68% of the area) with grass seed as the predominant crop. Although much has been lost, there are still remnants of the historic qualities of the Willamette River and its floodplain within the study area. The floodplain was historically dynamic with an extensive forest and a shifting mosaic of river, side channels, alcoves and islands. Although the land has been significantly modified since the mid-nineteenth century to accommodate human uses, it remains a floodplain in which the river continues to influence the landscape. This is evident in the set of crops that can be grown in the area and in the configuration of many agricultural fields. Annual flooding, sometimes for days at a time, dictates crop choices for many farmers and it is common to see agricultural fields adjacent to and shaped by the river and its associated floodplain vegetation (Figure 2b,c,d).

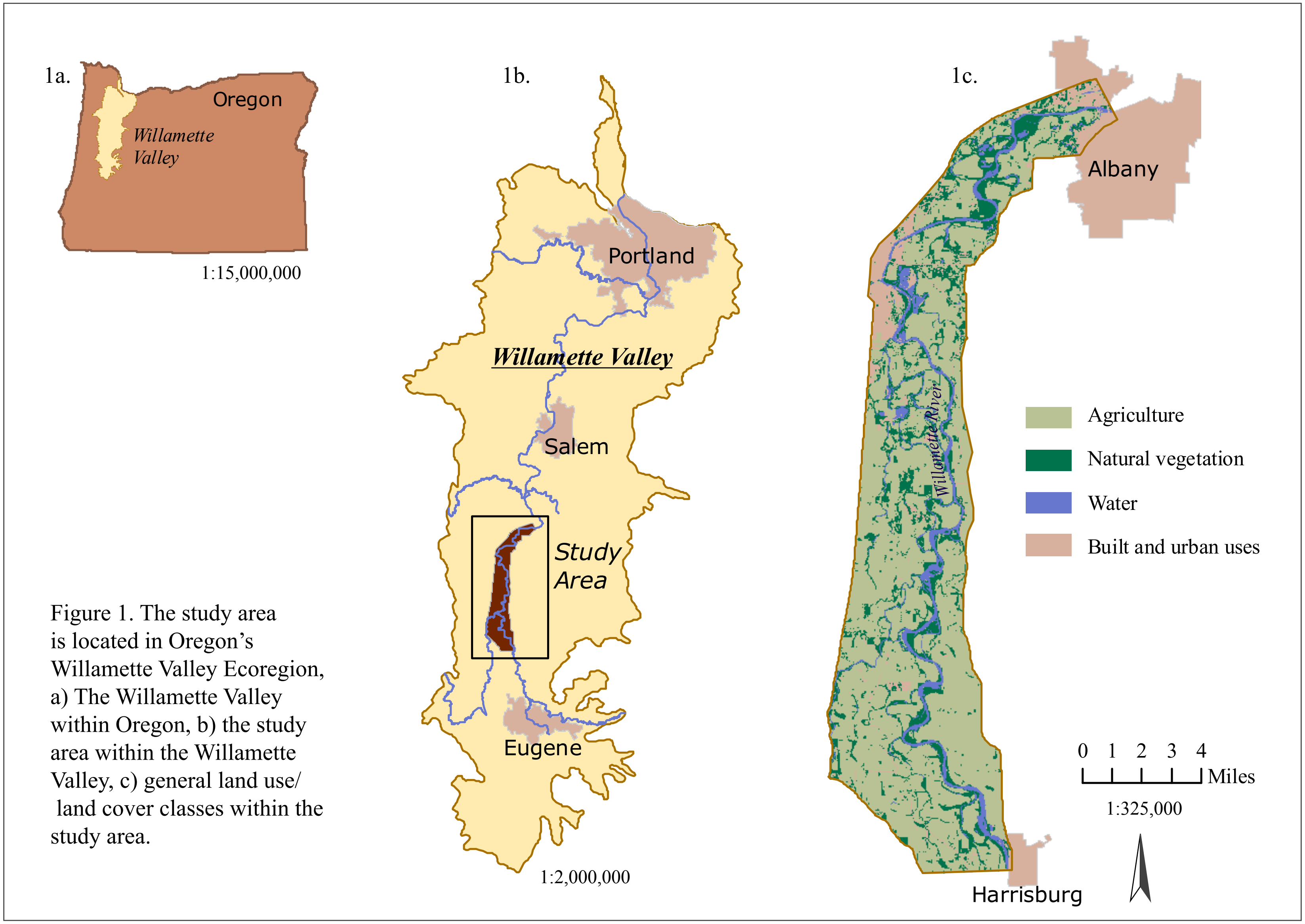

Figure 1. The study area is located in Oregon's Willamette Valley Ecoregion, a) The Willamette Valley within Oregon, b) the study area within the Willamette Valley, c) general land use/ land cover classes within the study area.

2a.

2b.

2c.

2d.

2e.

Figure 2. The Willamette River and farming in the floodplain, a) the Willamette River near Peoria Road, b-e) agricultural fields within the study area.

Research questions

My research explores the potential of the study area's privately owned agricultural lands to provide ecosystem services. In other words: can agricultural crop options be expanded to include ecosystem services? The provision of ecosystem services from a domesticated landscape will be jointly influenced by the availability of natural resources from the land and the willingness of landowners to produce the services. I explore the interaction of resource availability and landowner willingness through two broad categories of landscape processes: biophysical and sociocultural. I evaluate the availability of three ecosystem services from the study area's biophysical environment to represent biophysical processes and I explore farmers' perspectives about ecosystem service production as one aspect of sociocultural processes. In my research these two broad categories of landscape processes are presented as biophysical and sociocultural components. Each component is addressed with a sub-questions and the integration of the two components is at the core of my overall question:

Biophysical sub-question:
What quantities of ecosystem services are available from the landscape?

Sociocultural sub-question:
What are the perspectives of agricultural landowners that influence their willingness to produce ecosystem services?

Dissertation question:
What is the potential of floodplain agricultural landscapes in the Willamette Valley to provide ecosystem services?

I address the biophysical question using a geographic information system (GIS) based approach to quantify the availability of three ecosystem services from the study area: non-structural flood storage, carbon sequestration and floodplain forest. These three ecosystem services were chosen because they are relevant and potentially available from the study area's floodplain agricultural landscape, their production could benefit local communities and their amounts can be quantified using GIS. I address the sociocultural question through: 1) qualitative interviews with farmers to understand their perspectives and, 2) profiles of the study area's major crops. The biophysical and sociocultural components are synthesized in an alternative futures evaluation to compare the present day landscape with a possible future landscape circa 2050. The research questions and components of my dissertation are diagrammed in Figure 3.

Overview of chapters

In Chapter II (Ecosystem services), I clarify terms used in the dissertation, discuss the evolution of the ecosystem services concept and prevalent research approaches and, present the conceptual underpinnings for my analytical approach.

In Chapter III (Study area and research introduction), I reintroduce the study area with additional details and discuss its representation for my research. I provide background on alternative futures analyses and introduce the analytical approach for each component and the synthesis shown in Figure 3.

In Chapters IV, V and VI, I present background, analysis and results for each of the three biophysical components: non-structural flood storage (IV), carbon sequestration (V) and floodplain forest (VI).

In Chapters VII and VIII, I present the sociocultural component of my research. In Chapter VII, I describe my process and discuss the results of my interviews with farmers. The study area's major present-day agricultural crops are characterized in Chapter VIII.

The analytical synthesis of the research components is presented in Chapter IX and in Chapter X, I offer a concluding discussion.

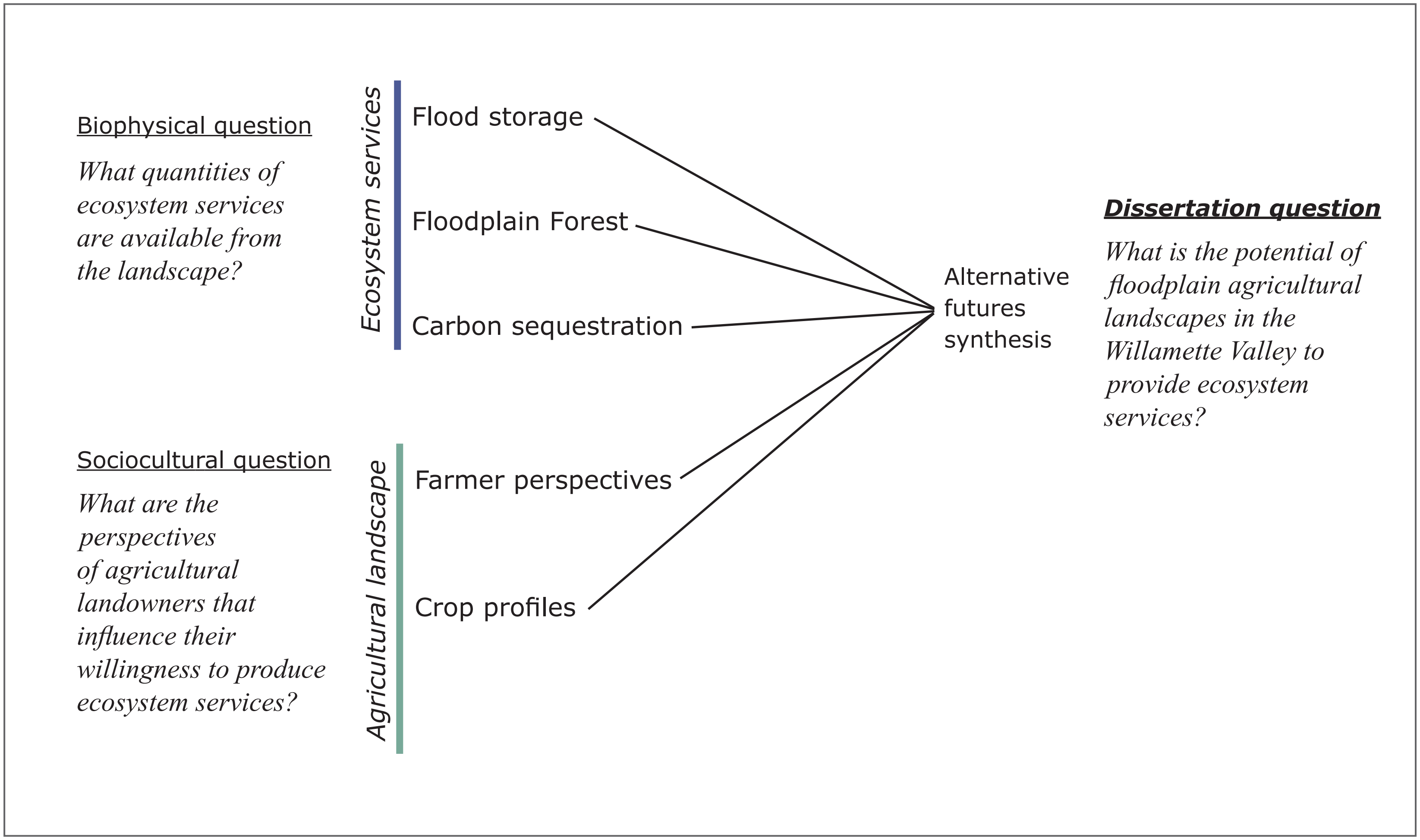

Figure 3. Dissertation questions and components.

CHAPTER II

ECOSYSTEM SERVICES

Introduction

The purpose of this chapter is to provide background and to place my dissertation in a broader context of ecosystem services research and thought. Ecosystem services are not well defined and so I begin with a definition of terms and an introduction followed by a section on the foundations of the ecosystem services concept. I discuss the two main approaches to ecosystem services in the literature: economic and ecological. The section on economic approaches is long compared to the others because this approach has become popular and currently dominates the research agenda. I discuss the economic methodology applied to ecosystem services and the underlying economic frameworks and assumptions because it is important to understand how these relate to ecosystem service characteristics and human values. I briefly discuss spatial mapping of ecosystem services and conclude with the concept of a landscape approach to ecosystem services.

Definition of terms

Some of the terms found in ecosystem services literature are not well defined or universally understood. In Figure 4 and the following text, I clarify key terms used in this chapter and throughout the dissertation.

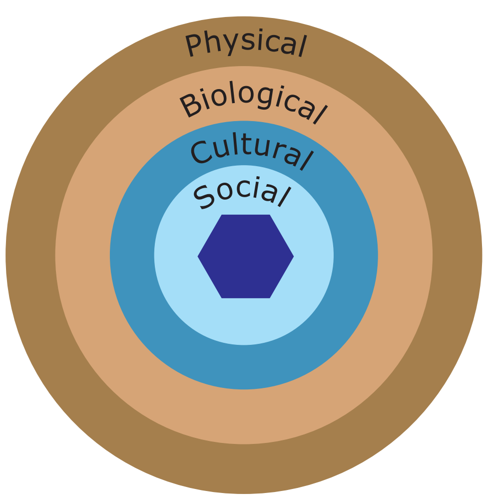

Figure 4. Clarification of key terms. People's social and cultural systems exist within particular biological and physical environments. Figure adapted from Pavao-Zuckerman (2000).

Biophysical refers to the biological and physical parts of a landscape. Some authors refer to this part of the landscape as *nature*. In the dissertation, I use the terms biophysical environment and biophysical system(s) interchangeably to refer to this part of a landscape.

Sociocultural refers to the human systems within a landscape; these influence spatial patterns and processes on the landscape. The term *society* is used by some authors to refer to this part of the landscape.

Landscapes evolve through the interactions of biophysical environments and sociocultural systems.

The biophysical environment provides *natural resources* which are also referred to as environmental resources, ecological resources, environmental services and ecosystem services. Ecological (ecosystem) processes and functions take place within the biophysical environment.

The term *ecosystem services* itself is sometimes ambiguous. It is often used to refer to a suite of goods and services such as nutrient cycling and pollination but it is also used to refer to ways of approaching decision-making and management of these goods and services. In the dissertation I use the term ecosystem services to refer to the goods and services themselves and the terms approach, concept and framework to qualify other meanings of ecosystem services.

WHAT ARE ECOSYSTEM SERVICES?

Ecosystem services are the conditions and processes through which natural ecosystems and the species that make them up, sustain and fulfill human life. (Daily 1997a)

Daily's definition is one of several that can be found in ecosystem services literature. The lack of a commonly agreed upon definition indicates that, as a field of research, ecosystem services is complex, multidisciplinary and still in early stages of development. In more recent publications, ecosystem service definitions are modified from Daily's 1997 version and worded in a way that shifts the role of ecosystems from sustaining and fulfilling human life to providing benefits to people. These include:

Ecosystem services are the benefits people obtain from ecosystems. (Millennium Ecosystem Assessment 2005)

Final ecosystem services are components of nature, directly enjoyed, consumed, or used to yield human well-being. (Boyd and Banzhaf 2007)

> Ecosystem services are the aspects of ecosystems consumed and utilised to yield human well-being. (Turner and Daily 2008)

These differences in wording and emphasis might be considered unimportant variations in language that help to convey the concept to a broader audience. However, if conceptual definitions are to serve as the foundation on which to build, then the choice of words to describe the relationship of people to natural ecosystems matters. Daily's 1997 definition describes a relationship in which people depend on ecosystem processes to sustain life; Boyd and Banzhaf and, Turner and Daily describe a relationship in which ecosystems produce a suite of benefits for people to use.

Seppelt et al. (2010) and Cornell (2011) document the increase in ecosystem services research in the past two decades but there is still confusion and disagreement about what ecosystem services are, how they should be classified and how their value should be characterized. There is agreement about the problem: people depend on the functions and processes of nature for vital needs such as water and food as well as experiences that we associate with being human such as scenic beauty and recreation; and, due to past, present and anticipated future use of natural resources, earth's ability to continue replenishing those resources is at risk. There is, however, disagreement about how to address the problem. A significant segment of the research community is approaching the problem by seeking to integrate economics with ecology (Polasky et al. 2005, Farber et al. 2006, Hein et al. 2006, Turner and Daily 2008, Daily and Matson 2008, Polasky et al. 2009, Daily et al. 2009). This approach stems from the idea that monetary valuation of nature's resources (ecosystem services) is the most expedient way to ensure that they are effectively incorporated into decision-making processes. Others argue that monetary valuation of ecosystem services will not solve the problem and may do harm by sending a message that nature, like everything else, can be bought for the right price (McCauley 2006, Sagoff 2008, Peterson et al. 2010). I have made generalizations in characterizing these examples; ideas about how to approach the problem are not black and white (e.g. to use monetary valuation or not) and new ideas continue to emerge.

Ecosystem services literature suggests that much of the research remains inside disciplinary boundaries with individual disciplines tackling specific aspects of the problem from their own perspective. Economists propose classification systems that suit their economic models and look to biophysical scientists to provide the data for the models. The focus of the scientific community, on the other hand, is to better understand and characterize the ecosystem functions and processes associated with ecosystem service production. This scientific understanding may, or may not, be compatible with economic approaches. A common underlying assumption in ecosystem services research is that the answers will be found by integrating scientific assessment and measurement with economic models. Embedded in this assumption are two additional assumptions: 1) ecosystem services are a reasonable fit with accepted economic concepts of the relationship between people and the land and also with the economic methods of valuation that stem from those concepts; 2) ecosystem services will be competitive in economic markets once the scientific community is able to supply the data necessary to characterize and monetize them. These assumptions may turn out to be well founded but the unique characteristics of ecosystem services and early stages of research suggest the need to consider approaches that do not rely on these assumptions. Without research that considers the unique qualities of ecosystem services and a willingness to look beyond existing models and disciplinary boundaries, progress will be constrained and opportunities may be missed.

Foundations of ecosystem services

The term ecosystem services is relatively recent but the conceptual underpinnings have been articulated and evolving since at least the time of Plato (Daily 1997a). As Daily notes with her example from Plato, man's dependence on earth's processes is most often acknowledged after resources have been damaged or depleted. Mooney and Ehrlich (1997) trace modern awareness of ecosystem services to an 1864 publication by George Perkins Marsh titled *Man and Nature: or, Physical Geography as Modified by Human Action* (Marsh 1864). Marsh discusses at length the ways in which people have altered what he refers to as the woods, the waters and the sands. He writes of the balance between man and nature, "Hence, the action of man upon the organic world tends to subvert the original balance of its species…" and, of unintended consequences, "The felling of the woods has been attended with momentous consequences to the drainage of the soil, to the external configuration of its surface, and probably, also, to local climate…".

The term *ecosystem* did not appear until 1935 when it was introduced by A. G. Tansley in his *Ecology* article "The Use and Abuse of Vegetational Concepts and Terms". What Tansley was describing, according to Golley (1993) was an "holistic and integrative ecological concept that combined living organisms and the physical environment into a system". Mooney and Ehrlich (1997) provide numerous examples from the 1940s and 1950s of individual authors, including Aldo Leopold and Paul Sears, articulating the ways in which ecological systems and processes are connected and compromised by human activity.

In 1955, an interdisciplinary symposium with international participation addressed the topic of *Man's Role in Changing the Face of the Earth* (Thomas 1955). The list of participants is impressive and includes Carl O. Sauer, Lewis Mumford, Marston Bates, Paul Sears, Sir Charles G. Darwin (grandson of Charles Darwin) and Luna Leopold (son of Aldo Leopold). The printed volume is dedicated to George P. Marsh and his work is honored in the introduction. The symposium addresses the impact of human activity, past and present, on biological and physical processes at multiple scales. Scientific assessments that describe and document the biophysical world are interwoven with presentations that discuss the role of culture and human values. The concluding session of the symposium, titled Prospect, raises questions about spiraling populations, limited resources and man's relationship to nature and his fellow-men. A common thread in the symposium conclusion is the relationship of a growing population to limited resources and the potential for industrialized societies to exacerbate resource depletion.

In 1972, Paul and Anne Ehrlich published a revision of *Population Resources Environment: Issues in Human Ecology* (Ehrlich and Ehrlich 1972) which they intended to serve as a "reasonably comprehensive and reliable sourcebook" for students, teachers and general readers. The book links past, present and future population size and distribution with an assessment of resource availability. As with *Man's Role in Changing the Face of the Earth*, the Ehrlichs warn of the potential for an increase in human population that cannot be supported by Earth's limited resources. In chapters on the environment and ecosystems, the authors stress the interconnected nature of systems, man's dependence on those systems and the potential for human activity to deplete resources:

> An understanding of the flow of energy and the cycling of materials in ecosystems is essential to our perception of what is perhaps the most subtle and dangerous threat to man's existence. This threat is the potential destruction, by man's own activities, of those ecological systems upon which the very existence of the human species depends.
>
> Overpopulation and industrialization have contributed in various ways to the general deterioration of the environment upon which humanity is completely dependent for life.

The 1970 report, *Man's Impact on the Global Environment: Assessment and Recommendations for Action* (Study of Critical Environmental Problems 1970) includes a section with the title *Environmental Services*. The section begins, "It is a mark of our time, and a signal of the degree to which man is ecologically disconnected, that the benefits of nature need to be enumerated. More important, however, is the need to evaluate each service in terms of the cost of replacing it or the costs that may result from the loss of doing without it (including future costs that may result from the loss of additional services)". The report then lists and describes specific environmental services including insect pollination, pest control, climate regulation, soil retention and formation, flood control and cycling of matter. This is likely the first published enumeration of specific ecosystem services (Mooney and Ehrlich 1997).

In 1977 Walter W. Westman asked, *How much are nature's services worth?* (Westman 1977). One of his stated purposes was to illustrate the importance of accounting for the benefits of nature's services in societal decision-making. He also identifies underlying assumptions associated with assigning monetary value to nature's services that still exist today but are seldom questioned. Examples of these assumptions are that monetary units are socially acceptable as a means to equate the value of natural resources destroyed and developed and, that the amount of compensation in monetary units accurately reflects the full value of loss. The points he raises about why it is so difficult to fit the value of nature's services into existing monetary frameworks are as relevant today as they were in 1977:

> In practice, however, we rarely repair all the damage [using repair or replacement cost to assign monetary value] …, and in many instances, we do not have the technology to replace the function (for example, what inventor can lay claim to a machine that regulates the global climate?).
>
> It is in part because of the interconnected nature of the complex systems of nature that valuation of individual services lost is so inevitably misleading.

In 1992, Ehrlich and Ehrlich (1992) and Perrings et al. (1992) contributed to a special issue of *Ambio* about the economics of biodiversity conservation. Both papers focus on the critical role of biodiversity in providing ecosystem services and use economic language in characterizing those services. Ehrlich and Ehrlich use the term ecosystem services and distinguish those services with use value (for example food) from those with non-use value (for example the beauty of a butterfly). They recognize four categories of value: ethical, aesthetic, direct economic and indirect economic. Perrings et al. (1992) use the term ecological services rather than ecosystem services throughout most of their paper but both terms are present and appear to be used interchangeably. These authors distinguish three concepts of value: 1) incentive or market value, 2) individual or private value and, 3) social value which is the aggregate impact on the welfare of all individuals, now and into the future (Perrings et al. 1992).

In 1997 two influential publications, Costanza et al. (1997) and Daily (1997b), advanced the topic of ecosystem services by increasing public awareness and spurring research interest. Costanza et al.'s (1997) article in a widely read journal estimated the monetary value of all of earth's ecosystem services. For the lay audience, this presented the topic in terms that were easily understood and got the attention of those who might not otherwise pay attention. The research itself spurred an academic exchange that included those who rallied around the conclusions and those who pointed out the flaws in the research methods. The book *Nature's Services: Societal Dependence on Natural Ecosystems* (Daily 1997b) is a collective endeavor by contributors from multiple disciplines for the purpose of fostering an appreciation of the value of natural ecosystems. Chapters provide an introduction to ecosystem services, discuss ecosystem process and function across scales and, present basic economic concepts and models. The final section of the book offers case studies to provide specific examples of ecosystem services.

Classification of ecosystem services

Multiple classification systems have been proposed for ecosystem services but this topic remains unresolved and sometimes contentious. Differences in disciplinary approaches to ecosystem services are evident in the proposed systems: economists tend to focus on identifying direct and tangible benefits that people use (Boyd and Banzhaf 2007, Wallace 2007, Fisher et al. 2009, Balmford et al. 2011) and, ecologists tend to focus on connecting ecosystem function and process to flows of energy, goods and services (Chee 2004, Kremen 2005, De Groot 2006, Luck et al. 2009).

An early classification system proposed by Daily (1999) organizes ecosystem services into five broad categories: production of goods, regeneration processes, stabilizing processes, life-fulfilling functions and preservation of options. The overall list of ecosystem services is comprehensive and emphasizes the wide range of benefits provided by ecosystems. The classification in the Millennium Ecosystem Assessment (2005) is similar to Daily's with four broad categories (supporting, provisioning, regulating and cultural) and a more condensed list of ecosystem services. The Millennium Ecosystem Assessment's classification framework is extended to specifically link the four categories of ecosystem services to what they refer to as constituents of human well-being (security, basic material for good life, health, good social relations and, freedom of choice and action). Both of these systems are organized and presented in a way that makes them easily understood by a broad audience but both have been criticized for a lack of operational clarity (Boyd and Banzhaf 2007, Wallace 2007, Fisher and Turner 2008).

The classification systems proposed by Wallace (2007) and Boyd and Banzhaf (2007) organize ecosystem services from an economic perspective. Boyd and Banzhaf (2007) assert that progress in ecosystem services is hampered by a failure to standardize definitions and accounting units. The foundation of their framework is what they call a *final ecosystem service unit* which is defined "in a way that is methodologically and economically consistent with the definition of goods and services used in the conventional income accounts". The final service units are the "end-products of nature" and the authors stress the importance of making the distinction between these end products and intermediate processes and functions. In the construct of Boyd and Banzhaf, water purification is not an ecosystem service; the ecosystem service is clean water only as it relates to human health and recreation. Wallace (2007) makes an argument similar to Boyd and Banzhaf (2007) and characterizes the problem with other classification systems as mixing ends and means. As an example of this, The Millennium Ecosystem Assessment classifies pollination as a regulating ecosystem service; but, according to Wallace, pollination is a means to an end (food) rather than an ecosystem service. Wallace's system has three broad categories: human values (for example, adequate resources, protection from predators and diseases), ecosystem services experienced at the individual human level and, processes and assets that need to be managed to deliver ecosystem services. Wallace asserts that processes that are required to deliver ecosystem services (for example, pollination, water regulation and photosynthesis) are means to an end and not themselves ecosystem services.

In a response to Wallace's paper (2007), Costanza (2008) makes a case for multiple ecosystem service classification systems. Costanza takes issue with Wallace's basic premise and finds his approach "a gross simplification of a complex reality". Costanza argues that the breadth and complexity of ecosystem services necessitates multiple classification systems. He provides two examples of different classification systems, one from an economic perspective and another that considers the spatial characteristics of ecosystem services. Costanza states that the goal should not be one standard classification system but rather "a pluralism of typologies that will each be useful for different purposes".

Value and economic approaches to ecosystem services

Value – concept and language

Concepts and language associated with value in ecosystem services literature can be confusing and inconsistent. Farber et al. (2002) address this by providing definitions for three concepts: value system, value and valuation. Value systems refer to "the normative and moral frameworks people use to assign importance and necessity to their beliefs and actions". Value is the "contribution of an action or object to user-specified goals". Valuation is "the process of expressing a value for a particular action or object". It is important to note that money is not included in these definitions. The determination of a monetary amount for a good or service is a type of valuation where the value is expressed in monetary terms, i.e. monetary valuation (also referred to as economic valuation). Other authors are not always as careful as Farber et al. to specifically define terms associated with value and one particular source of confusion is the lack of distinction between value and valuation. There is agreement that ecosystem services have value but there is not agreement regarding how that value should be characterized and there are differing ideas about approaches to valuation.

My discussion of economics with respect to ecosystem services is organized into three sections: the characterization of value, approaches to economic valuation of ecosystem services and, the goodness of fit between the discipline of economics and ecosystem services.

Characterization of value

The language used to describe and distinguish types of value in ecosystem services research continues to evolve. There is general agreement about two broad categories of environmental goods that people value: those with *use value* and those with *non-use value*. There are not, however, consistent definitions of the two categories. The National Research Council (2005) defines *use value* as the use of an environmental resource, including both commercial and non-commercial uses. Chan et al. (2011) define *use value* as the direct (consumptive and non-consumptive) and indirect uses of ecosystem goods and services. Although not explicitly stated, use value implies present use rather than future use. The term non-use value has been used as a broad umbrella to point out that people care about many things that may be intangible and have no present use value. According to A. Myrick Freeman (2003), the terms “existence”, “intrinsic”, “nonuse” and “passive-use” have all been used to refer to natural resource values that are independent of people’s present use of the resource. Chan et al. (2011) recognize existence value as one of three sub-categories of non-use value: 1) existence value captures the satisfaction of knowing that something exists (for example wilderness or a particular species), 2) bequest value is knowledge that an environmental amenity will exist for future generations and, 3) option value is the premium that people are willing to pay to preserve an environmental amenity. Freeman (2003) asserts that the ambiguity in terms is unimportant. However, if the distinctions in non-use categories serve as a basis for choosing an appropriate non-market valuation method (discussed in the following section), the ambiguity could be more significant than a semantic inconsistency.

Economic Valuation Methods

The purpose of economic valuation methods is to determine a monetary value for a good or service. There are two broad categories of economic valuation methods: market and non-market. Ecosystem goods that have direct use value and are exchanged in current markets, for example food and fiber, have monetary value established by market activity. De Groot et al. (2002) refer to this as direct market valuation. Most ecosystem services with non-use or indirect use value, for example nutrient cycling and genetic resources, are not represented in current economic markets and associating their benefits with a monetary value has proved challenging. These ecosystem services are referred to as non-market goods and services because their monetary value cannot be directly established by market activity. Economic approaches to non-market valuation have received considerable attention in the past 20 years (Lockwood 1998, Farber et al. 2002, Champ et al. 2003, National Research Council 2005, De Groot 2006, Farber et al. 2006, Fisher et al. 2008, Bateman et al. 2011) but, as yet, their practical application for ecosystem services is limited. I briefly discuss economic approaches to non-market valuation in the following paragraphs. Refer to Table 1 for an overview of economic valuation methods.

Substitution or replacement costs

In cases where an ecosystem service replaces or substitutes for a marketed good, the monetary value of the ecosystem service can be estimated from the market value of that good. One often cited example of this method is New York City's choice to fund restoration of the Catskills watershed rather than purchase a new filtration system for drinking water (Chichilnisky and Heal 1998, Daily and Ellison 2002, National Research Council 2005). A cost comparison showed that the watershed restoration would be more cost effective than replacing the city's water filtration system. It is acknowledged that this substitution or replacement valuation method provides a monetary valuation for only a portion of the benefits provided by the ecosystem service (Heal 2000). In this case, the monetary value represents the water filtration benefit but does not include additional benefits such as nutrient cycling and cultural resources.

Method	***Monetary value determination***	***Generic example***
Market based	Value is determined by current market activity.	Food or timber
Non-market based		
Substitution or replacement	Value is determined by the cost of providing the same good or service by other means.	The monetary value of restoring watershed processes to provide clean water is determined by the cost of installing a water filtration system for the same purpose.
Revealed preference	Value is determined indirectly from current market activity.	The monetary value of having a park adjacent to a home is determined by the difference in sales price of two houses that are identical except for park adjacency.
Stated preference	Value is determined by asking people what they would pay for a good, service or amenity. Individual responses are aggregated to determine value.	Survey participants are asked what they would be willing to pay for restoring native habitat in a nearby natural area.
Discourse-based	Value is determined by participatory group process.	Local community members collectively discuss and determine the monetary value of restoring native habitat in a nearby natural area.
Benefit transfer	Value is determined by using existing data that have been generated by other researchers for their own projects.	A previous study determined the monetary value of native bee pollination in coffee production in Costa Rica. This monetary value is used in determining the value of native bee pollination for melon crops in California.

Table 1. Overview of economic valuation methods.

Revealed preference and stated preference methods

Economists have a suite of methods (sometimes referred to as models in economic literature) that can be used to derive monetary value for goods and services that are not traded in current markets and cannot be valued using substitution or replacement costs. There are two primary underlying approaches for these methods: 1) in cases where relationship can be established between a non-market good or service and current markets, the monetary value can be derived from current market behavior, 2) where no relationship can be established between current markets and non-market goods and services, people are presented with hypothetical situations and asked to make choices, state preferences or, indicate their willingness to pay. In the first approach, referred to as revealed preference, monetary values are *revealed* through people's choices and activity in current markets. Associating amenities with property values is often used to illustrate revealed preference. For example, the monetary value of living adjacent to a park can be estimated by the difference in selling price of two homes that are similar in all respects (size, number of bedrooms, construction quality, lot size) except one is adjacent to a park and the other is not. In the second approach to monetary valuation, referred to as stated preference, monetary values are derived from what people say they would do rather than activity that can be observed in actual markets. People are asked in an interview or survey how much they would be willing to pay, for example, to save Polar bears or maintain a local natural area. Participants are not contributing or committing monetary funds, only stating what they would pay. My generalized examples greatly simplify the sophisticated aspects of stated preference methods which include research context (for example where and how questions are asked), consideration of the knowledge level of participants and careful wording of questions. Some authors use the terms stated preference and contingent valuation interchangeably but others are specific that contingent valuation and choice experiments (also referred to as choice modeling) are subsets of stated preference methods (Lockwood 1998, O'Neill and Spash 2000, Bateman and Mawby 2004). As described by Powe et al. (2005), contingent valuation methods use a single scenario in which there is a potential for a change in environmental quality; choice experiments ask respondents to choose among multiple scenarios, each expressed as a different bundle of attributes.

Deliberative or discourse-based valuation

The literature indicates a growing interest in developing valuation methods based on deliberative group processes rather than the aggregation of individual preferences. Wilson and Howarth (2002) use the term discourse-based valuation and argue that, given the public goods nature of ecosystem services, valuation should be based on small group deliberation. Spash and Vatn (2006) refer to participatory approaches that include focus groups, citizen juries and consensus conferences in small group deliberation. Norgaard (2010) refers more generally to the need for richer ways of understanding that are more "collective, participatory, and discursive forms of learning, knowing, and governing".

Benefit transfer

A method known as benefit transfer has been used to estimate the monetary value of ecosystem services (Costanza et al. 1997, Farber et al. 2006, Iovanna and Griffiths 2006, Troy and Wilson 2006). In benefit transfer, monetary values that have been previously derived for other purposes are *transferred* to the project at hand. Comprehensive literature reviews are commonly used to locate appropriate source data for benefit transfer and data may be adjusted to better fit the context to which the values are applied. As long as the source data are deemed appropriate for benefit transfer, there are no restrictions on the original valuation method. Value determination for the source data may come from direct market, revealed preference, stated preference or discourse-based methods. For example, Costanza et al.'s (1997) benefit transfer method synthesized previous research to determine the monetary value of global ecosystem services. They explain that the majority of the values used in their benefit transfer are from studies based on a type of stated preference known as willingness to pay but, the studies are "based on a wide variety of methods".

Non-market valuation - caveats and limitations

As I briefly discuss in the following paragraphs, the methods used to derive monetary value for ecosystem services have limitations and, there are questions about the validity of their use for this purpose.

Substitution or replacement costs - caveats

When a substitution or replacement value can be determined, it is acknowledged that the ecosystem service is not an *exact* substitute (Westman 1977, Ehrlich and Ehrlich 1992, Gatto and De Leo 2000). Arguments can be made on both sides; an ecosystem service may not be an exact substitute because it provides benefits over and above its counterpart or, it may not be an exact substitute because it cannot be controlled and delivered in the same manner as its counterpart. On one hand, the ecosystem service is providing benefits at no additional cost; on the other hand, people have less control over the quantity and timing of benefit delivery. As noted in the Catskill Watershed restoration example, the monetary substitution value generally accounts for a single benefit and, in most cases, the ecosystem service provides additional benefits that are not assigned a monetary value.

Revealed preference - caveats

Revealed preference methods are limited in utility because the number of ecosystem services that can be credibly linked to existing market activity is small. Ecosystem services that are associated with commercial or recreational fishing and those that can be linked to recreational travel costs are two of the most commonly noted examples of revealed preference valuation (Boyle 2003, Parsons 2003, Alberini et al. 2007, Lienhoop and Ansmann 2011).

Stated preference - caveats

The utility of stated preference methods is yet to be decided. While some researchers find them promising and are working to improve the methods (Hanemann 1995, Fischer and Hanley 2007, Shapansky et al. 2008, Schläpfer 2008, Hoyos 2010, Johnston et al. 2011), others argue that the approach is basically flawed (Diamond and Hausman 1994, Ludwig 2000, Spash 2008, Meinard and Grill 2011). What is promising about stated preference methods is the potential to address a fundamental problem with the economic valuation of many ecosystem services; that problem is the inability to credibly connect the services with any form of market activity. Stated preference methods have acknowledged shortcomings which Venkatachalam (2004) divides into two broad categories: validity (or accuracy) and reliability (or reproducibility). An example of a credibility problem is a misunderstanding about the question being asked (Diamond and Hausman 1994). Questions can be interpreted differently by individual respondents, and those interpretations are not necessarily consistent with the intentions of the interviewer or survey designer (Svedsäter 2003). The degree to which respondents are informed will also influence stated preference studies. Results are deemed more reliable when people have knowledge about the real world circumstance of the hypothetical scenario they are asked to consider (Venkatachalam 2004, Barkmann et al. 2008, Christie and Gibbons 2011).

Benefit transfer - caveats

There are more cautions than clear guidelines about the appropriate use of benefit transfer for ecosystem service valuation (Willis and Garrod 1995, NRC 2005, Soma 2006, Spash and Vatn 2006, Johnston et al. 2006, Plummer 2009, Baskaran et al. 2010). Benefit transfer remains controversial, in part, because ecosystem services depend on their specific biophysical and social context and, therefore, may vary significantly from one location to another. Plummer (2009) cites an example where monetary values for disturbance prevention, recreation, and aesthetic character are transferred from study sites in South Carolina and New Jersey to a site in Washington state based on the common land cover type “beach”. As Plummer notes, this transfer of monetary value is questionable given the differences in climate, seasonal use and disturbance regimes between the east and west coasts of the United States. Benefit transfer is also hampered because some ecosystem services have not been associated with a monetary value in any context. In these cases the ecosystem service is assigned a monetary value of zero even though this is clearly inaccurate (Costanza et al.1997, Heal 2000).

Economic Foundations and Ecosystem Services – Goodness of Fit Questions

Economics and ecosystem services

Some goods, by their very nature, are unsuited for efficient management by markets.
(Krugman and Wells 2005)

Krugman and Wells, both economists, make this statement in a first year college microeconomics textbook. The methods discussed in the previous section require at least two assumptions: the first one is that monetary valuation of ecosystem services is an appropriate metric and the second is that economic theory is compatible with the qualities of ecosystems and the goods and services they provide. Economists and non-economists alike have noted the ways in which the fundamental principles of economics are inconsistent with qualities of ecosystem services. Perspectives from within the discipline of economics deserve particular attention:

> It is ironic that environmental problems in economics are thought of as problems of market failure rather than as evidence of the applicable limits of the market model. (Norgaard 1984)

> The history of science warns us that the mere popularity of a particular epistemological program is not sufficient evidence of its truth content. Nor is popularity a sufficient guarantee that those in a shared pursuit will not lose sight of the larger issues at hand. (Vatn and Bromley 1994, on the topic of natural resource valuation)

> The commodity 'fiction' twists the perception of the environment from systems preservation to items use or transformation. This is a problem of increased importance as we approach potential systems perturbations. (Vatn 2000)

> Nature has been ill served by 20th century economics. When asked, economists acknowledge nature's existence, but most would appear to deny that she is worth much. (Dasgupta 2008)

Gómez-Baggethun et al. (2010) provide historical context for understanding concepts of nature and value in economic theory. In their characterization of 19th century Classical economics, the value of nature was in its use value only; sources of wealth came from land (as a production input) and labor. By 1870, ideas had shifted to what is now called Neoclassical economics. Gómez-Baggethun et al. (2010) distinguish the shift in focus from labor, land and use value in Classical economics to labor, capital and exchange value in Neoclassical economics. By the middle of the 20th century, Neoclassical economics had restricted its scope to goods and services that were valued in monetary terms. It is this legacy of Neoclassical economics that serves as the foundation for economic theory in approaches to ecosystem services (Spash and Vatn 2006). Since the 1960s, the specialized branches of Environmental and Ecological Economics have emerged but the degree to which these have contributed to new theoretical ideas is questioned (Norton and Noonan 2007).

One common criticism of monetary valuation of ecosystem services is that a single expression of value is simply inappropriate (Rees 1998, Gatto and De Leo 2000, Ludwig 2000, O'Neill 2007). A single metric, monetary or other, is inadequate to characterize the complexity of *either* human values or ecosystem functions and processes. It is argued that essential information is set aside or obscured to arrive at single expression of value and this is at least misleading and potentially counterproductive (Vatn and Bromley 1994, Pritchard et al. 2000, Kosoy and Corbera 2010, Peterson et al. 2010). Ecological proponents of monetary valuation for ecosystem services assert that this will cause societies to value them more highly and therefore afford protection (Edwards and Abivardi 1998). Mark Sagoff (2008) disagrees: "By 'putting a price on it' we regard nature as a resource to exploit rather than a heritage and an endowment to maintain. This is the most self-defeating path environmentalists can take."

In his argument against approaching the environment as a commodity, Vatn (2000) describes two forces that limit market concepts in non-market circumstances: 1) ethical and cultural and, 2) technical. Vatn asserts that cultural and ethical societal norms establish boundaries about what can and cannot be marketed. He offers friendship and the right to vote as examples of what our society excludes from markets and suggests that certain rights to natural goods may be in this category. Although not labeled in the same way, Vatn's idea of technical limitations is a common thread in ecosystem services literature. It refers to the ways in which basic economic principles are incompatible with the realities of ecosystem function and process and inconsistent with preserving natural resources. In the following sections I summarize key themes regarding the goodness of fit between ecosystem services and economic foundations.

Substitution and scarcity

Economic value assumes that individuals are choosing between goods that are substitutable (Freeman 2003). Krugman and Wells (2005) define substitutes as "pairs of goods for which a fall in the price of one results in less demand for the other". They use muffins and doughnuts as an example; if the price of doughnuts falls, some consumers will shift from eating muffins to eating doughnuts thus reducing the demand for muffins. This idea extended to natural resources assumes that a human benefit lost to impaired or destroyed ecosystems can be substituted by technology and other forms of human capital (Prugh et al. 1999, Dasgupta 2010). This assumption has been challenged with two main arguments. First, for a significant number of ecosystem services there is nothing that would qualify as a substitute (Ehrlich and Mooney 1983, Orians and Kunin 1990, Dasgupta et al. 2000, Ludwig 2000, Dasgupta 2008). Second, current understanding of ecosystem function limits the degree to which appropriate ecosystem service substitutes can be fully characterized (Westman 1977, Myers 1993, Rees 1998, Gatto and De Leo 2000).

The concept of scarcity is central in the discipline of economics (Rees 1998, Freeman 2003, Krugman and Wells 2005). However, as Baumgartner et al. (2006) point out, economic models limit the concept of scarcity to one of *relative* scarcity; the scarcity of a good or service is defined relative to similar goods and services. This concept of scarcity assumes that resources are available to produce the goods and services and, that people are making choices among substitutable goods and services. For example, a bottler of spring water initially produces equal numbers of pint and quart bottles of water. Consumers of their water preferentially purchase the pint bottles because they are easier to carry around. The pint bottles become scarce relative to the quart bottles, demand increases for the pint bottles and the bottling company shifts production to increase the number of pint water bottles to meet the demand. The inputs (raw materials, machinery, labor) are essentially the same for the pint and quart water bottles; demand, supply and production are determined by the market.

The distinction between *absolute* scarcity and *relative* scarcity is important with respect to ecosystem services. Relative scarcity assumes resources are available for the production of goods and services; the resources may be scarce and this is reflected in the monetary value of outputs. Relative scarcity does not accommodate circumstances in which resources are actually unavailable and there is no substitute. In the example of bottled spring water, if the spring were to dry up or become contaminated, the bottling company could not shift inputs to produce a similar good. The resource is absolutely scarce; there is no spring water and no substitute. From an economic perspective, the bottling company would find another spring and continue production. This might increase their production costs but the increase would be reflected in the monetary value of the bottled water. The concept of absolute scarcity allows for the possibility that at some point moving on to another spring will not be an option; the resource will be depleted and unavailable at any monetary cost.

Non-linearity and unpredictability

The natural systems that provide ecosystem services are poorly understood but there is agreement that they are dynamic, complex and interrelated (Westman 1977, Chavas 2000, Prichard et al. 2000, Rockstrom et al. 2009). The production of ecosystem goods and services cannot be controlled or predicted in the same way as the production of shoes or shirts. Even with a perfect understanding of ecosystem function, the production of ecosystem services will be variable and subject to abrupt changes. Perrings et al. (1992) characterize ecosystem relationships as "… fundamentally non-linear, with lags and discontinuities, thresholds and limits". There is concern that the lack of knowledge about ecosystem functions and processes, particularly with respect to thresholds and limits, could have catastrophic consequences (Ehrlich and Ehrlich 1992, Scheffer et al. 2001, Dasgupta 2008, Lenton et al. 2008, Rockstrom et al. 2009).

Irreversibility

Fisher (2000) presents an economic perspective of reversibility which argues that either everything is reversible or nothing is reversible. In the first argument, nothing is reversible in the sense that time does not run backwards. In his alternate argument, everything is reversible given sufficient resources and time. The "everything is reversible" argument assumes a sense of time that may be more relevant to geologic processes than human ones. This perspective on reversibility is primarily academic and lacks real-world application to human scale processes. From an ecological perspective, irreversibility occurs when ecosystem processes are damaged or destroyed to a point of no return and it is impossible to retrieve what has been lost (Chavas 2000, Dasgupta 2008, Rockstrom et al. 2009). This concept is sometimes associated with the idea of an unpredictable tipping point or threshold which when crossed can trigger abrupt and irreversible changes in a system (Groffman et al. 2006). In the ecological perspective of irreversibility, there are potential consequences for human processes if, and when, ecosystems reach a point of irreversibility.

Economic production/ ecological reality

In a discussion of key economic concepts for approaches to ecosystem services, Fisher et al. (2008) use the production of trousers as an example. The problem with this is that ecosystems do not, and never will, function in the same way as human factories. Economic production characterizes goods and services in specific units (pairs of trousers, pounds of carrots, hours of labor) that can be bounded, quantified and associated with a monetary value. This system of production makes it possible to exchange goods and services in a way that accounts for all transactions, but it does not transfer to ecosystems. Ecosystems will not produce goods and services in the same way as human factories; it will not be possible to order a quantity of nutrient cycling to be delivered at a specific time and location. Economists approach ecosystem services as if ecosystems are aggregations of separable components from which to choose (Boyd and Banzhaf 2007, Wallace 2007, Balmford et al. 2011). The focus is on tangible ecosystem outputs that are useful to individuals but little attention is given to the importance of the factory itself. Ecosystems are quite different from factories that produce trousers; they produce in ways that are inherently variable, complex and rarely completely understood from a human perspective; they cannot be relocated or easily rebuilt.

Values and economics

The individual is central to Neoclassical economic theory; each person is motivated to better his or her own set of circumstances (Freeman 2003, Krugman and Wells 2005). For the most part, non-market ecosystem services have been used as public goods, available to all at no monetary cost (everyone benefits, no one pays). The non-monetary costs of that use are now apparent in the depletion and degradation of mutually shared natural resources. The concept of individuals bettering their own circumstances does not translate well to the public goods quality of ecosystem services. These are commonly shared resources, their benefits are best understood as societal rather than individual and market economies are not well suited for the long-term provision of these benefits. The shift from personal betterment to societal well-being is a major hurdle in moving from concepts of ecosystem services to implementation. Society acknowledges that ecosystem services have value but there is no agreed upon expression of that value.

There is growing awareness among scientists, policy-makers and the general public that natural resources are not inexhaustible public goods whose value can be set aside. Concern about the consequences of resource depletion and degradation has caused a sense of urgency to express the value of natural resources in ways that are practical and implementable. In modern society, economic valuation is the accepted norm for the exchange of goods and services and so this would seem to be the most expedient pathway to acknowledge the value of natural resources. However, expedient does not always mean the most appropriate and in the overall concept of ecosystem services, the goodness of fit between economics and ecosystem services merits scrutiny.

Ecological approaches to ecosystem services

I use the term "ecological approach" as a broad umbrella for research focused on understanding and characterizing ecosystem functions and processes as they relate to ecosystem services. The scope of the research is broad and ranges from global assessments to fine grain study of particular processes or functional components. Types of research projects include assessments of multiple ecosystem services in a particular geographic region (Peterson et al. 2003, Chan et al. 2006, Naidoo and Ricketts 2006), the study of ecosystem services associated with a particular ecosystem type, for example tropical (Guariguata 2009, Locatelli and Vignola 2009, Rodrigues et al. 2011) and investigations of the detailed processes associated with specific ecosystem services, for example pollination (Ricketts 2004, Kremen et al. 2004, Lonsdorff et al. 2009, Winfree and Kremen 2009, Isaacs and Kirk 2010).

Global assessments

Vitousek et al. (1986) assessed human impact on the biosphere by calculating global net primary productivity (NPP) based on cover type (for example forest, desert, marine). They estimated that people use or co-opt nearly 40% of potential terrestrial NPP and with current patterns of resource use this number would continue to grow. Wackernagel et al. (2002) use the idea of biophysical units to compare human demand on the environment to global bioproductive capacity. They conclude that since the 1980s, the use of environmental resources has exceeded earth's capacity to regenerate them. In a more recent assessment by Rockstrom et al. (2009), the scope has widened to include atmospheric conditions and the warnings are more urgent. The authors of this paper propose a framework of Earth-system processes and thresholds to identify what they refer to as "a safe operating space for humanity". Global assessments such as these reinforce the need for ecosystem service approaches and provide a broader context for the research but offer little in the way of practical guidance for implementation.

Organizing frameworks

Ecological approaches organize frameworks for understanding ecosystem services around functional relationships and interactions. Luck et al. (2003) propose a new ecosystem services unit called a service providing unit (SPU) which is based on characteristics of species populations. They argue that species populations are the primary contributors to ecosystem services and changes in species population characteristics signify a change in ecosystem service provision. Luck et al. (2009) combine the SPU concept with one called ecosystem service providers (ESP) in the SPU-ESP continuum which "encompasses service providers across various organizational levels, from populations of single species to multispecies functional groups and ecological communities". The framework links organizational levels with specific ecosystem services. Diaz et al. (2007) propose a framework for ecosystem service assessments based on relationships of plant functional traits to ecosystem properties and resulting ecosystem services. De Bello et al. (2010) synthesized 247 studies and found evidence that the type, range and relative abundance of plant functional traits are significant factors in ecosystem service provision. Yapp et al. (2010) use land cover vegetation classes to compare changes in ecosystem service provision due to land conversion. They relate vegetation structure and function to ecosystem function and then ecosystem function to ecosystem services.

Site scale research

Research by Taylor Ricketts (2004) provides evidence of a relationship between native tropical forest fragments and coffee production in Costa Rica. His study established plots and transects to compare proximity of coffee plantations to native and non-native forests; he then documented bee activity at coffee flowers and, measured pollen-deposition rates on the flowers. The results of his research show that coffee fields within 100m of native forest were visited more frequently by native bees and had higher rates of pollen-deposition. Ricketts chose to study pollination in coffee production, in part, because it could be linked to market activity. The study sites were carefully selected and the research took 2 years to complete. Projects like this which are able to connect habitat (native forest) to ecological process (pollination) to an ecosystem service with monetary value (coffee) are atypical. Research since Ricketts's 2004 study illustrates the complexity involved in understanding a single ecosystem service (pollination) and the need to be cautious about interpreting results too broadly. Chacoff et al. (2008) studied grapefruit pollination in Argentina and found that although pollinator visits decreased with distance to forests, this did not affect fruit production. They provide evidence that pollinator efficiency and pollen quality may be important factors. In a review and synthesis of 23 studies, Ricketts et al. (2008) conclude that there is a general pattern of a significant decline in pollinator richness and visitation rates with an increasing distance from natural habitat. As with the Chacoff et al. (2008) study, the Ricketts et al. (2008) synthesis could not conclude that the decrease in pollinator richness and visitation, in fact, reduced fruit and seed set.

Ecological knowledge – integration with ecosystem services frameworks

There is a significant body of ecological research contributing to ecosystems services knowledge. For the most part it remains scientific knowledge that has not yet been practically integrated with an ecosystem services concept. The research of Barbier et al. (2008) and Koch et al. (2009) illustrate the daunting nature of the task and why sufficient understanding will take time. Their research looks at mangrove forests as an ecosystem service for coastal storm protection. They show that wave attenuation is not simply a function of the presence or absence of mangrove trees; it is a complex set of interactions that depend on vegetation density and type (trees, seagrass, marsh), time of year, latitude, tidal level and, local geomorphology and bathymetry. This work begins to scratch the surface of understanding storm protection associated with mangrove forests; still to come is how this work might inform storm protection associated with other ecosystems and how the data are practically integrated with an ecosystem services framework.

Mapping ecosystem services

Mapping ecosystem services offers a way to understand their spatial distribution and relationships on the landscape. The map itself is useful for seeing patterns and relationships, and the process of creating a map makes it necessary to express ecosystem services explicitly rather than conceptually. The influential publication by Costanza et al. (1997) includes a distribution map of global ecosystem services which effectively communicates the research in a way that would not have been possible with text and tables alone. Costanza et al. created the map by associating land cover classes with ecosystem services. The same approach of using land cover as a proxy is still the most common methodology for mapping ecosystem services. The grain of the land cover data varies with the scope of the project; for global assessments the cover classes are generalized and for smaller extents the land cover classes are more detailed but, the underlying methodology has not changed. In 2008, Costanza contributed to a paper which characterized the spatial estimation of global ecosystem service values as quite crude (Naidoo et al. 2008).

Researchers have mapped ecosystem services to explore various aspects of their spatial distribution, for example, the spatial coincidence of multiple ecosystem services, the distribution of monetary values on the landscape and, changes in ecosystem service provision as a result of land conversion. Chan et al. (2006) examined the spatial relationships among seven ecosystem services including biodiversity in the Central Coast ecoregion of California. They were primarily interested in understanding correlations between biodiversity and the other ecosystem services, i.e. does planning for biodiversity conservation protect a broader suite of ecosystem services? Their results indicate that protecting biodiversity is not likely to also protect a broader suite of ecosystem services but, they did find what they refer to as hotspots in the landscape where multiple ecosystem services are provided.

Wilson et al. (2004) and Troy and Wilson (2006) associate land cover classes with monetary values to estimate a total landscape value of ecosystem services for the state of Massachusetts. They also map the spatial distribution of per hectare monetary value of ecosystem services. The study by Troy and Wilson (2006) also includes monetary valuation and maps for three counties in California and Maury Island in Washington state.

For this study, the authors describe each of the three locations (Massachusetts, California and Maury Island) and discuss how the differences in spatial extent, project purpose and data availability influence the specific spatial representations. At 2,500 hectares, Maury Island is significantly smaller than the other locations and this made it possible to assemble new data and create a more detailed land use/ land cover representation to better suit the project needs.

Polasky et al. (2008) and Nelson et al. (2009) use spatially explicit mapping in the Willamette River Basin, Oregon to explore trade-offs between ecosystem services that support biodiversity conservation and those that support commodity production. Polasky et al. (2008) combine spatially explicit economic and biological models with the idea of an efficiency frontier to show the effects of changing landscape patterns on conservation and commodity production. They graph expected number of species versus monetary production value to show how these interact as landscape patterns change. Their results suggest that seeking to maximize one landscape function (conservation or economic) will result in significant negative impacts on the other; but, there are landscape patterns where levels of both biological conservation and economic production can be high. Nelson et al. (2009) compare the 1990 Willamette River Basin landscape with three future (circa 2050) landscapes based on scenarios developed by the Pacific Northwest Ecosystem Research Consortium (Hulse et al. 2002, 2004). The three future scenario landscapes are based on different sets of assumptions about landscape change: Development, Plan Trend (current patterns continue into the future) and Conservation. Nelson et al. (2009) map and compare changes in water quality, soil conservation, storm peak management, carbon sequestration, biodiversity conservation and market value of commodity production between the 1990 landscape and each of the three future scenario landscapes. In their results, the 2050 Conservation scenario landscape provides higher levels of all ecosystem services except market value of commodity production. The Development scenario also shows increases of carbon sequestration and only slight decreases in water quality and soil conservation.

Software has become available in the past five years to extend ecosystem service mapping to the planning community. Artificial Intelligence for Ecosystem Services (AIRES) is a web-based tool directed at a worldwide audience for rapid ecosystem service assessment and valuation (ARIES 2011). The underlying approach of this effort is largely economic; they define ecosystem services as the economic benefits provided by nature to humans, and their assessments are based on identifying service beneficiaries. Integrated Valuation of Ecosystem Services and Trade-Offs (InVEST) (Nelson and Daily 2010, Tallis and Polasky 2011, Tallis et al. 2011) is a Geographic Information System (GIS) tool that uses economic and ecological production functions based on land use/ land cover data. InVEST is intended for resource decision-makers from governments, non-profit organizations and corporations as a tool for planning and management of ecosystem services. InVEST has been developed with the user in mind but it still requires GIS knowledge and a certain level of expertise to run and interpret the models. There is great potential for this type of tool to advance ecosystem services planning at local landscape scales (for example cities and small watersheds), particularly if stakeholders are included in the process. Setting up a project requires a series of questions to be answered that push ecosystem services from a vague concept toward purposeful action: How should ecosystem services be represented?, How should they be evaluated?, What do the results of the evaluation mean? and, What, if any, action should be taken?

Laying ground for a new approach

Economic language in ecosystem service approaches

Since the publications by Costanza et al. (1997) and Daily (1997b) it has become increasingly common to use the language of economics to communicate concepts associated with natural resources and ecosystem services. Expressing the value of natural resources in economic terms has been successful in raising awareness of their importance. People are familiar with the terms and this makes it easier to initially communicate ideas. However, people are familiar and comfortable with the terms because they have preconceived ideas about their meaning and these preconceptions are rooted in economics. *Natural capital*, *natural assets*, *ecosystem goods and services* and *benefits* are all terms that have an association with economic ideas and expressions of value. In the preface of a book about natural capital (Prugh et al. 1999) the authors explain, "the environment is a form of capital, here called 'natural capital'. Natural capital is necessary for human economic activity and survival". In a discussion of Neoclassical economics Prugh et al. write that the terms environment, natural resources, land and natural capital all mean the same thing. In a more recent book, also about natural capital (Kareiva et al. 2011), the authors assume that it is not necessary to define or explain what the term means. In the historical context provided by Gómez-Baggethun et al. (2010), economic theory has evolved from Classical Economics where land (natural capital) is seen only as a production input and Neoclassical economics where the value of land (natural capital) was excluded if it could not be valued in monetary terms.

Although not explicitly stated, a suggested objective of economic approaches to ecosystem services is to bring the natural capital that has been excluded by Neoclassical economics into current economic frameworks. Doing so assumes that the problem is the valuation of the biophysical environment with respect to sociocultural systems and the objective can be achieved by characterizing the biophysical environment in ways that are consistent with sociocultural economic frameworks. Defining the problem as one of characterization and valuation sets aside the question of the relationship between sociocultural systems and biophysical environments. The relationship between people and their biophysical environment is multidimensional and reducing it to a matter of economic valuation is likely to prove inadequate if ecosystem service approaches are to match the scope and extent of natural resource depletion in ways that endure.

The essence of an ecosystem in ecosystem service approaches

The core concept of an *ecosystem* has been left behind in utilitarian approaches to ecosystem services. Approaches that identify specific elements of ecosystems as beneficial and therefore valuable are at odds with the original concept of an holistic and integrative combination of living organisms and the physical environment into a system (Golley 1993). Concepts that identify ecosystem services as only those parts of an ecosystem that can be shown to have benefits (utility) to people, are ignoring the essence of an ecosystem. Enumerating the benefits that nature provides (Study of Critical Environmental Problems 1970) and estimating their monetary value (Costanza et al. 1997) have served to communicate why healthy ecosystems are vital. Extending these ideas of naming benefits and assigning monetary value to operational models has moved the concept away from ecosystems and toward existing ideas about human utility.

Practical application of an ecosystem services concept

Although there has been a considerable amount of research in the past 20 years focused on economic valuation of ecosystem services, there are relatively few examples where this leads to practical implementation of an ecosystem services concept. The most cited success story dates to 1996 when New York City funded restoration of the Catskills Watershed to filter the city's drinking water. Proponents of ecosystem service approaches to natural resource management were hopeful that this project would serve as a model for new ways of working but the literature shows little evidence that this has come about. According to McCauley (2006), there may now be a need for New York to turn to technology to address a water turbidity problem. If this is the case, it could upset the ecosystem services economic argument that the restoration option is more cost effective than alternative technology. The lack of success stories and questions associated with economic approaches to ecosystem services indicate the need for other approaches.

Ecosystem services as a coevolutionary process

Ecosystem service approaches are not the answer to a problem but offer a pathway to begin shifting societal understanding of the current landscape relationship between sociocultural and biophysical systems. Historically and in the current landscape pattern, people use biophysical resources for their benefit as they see fit (within social and legal constraints). Research over the past 25 years provides evidence that this pattern of use has drained biophysical resources to a degree that the current landscape relationship is not sustainable (Vitousek et al. 1986, Wackernagel et al. 2002, Rockstrom et al. 2009). The relationship will change, either forced by resource depletion or intentionally through human action. An ecosystem services approach offers a pathway for intentional action. The idea of addressing the relationship between biophysical and sociocultural landscape systems is consistent with the concept of coevolution between society and nature (also referred to as ecological systems) put forth by Norgaard and others (Norgaard 1984, Gual and Norgaard 2010, Kallis and Norgaard 2010). Evolution is broadly defined as "change over time and space" (Gual and Norgaard 2010). The coevolutionary concept extends the biological concept of "an evolutionary process based on reciprocal responses between two closely interacting species" to systems relationships that "encompass any ongoing feedback process between two evolving systems, including social and ecological systems" (Norgaard 1984). Kallis and Norgaard (2010) point out that ecological coevolution among species differs from coevolution involving society in being a "value-free process of change" in which the relationship can be "mutually cooperative, but also competitive, parasitic, predatory or dominative". Another important distinction is that there is no intent in ecological coevolution and one of the key opportunities in a coevolutionary concept of society and nature is intentional change on the part of society.

A landscape approach to ecosystem services

Costanza (2008) asserts that the complexity of ecosystem services calls for a "pluralism of typologies" for ecosystem service classification to serve different purposes. The complexity and newness of the idea of ecosystem services calls for multiple research approaches, each of which can offer unique contributions to the overall concept.

The approach that I propose begins with a conceptual definition consistent with Daily's 1999 definition in which the emphasis is on the life-sustaining aspect of a landscape's biophysical environment. This provides a different foundation from definitions such as Boyd and Banzhaf's (2007) in which the emphasis is on *benefits to* people from the biophysical environment. Definitions that focus on benefits to people reinforce the pattern of people *using* biophysical resources for their benefit. Since that pattern of use has contributed to the current impaired landscape condition, other ways of understanding the problem should be part of an ecosystem services research agenda.

The scope of economics is primarily within the sociocultural sphere of the landscape; biophysical resources are relevant only to the degree that their individual components are considered useful in economic terms (Figure 5a, b). The focus of ecology is the biophysical environment; human activity is relevant when it affects ecosystem function and process (Figure 5a, b). Each discipline has accepted theories, ways of thinking and research methods that have evolved to suit its particular needs. Ecosystem services can be perceived as both an economic and an ecological conception and, as such, each discipline offers a distinct perspective in understanding and approach. Ecosystem services can also be seen as a landscape conception where the focus is not on either the sociocultural system or the biophysical environment but on the relationship between the two (Figure 5c). In stating the problem, foundational writings in ecosystem

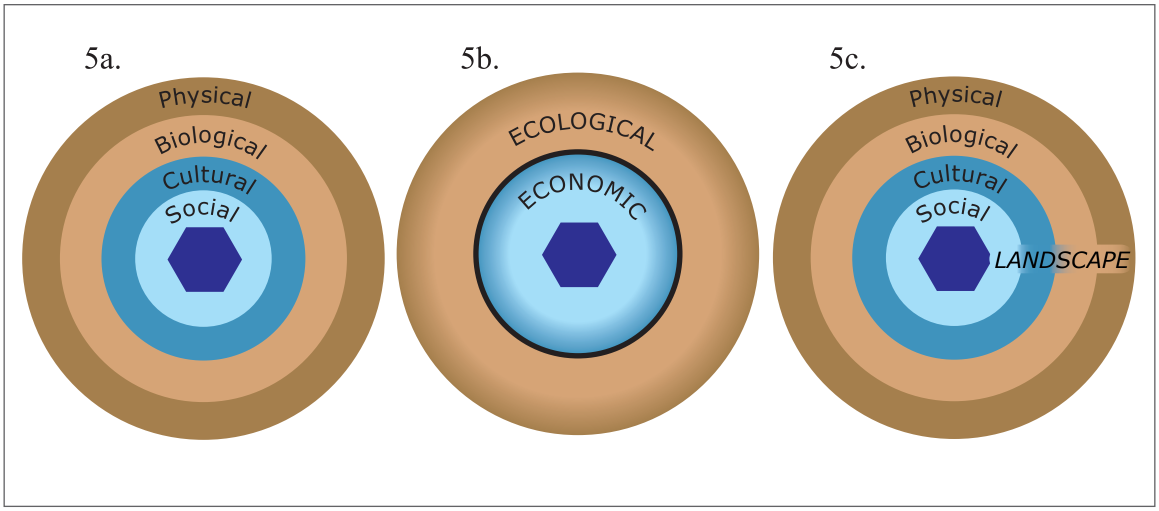

Figure 5. a) The physical, biological, cultural and social parts of the landscape. b) Ecological approaches to ecosystem services focus a landscape's biophysical environment; economic approaches to ecosystem services focus on a landscape's sociocultural systems. c) a landscape approach to ecosystem services focuses on relationships between a landscape's biophysical environment and sociocultural systems.

services discuss the role of landscape relationships. Marsh wrote of man's actions as undermining the balance of species (Marsh 1864); *Man's Role in Changing the Face of the Earth* (Thomas 1955) questions man's relationship to nature and his fellow-men. The authors who first enumerated ecosystem services felt the need to do so because of the disconnection between people and nature: "It is a mark of our time, and a signal of the degree to which man is ecologically disconnected, that the benefits of nature need to be enumerated." (Study of Critical Environmental Problems 1970). Ecosystem services research since the late 1990s has focused on systematic approaches in ecology and economics and, for the most part, set aside questions of relationships in actual landscapes. These questions are difficult to address from a research perspective because the problems are new enough that there is not a clear research pathway. However, aspects of landscape relationships may have a role to play if ecosystem service approaches are to meaningfully address long-term natural resource availability. The concept of landscape relationships is the foundation for my proposed landscape approach to ecosystem services. It is more experimental than other approaches in that it does not assume that current theories, disciplines or research methods are adequate to address the problem.

Key constituents of a landscape approach

Landscape scale – the intersection of biophysical processes and human experience

The case has been made that meaningful progress toward implementing an ecosystem services concept will require involvement of institutions and policy-makers (Carpenter et al. 2006, Daily and Matson 2008, Fisher et al. 2008, Daily et al. 2009, Norgaard 2010). Although this is critical, the scale of institutional change is detached from most people's experience of landscape. Policies and institutions can influence landscape change by creating or impeding possibilities but, they do not themselves form landscape relationships. Fundamental landscape relationships evolve through individual people's experience in particular places. Policies and institutions may set the conditions, but they do not intermediate between a person and their experience of landscape.

The focus of my proposed landscape approach to ecosystem services is at the intersection of a biophysical scale that is large enough to provide ecosystem services and a sociocultural scale where people's personal experience connects them in some direct, perceptual way to the landscape. Examples of this scale include small watersheds, a fishing village or, an agricultural community within an ecoregion. Working at this scale offers a unique set of circumstances to address the concept of value in an ecosystem services approach. Ecosystem services are place specific; the qualities of the biophysical environment determine the availability of ecosystem services and the qualities of the sociocultural system determine the need. In the landscape approach to ecosystem services I propose, people connect their values to their landscape through personal experience rather than abstract notions of ecosystem service classification and valuation methods.

Identify key ecosystem services in the landscape

Rather than beginning with questions of valuation for specific ecosystem services, a landscape approach begins by identifying ecosystem services that are available from the biophysical environment and would have value for the community (the sociocultural system). I have chosen non-structural flood storage, carbon sequestration and floodplain forest as ecosystem services for my dissertation because these are available from the study area's river floodplain environment and have potential benefit for local communities. Two mapped representations are used to explore the biophysical potential of the landscape to provide these ecosystem services. The first map represents current conditions; the second represents a possible future condition in which agricultural operations incorporate production of the three ecosystem services. A quantitative comparison of ecosystem services from each representation, present and future, provides a first approximation of what is possible from the landscape's biophysical resources.

Understand human relationships to ecosystem services

Once the ecosystem services are identified, the next question is not, How much are the ecosystem services worth?; but, How might they become an integral part of the landscape? Rather than ask if ecosystem services are economically efficient or productive, this approach asks if they can be economically feasible in a particular landscape. Questions of economic feasibility need to be explored as part of the process; what is feasible depends on the particulars. For example, it may be economically feasible to increase carbon sequestration by converting pasture to forest but not economically feasible for a similar conversion with higher value row crops. In this dissertation, interviews with farmers explore the landscape relationships of the potential producers of ecosystem services. The interviews are intended to be a preliminary inquiry into how ecosystem services could function in this particular agricultural landscape and to get a sense of farmer's interest in providing them. The perspectives of those who would benefit from the supply of ecosystem services is another key component in understanding landscape relationships that is not part of my research.

Intentional landscape change

Evidence to substantiate the monetary value of ecosystem services will not come anytime soon and, when it does, there are no guarantees that ecosystem services will be competitive in market settings. Making ecosystem services part of well-functioning landscapes may require intentional community action that is motivated by the desire for a particular landscape evolution rather than economic efficiency. This is not to say that money does not matter, particularly if ecosystem services are provided by private landowners. Money will be part of the process but it does not need to be the starting point. Like other aspects of ecosystem services, valuation will be influenced by the particular landscape circumstances. Heal (2000) argues for a similar approach to conservation incentives: "The key step would be the provision of incentives, not valuation of services. In this case, valuation would be a by-product…". He discusses the need to first make conservation (or the provision of ecosystem services) an attractive option for landowners, "…we have to translate some of the social importance of ecosystem services into income and ensure that this income accrues to the owners of the ecosystems as a reward for their conservation."

Ecosystem services: exploratory research in coevolutionary relationships

A landscape approach reorders a conventional research sequence. Scientific and economic approaches seek to characterize and quantify biophysical resources and establish monetary valuation *before* implementing change on the landscape. A landscape approach seeks to implement change as part of the research process, not in a way that is haphazard or hasty but is deliberately experimental and acknowledges the inherent uncertainty of ecosystem services research. To fully understand how ecosystems function, they are researched from multiple perspectives. Some researchers focus on understanding individual components or processes while others seek to understand relationships and interactions of the ecosystem as a whole. In a similar way, understanding ecosystem services as a coevolutionary relationship will require research that addresses the system as a whole, not just the individual components of ecology and economy. The importance of understanding ecosystem services in their local context is acknowledged (Pritchard et al. 2000, Dasgupta 2008, Mooney 2010). Daily et al. (2000) note that from a biophysical perspective, "Putting theory into practice will therefore require locally based information." The importance of social context has been noted by numerous authors (Vatn and Bromley 1994, Daily 1999, Vatn 2000, Turner and Daily 2008, Fisher et al. 2009, Luck et al. 2009). Dasgupta et al. (2000) contend that, "The roots of global environmental problems are local, and their solution requires linking local with global perspectives." Although the importance of local context is acknowledged, there is little evidence in the literature that this aspect of ecosystem services has received significant research attention. Local-scale research for the purpose of understanding the relationships between a landscape's biophysical environment and its sociocultural systems can contribute new knowledge and at the same time serve as *in situ* research sites for long term scientific studies. If these projects are explicitly exploratory and adaptive, they can incorporate concepts of coevolution between social and ecological processes and allow for the possibility of emergent landscape change that cannot be anticipated in advance. The ecosystem services research agenda is relatively young and the problems pose new challenges to the research community. In addition to existing disciplinary approaches and research methods, more exploratory approaches to ecosystem services could contribute to overall understanding and move the concept toward landscape change.

CHAPTER III

STUDY AREA AND RESEARCH INTRODUCTION

Introduction and overview

This chapter begins with an introduction to the study area and an overview of my analytical approach. I then provide general and project specific background on alternative futures because this serves as the framework for my research. I discuss landscape representation and conclude with a description and comparison of the two research landscapes.

The study area is located in the southern part of Oregon's Willamette Valley Ecoregion between the cities of Albany and Harrisburg (Figure 6). Its 65,000 acres are centered on the Willamette River and extend across the floodplain to major roads on the east and west boundaries. The majority of the study area (68%) is in agricultural production with grass seed as the main crop. The area combines qualities that make it well suited for exploring a landscape approach to ecosystem services: 1) it is a working agricultural landscape, 2) it is an area that has been identified with high potential for restoring natural floodplain processes (Gregory et al. 2002a, Wallick et al. 2007), 3) its spatial extent is sufficient to provide ecosystem services at a landscape scale and, 4) people are connected to the land through personal experience. For farmers whose families have been farming the same ground for multiple generations the connections are deep and at the core of their livelihood and culture. The connections for urban dwellers are different, perhaps more casual and formed from their cars while driving through scenic agricultural fields or from kayaking on the river; but, they are still connected to this particular place. I see potential for ecosystem services to be part of the study area's agricultural landscape and I explore this potential with three ecosystem services: non-structural flood storage, carbon sequestration and floodplain forest. These particular ecosystem services were chosen because the study area's biophysical environment can provide them, there is potential to include them in agricultural production, nearby urban communities would benefit from their production and incorporating them into the landscape would be an intentional shift in the coevolutionary relationship between the biophysical and sociocultural parts of the study area.

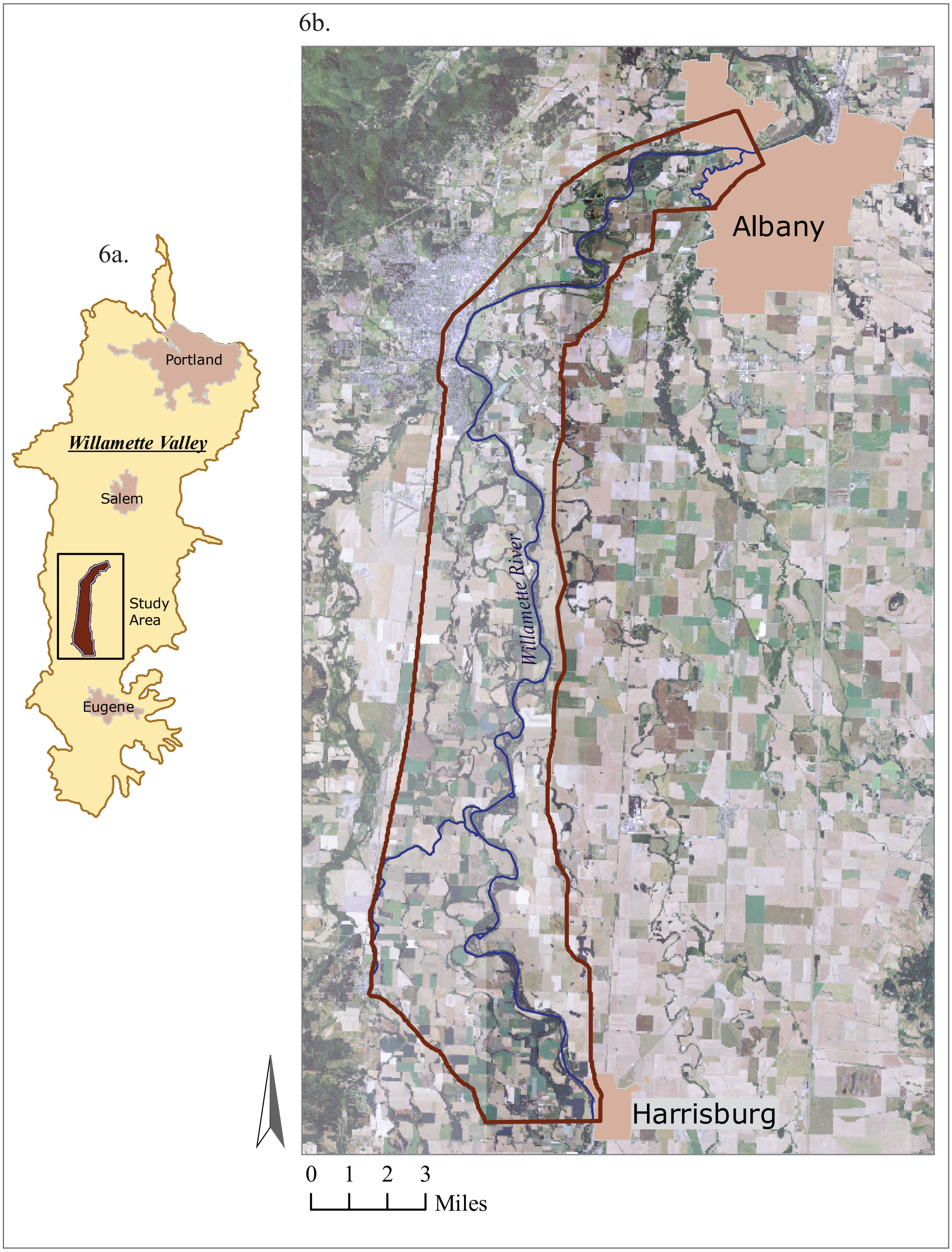

Figure 6. Study area, a) Location within the Willamette Valley, b) Willamette River and the communities of Harrisburg and Albany. Aerial photograph - 2009 National Agriculture Imagery Program.

I compare two representations of the landscape to explore the potential for ecosystem service production: the current condition (circa 2000) and a possible future condition (circa 2050). Each landscape is mapped in a geographic information system (GIS) based on land use/ land cover; this allows the representations to be evaluated and compared for each of the 3 ecosystem services. The comparison metric for non-structural flood storage is the volume of water stored in channels, for carbon sequestration it is metric tons of carbon and for floodplain forest it is the area of floodplain forest. The landscape representations are based on the alternative futures work of the Pacific Northwest Ecosystem Research Consortium (Hulse et al. 2002, PNW-ERC 2002a). I use the land use/ land cover classes developed for their Willamette River Basin Planning Atlas (Hulse et al. 2002) and my 2050 landscape representation is a modification of their conservation oriented future landscape based on my interviews with farmers.

Alternative futures

Background

I use an alternative futures framework as the foundation for the analysis. This allows integration of quantitative characteristics of the biophysical environment with qualitative sociocultural characteristics and provides a way to explore future landscape options. An alternative futures framework is a tool for exploration, not a means to predict the future. It is a scenario-based approach that explores plausible options for the future of a place, an organization or a community to see what effects each option has on things people care about (Hulse et al. 2000). Scenario-based approaches have been used broadly for a variety of purposes. At one end of the spectrum, Peter Schwartz (1991) suggests this is a worthwhile decision-making approach for individuals. At the other end of the spectrum, the Intergovernmental Panel on Climate Change uses emissions scenarios as the basis to assess potential consequences of global climate change (IPCC no date).

Multiple typologies have been proposed to classify scenarios. Among them are: Hirschhorn's (1980) morphology with primary distinctions between process and state scenarios, van Notten et al.'s (2003) more complex typology based on three overarching themes (project goal, process design and scenario content) and Liu et al.'s (2007) three broad categories of strategic, exploratory and anticipatory. Although stated with different vocabularies, there are common qualities of learning, ordering and ways of understanding in scenario literature. Schwartz (1991) states that scenarios are vehicles for helping people learn and a tool for ordering one's perceptions; Hirshhorn (1980) states that scenarios have the power to broaden people's sights and help them organize their thinking about the relationship between their actions and their context; Wack (1985) states that scenarios can change decision-makers assumptions about how the world works and compel them to reorganize their mental model of reality; and, the European Environmental Agency (2001) asserts that a good scenario should challenge the beliefs and broaden the understandings of experts and policymakers.

What constitutes a scenario, how the scenario is developed and how it is evaluated depends on its purpose. The foundation of current scenario approaches can be traced to the work of Pierre Wack and others at Royal Dutch/ Shell in the 1960's and 1970's (Wack 1985, Schwartz 1991). In this large business environment, experts, analysts and executives were involved in multiple rounds of scenario development. The process for a small business is more apt to be business partners collectively considering their options in a long-term business environment (Schwartz 1991). When the purpose is landscape planning or design, it is common to have multiple scenarios with each one describing a possible alternative future. Each alternative future has a spatially explicit representation and the project as a whole includes a means to compare and evaluate scenario outcomes (Murray et al. 1971; Steinitz et al. 1996, 2003; Hulse et al. 2000, 2002; Nassauer and Corry 2004). How a scenario is defined and who is involved in the process depends on the project and is influenced, in part, by the length of the project and available resources. Murray et al. 1971 used a 'best professional judgment' approach involving five members of the research team. Hulse et al. (2002) engaged in a 30 month process with lay and professional citizen groups to define sets of assumptions for their scenarios. A key product of any scenario development is a clear statement of scenario objectives and assumptions which enable others to understand and evaluate the process (European Environmental Agency 2001, Shearer 2005).

Alternative futures in the dissertation

The scenario for my future landscape (circa 2050) is based on the work of the Pacific Northwest Ecosystem Research Consortium (PNW-ERC). In this previously mentioned project (Hulse et al. 2002), future scenarios were developed for the Willamette

River Basin (see Appendix A for a map) in a 30 month process involving a broad group of stakeholders. The PNW-ERC's process began with a spatially explicit representation of the then current landscape (circa 1990) followed by stakeholder involvement to develop three plausible alternative future scenarios: Development 2050, Plan Trend 2050 and Conservation 2050. This provided researchers with five (one past, one current, three future) spatially explicit (GIS) landscape representations that could be compared with a set of evaluation models (for example, terrestrial wildlife and water availability). My research compares two landscape representations: current conditions (circa 2000) and a modified version of the PNW-ERC's Conservation 2050 landscape. Of the three PNW-ERC future scenarios, Conservation 2050 is the least propelled by economic wealth production and the most propelled by increasing ecosystem function and process. It is, therefore, the most consistent with a landscape approach to ecosystem services. The purpose of modifying the PNW-ERC's Conservation 2050 representation is to explicitly address the question of ecosystem services from the agricultural landscape. I use the perspectives of farmers from my sociocultural question (*What are the perspectives of agricultural landowners that influence their willingness to produce ecosystem services?*) as guides for my modification. For example, my interviews inform the choice of which crops to convert to ecosystem services in 2050 and also how much land is converted from conventional crops to ecosystem services. These choices based on my sociocultural question have a quantitative effect on the answer to my biophysical question (*What quantities of ecosystem services are available from the landscape?*).

Landscape representation

The current (2000) and future (2050) landscapes are represented in a geographic information system (GIS) as a grid with a cell size of 30m X 30m and a common set of land use/ land cover classes (Table 2). These land use/ land cover (LULC) classes serve as the foundation for evaluating and comparing ecosystem services in the two landscapes. Carbon sequestration is estimated from values associated with each LULC class, floodplain forest is comprised of specific LULC classes and non-structural flood storage is compared using the representations of water in each landscape. Comparisons of the agricultural parts of the landscape are also based on LULC classes.

*Value **	*Land use/ land cover (LULC)*	*2000 (acres)*	*2050 (acres)*	*Land use/ land cover aggregation*
1	Residential 0 - 4 DU/ac	1,039	991	Built
2	Residential 4 - 9 DU/ac	152	229	Built
3	Residential 9 - 16 DU/ac	20	46	Built
4	Residential > 16 DU/ac	3	10	Built
6	Commercial	160	152	Built
7	Commercial/Industrial	240	15	Built
8	Industrial	42	165	Built
10	Residential and commercial	0	1	Built
11	Urban non-vegetated unknown	251	150	Built
16	Rural structures	289	290	Built
18	Railroad	100	100	Built
20	Secondary roads	350	350	Built
21	Light duty roads	1,124	1,099	Built
24	Rural non-vegetated unknown	274	1,068	Built
29	Main channel non-vegetated	77	399	Built
32	Stream orders 5 - 7	0	3,401	Water
33	Water	4,486	1,918	Water
49	Urban tree overstory	53	168	Urban vegetation
52	Forest semi-closed mixed	395	321	Mixed Forest
53	Forest closed hardwood	5,500	6,780	Mixed Forest
54	Forest closed mixed	698	1,810	Mixed Forest
55	Upland semi-closed conifer	0	5	Mixed Forest
56	Conifer 0-20 yrs	109	0	Conifer forest (aged)
57	Forest closed conifer 21-40 yrs	0	0	Conifer forest (aged)
58	Forest closed conifer 41-60 yrs	1	3	Conifer forest (aged)
59	Forest closed conifer 61-80 yrs	3	18	Conifer forest (aged)
60	Forest closed conifer 81-20	2	26	Conifer forest (aged)
61	Forest closed conifer >200y	0	1	Mixed Forest
66	Hybrid poplar	66	214	Woody agriculture
67	Grass seed rotation	17,812	10,618	Grass seed rotation
68	Irrigated annual rotation	10,763	7,552	Row crop, grain
71	Grains	3,011	1,473	Row crop, grain
72	Nursery	472	404	Row crop, grain
73	Caneberries & Vineyards	558	202	Berry, vineyard, orchard, perennial
74	Double cropping	181	54	Row crop, grain
76	Mint	1,617	890	Row crop, grain
78	Sugar beet seed	477	259	Row crop, grain
79	Row crop	0	342	Row crop, grain
80	Grass	0	592	Grass seed rotation
81	Burned grass	0	1	Grass seed rotation
82	Field crop	0	790	Row crop, grain
83	Hay	2,973	4,101	Hay/ pasture
84	Late field crop	0	258	Row crop, grain
85	Pasture	1,493	4,353	Hay/ pasture
86	Natural grassland	1,541	3,940	Natural grassland
87	Natural shrub	2,880	4,791	Natural shrub
88	Bare/fallow	921	714	Row crop, grain
89	Flooded/marsh	13	609	Marsh/wet shrub
90	Irrigated field crop (perennial)	3,188	1,605	Berry, vineyard, orchard, perennial
91	Turfgrass/park	606	129	Urban vegetation
92	Orchard	352	529	Berry, vineyard, orchard, perennial
93	Christmas trees	587	449	Woody agriculture
95	Woodlot	5	271	Woody agriculture
98	Oak	154	169	Oak
101	Wet shrub	0	211	Marsh/wet shrub

** These unique numeric values for each land use/ land cover class come from the PNW-ERC data.*

Table 2. Detailed and aggregated land use/ land cover classes for ca. 2000 and 2050 landscape representations.

The current landscape

For my purposes, the most suitable representation of current landscape conditions (Figure 7a) was developed for the Willamette Valley Ecoregion (Figure 6) with circa 2000 data (PNW-ERC 2005). This representation is an update of the 1990 current condition landscape used by the PNW-ERC. Developing the two representations (1990 and 2000) followed the same basic process: 1) the initial landscape is derived from classification of Landsat Thematic Mapper (TM) imagery; 2) the agricultural landscape is refined through further Landsat interpretation along with examination of digital ortho-quadrangle images and county agricultural data; 3) the built landscape is refined with county taxlot records, census data and statewide transportation data; 4) the representation of water is based on data from the Pacific States Marine Fisheries Service with refinement using digital aerial images. Although the circa 2000 landscape is now 12 years old, it is the best available for my research needs. The detailed land use/ land cover classes allow distinctions to be made in the agricultural and vegetated parts of the landscape, and the attention given to refining the data (for example, agricultural classes and water) make this the most accurate representation of the real-world landscape.

The 2050 landscape

The foundation of my 2050 landscape representation (Figure 7b.) is the PNW-ERC's Conservation 2050 scenario. This is one of the three previously noted future scenarios that were developed with extensive stakeholder involvement. Refer to Appendix B for an overview comparison of the PNW-ERC scenarios; for a more detailed discussion refer to Hulse et al. (2002, 2004). The Conservation 2050 scenario is distinguished from the Plan Trend 2050 and Development 2050 scenarios with primary assumptions that prioritize ecological services through protection of aquatic life and wildlife habitats (Hulse 2002). These broad assumptions are an appropriate foundation for my work. However, the central theme of the Conservation scenario is the conservation and restoration of habitats and ecosystem functions, not the production of ecosystem services. Chan et al. (2006), Naidoo and Ricketts (2006) and Nelson et al. (2008) have shown that prioritizing conservation and restoration in a landscape does not necessarily result in a corresponding increase in ecosystem services. I have modified the

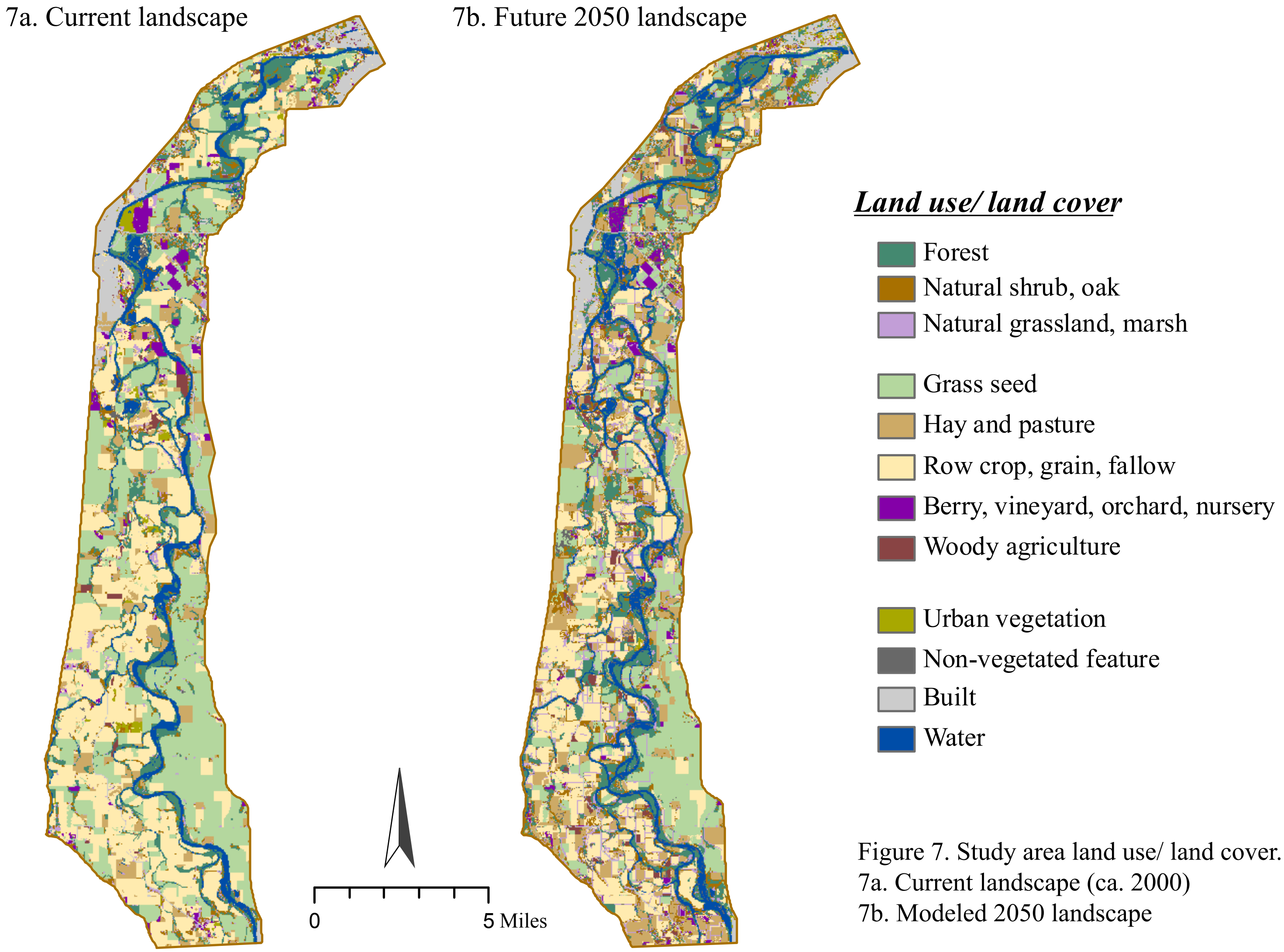

Figure 7. Study area land use/ land cover.
7a. Current landscape (ca. 2000)
7b. Modeled 2050 landscape

PNW-ERC's Conservation scenario based on my interviews with farmers to more directly address questions of ecosystem services from the agricultural landscape.

The underlying assumption for my modification of the PNW-ERC's Conservation 2050 scenario is that ecosystem services become viable crop options for farmers through funding and other forms of compensation. My interviews with farmers indicate that, with fair compensation, they would be interested in exploring options for incorporating ecosystem services into their agricultural systems. I developed guidelines for modifying the future landscape representation from farmers' comments and perspectives about cropping and agricultural operations. The built and water classes of my 2050 landscape are identical to the PNW-ERC's Conservation 2050; my modifications are in the agricultural and natural vegetation (forest, shrub and grassland) parts of the landscape. Refer to Appendix C for a more detailed description of the development of the 2050 landscape representation and a comparison with the PNW-ERC's Conservation 2050 representation.

There is a significant difference in grass seed production between my representation of 2050 conditions and the PNW-ERC's Conservation 2050; my representation decreases the amount of grass seed production by 37% and theirs increases grass seed production by 38% (relative to ca. 2000 conditions). This is due to a difference in scenario assumptions underlying the two representations. At the time of the PNW-ERC scenario development, grass seed production was well established and a strong component of the agricultural landscape. This contributed to PNW-ERC Conservation 2050 scenario assumptions that significantly increased grass seed production and decreased or eliminated other crops such as grain and row crops. At the time of my interviews (late 2009 to early 2010), the grass seed market had been in decline for a few years and the future was uncertain. Where conditions were suitable, farmers were replacing grass seed fields with wheat. What came out of the interviews were both short term perspectives (will the grass seed market pick up next year?) and longer term perspectives about crop choices. Farmers are most interested in new crop options where they are currently growing grass seed. The market decline may have triggered a willingness to discuss options but farmers' interest is not solely a reaction to the market. Fields used for grass seed production often have limitations (for example poorly drained soil) and in some cases grass seed is the only currently marketable crop that can be grown. Farmers would welcome viable alternatives for this ground for reasons other than the recent decline in the grass seed market. I have used this as operational guidance to incorporate ecosystem services in my 2050 landscape (see Appendix C).

Landscape comparison

Table 3 provides a comparison of the ca. 2000 and 2050 landscapes shown in Figure 7. In 2050, the built environment increases by 11%, forest and natural vegetation increase by 39%, conventional agricultural crops decrease by 20% and water increases by 16% (values are the area percent of each cover type). Changes in the built environment come directly from the PNW-ERC's Conservation 2050 scenario which specified relatively minor additions to the built environment in this portion of the Willamette River Basin. Changes in water also come from the PNW-ERC's scenario; they are a result of reconnecting historic river channels to restore floodplain processes. The changes in water are consistent with my 2050 scenario intentions where the additional channels contribute to non-structural flood storage (one of my ecosystem services). The changes in conventional agricultural crops, forest and natural vegetation can be attributed to assumptions in both the PNW-ERC's Conservation 2050 and my modifications. The trends of a decrease in agricultural crops and an increase in forest and natural vegetation are present in the PNW-ERC's Conservation 2050. These trends are amplified in my 2050 representation due to the transition of conventional agricultural crops to ecosystem services which are provided primarily by forest and natural vegetation land cover classes.

	2000 (acres)	2050 (acres)
Built environment		
Built	4,121	5,064
Urban vegetation	659	297
Built subtotal (acres)	***4,780***	***5,361***
Forest and natural vegetation		
Mixed forest	6,592	8,915
Conifer forest (aged classes)	115	49
Natural shrub	2,880	4,791
Natural grassland	1,541	3,940
Marsh/ wet shrub	13	820
Oak	154	169
Forest/ natural subtotal (acres)	***11,295***	***18,684***
Agriculture		
Grass seed rotation	17,812	11,212
Hay/ pasture	4,465	8,454
Berry, vineyard, orchard, perennial	4,098	2,335
Row crops, grains	17,442	12,736
Woody crops	658	934
Agriculture subtotal (acres)	***44,475***	***35,671***
Water	***4,486***	***5,320***

Table 3. Aggregated land use/ land cover comparison between the ca. 2000 and 2050 landscapes.

CHAPTER IV

BIOPHYSICAL COMPONENT:

NON-STRUCTURAL FLOOD STORAGE

Introduction

Restoring natural river processes through channel reconnection has the potential to simultaneously provide multiple ecosystem services such as habitat for native fish populations, non-structural flood storage and nutrient cycling. In the PNW-ERC's Conservation 2050 representation of water, historic channels have been reconnected to the mainstem of the Willamette River for the primary purpose of providing native fish habitat. As previously noted, my 2050 representation of water is identical to the PNW-ERC's Conservation 2050 representation. I compare the representations of water in my current and 2050 landscapes to explore the potential of restored side channel connections to provide non-structural flood storage. I do this by modeling excavation at selected locations to depict where side channels have been reconnected to the mainstem in the 2050 landscape using a 2-year flood event to determine the amount of excavation required for the connection. The analysis shows the change in side channel flood storage volume before (circa 2000) and after (2050) excavation and also compares the volume of the excavated side channel to the mainstem. The analysis is intended to be a preliminary assessment of the potential for reconnected side channels to provide non-structural flood storage as an ecosystem service.

Willamette River context

The mainstem of the Willamette River flows north ~ 300 km to the Columbia River from its starting point at the confluence of the South Fork Willamette and Middle Fork Willamette. Three reaches have been characterized along the river's course (Figure 8a) based on differences in geologic history and river morphology (Gregory et al. 2002b, Wallick et al. 2007). My study area is in the Upper reach which is distinguished from the other two as having a higher gradient and a form that was historically anastomosing with numerous side channels, alcoves and islands. Of the three reaches, Gregory et al. (2002c) consider the Upper reach to have the greatest potential to restore channel complexity.

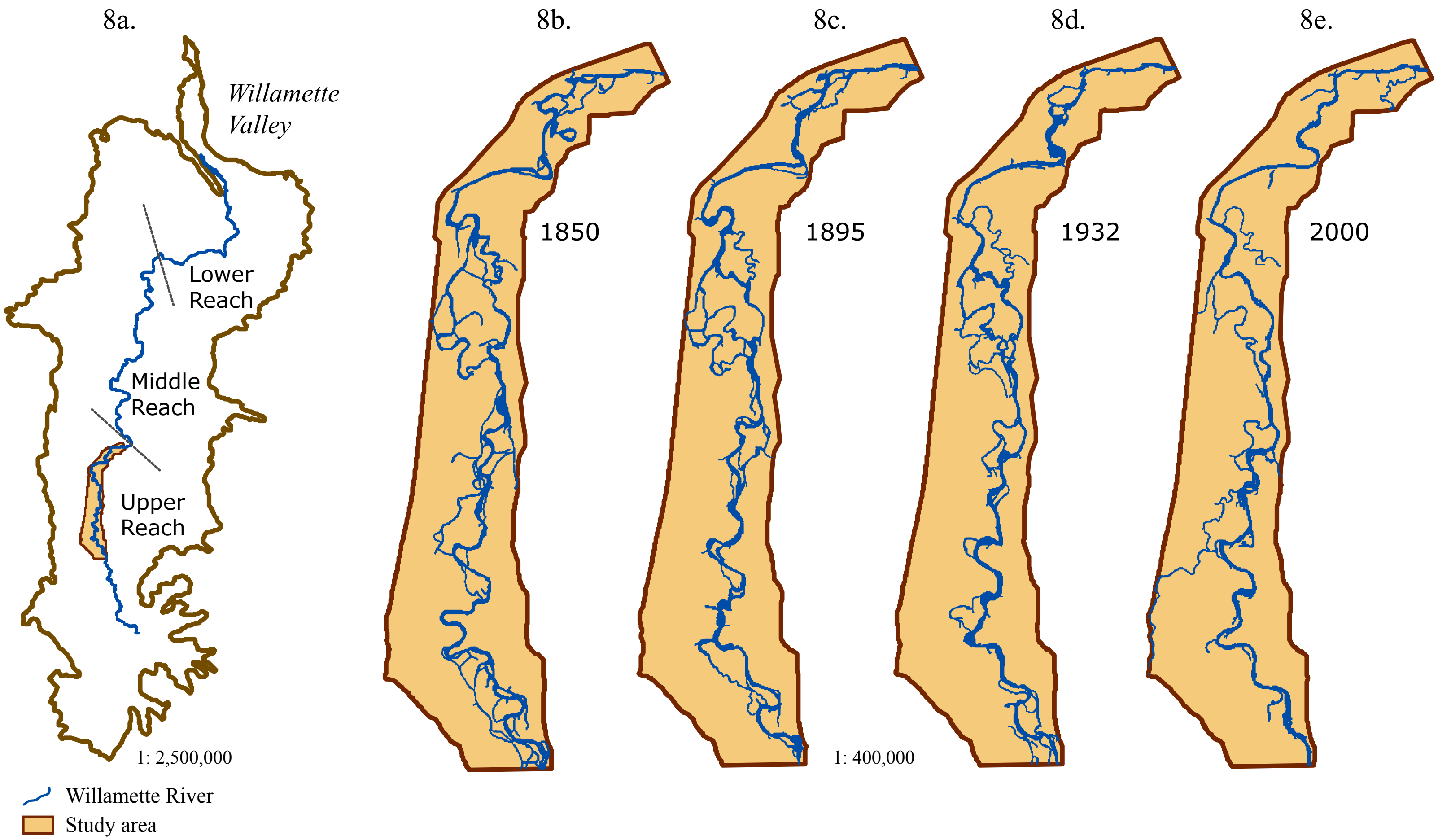

Figure 8. a. Willamette River showing Lower, Middle and Upper reaches. Mainstem Willamette, tributaries and side channels in the study area circa 1850 (b), 1895 (c), 1932 (d) and 2000 (e) (see Gregory et al. 2002b for a discussion of historic channel change).

Projects from the nineteenth and early twentieth centuries provide historic information about the Willamette River and its floodplain. In the 1850s, detailed surveys of land and water were conducted by the U.S. General Land Office and, in 1895 and 1932 the Army Corps of Engineers surveyed the river for navigation purposes. Mapped representations of these data compared with the present-day show significant changes in the river (Figure 8, b – e). Since mid-nineteenth century EuroAmerican settlement, the river and adjacent floodplain have been modified to improve navigation, create agricultural fields and, protect property and communities from flooding. These modifications have resulted in a river that is simplified and less dynamic than its historic condition; the main channel has been straightened, constrained by revetments and is less connected to side channels and floodplain processes. Although connections have been severed, recent data in the form of aerial color images and fine resolution topography from Lidar show that the imprint of the floodplain network and potential for restored processes remain on the land.

Site selection for channel reconnection analysis

Since the development of the PNW-ERC's Conservation 2050 scenario, two data sources have become available that inform the selection of locations for channel reconnection in a 2-year flood event: 1) color aerial images from the National Agriculture Imagery Program (NAIP) acquired at a one-meter sample distance with a horizontal accuracy of six meters (National Agriculture Imagery Program 2009) and, 2) a map of modeled flood inundation in a 2-year recurrence interval flood event (River Design Group 2012). Site selection for the channel reconnection analysis began with a visual comparison of the mapped (GIS) representations of water in the current landscape and the 2050 landscape (the representation of water in my 2050 landscape is identical to the PNW-ERC's 2050 Conservation scenario, see Appendix C) to mark locations where channels are connected to the mainstem Willamette in 2050 but not in the current landscape. This assessment was done with the 2009 NAIP image as a reference and the expertise of Stanley V. Gregory (Fisheries and Wildlife, Oregon State University) who knows the river well. The NAIP image showed that some of the side channels identified for reconnection in 2050 by the PNW-ERC are already connected to the mainstem, even at summer low flows. These sites were excluded from the pool of potential candidates for the analysis. The visual assessment identified sixteen potential side channel/ alcove reconnection sites. These sixteen sites were then assessed in the context of a 2-year flood event by comparing the side channel/ alcove elevation with the modeled water surface elevation for a 2-year event. This assessment showed that most of the sixteen candidate side channels are currently connected to the mainstem in a 2-year flood event and therefore, channel modification to reconnect them is unnecessary. I have modeled the three candidate sites where the side channel elevation is above the water surface elevation in a 2-year flood event and modification (excavation) is required for the channels to be connected to the mainstem at 2-year recurrence interval flood flows (Figure 9).

Process overview

As a foundation for the work, a continuous Lidar/ bathymetry surface was created for the study area. This surface incorporates bathymetry for the entire mainstem and a subset of side channels into a Lidar (Light Detection and Ranging) elevation surface. In the analysis, a 2-year flood event is used to compare side channel connection between the current landscape and the 2050 landscape. The analysis includes the three locations identified in the site selection process where side channel modification is required to provide a connection to the mainstem in a 2-year flood event. For these three locations, the channel bathymetry is modified (i.e. excavated) to create a 2050 representation that would allow water to flow from the mainstem into the side channel in a 2-year flood event. For each of the three sites, the change in side channel volume before (2000 landscape) and after (2050 landscape) modification is calculated and, the side channel volume is compared to the mainstem volume. In the following sections I first discuss the Lidar/ bathymetry surface then present the channel modification process and analysis.

Lidar/ bathymetry surface

Overview

A bathymetric surface is required for the analysis to estimate and compare the volume of water in side channels and the mainstem. The Lidar data (described in the following section) provide a high accuracy representation of elevation on land but the technology does not penetrate water. Where the surface is water, the Lidar report water surface elevation rather than the elevation of the river or channel bottom. As a foundation for the analysis, I created a continuous Lidar/ bathymetry surface for the study

9a.

9b. **Site A**

1:30,000

9c. **Site B**

1:25,000

9d. **Site C**

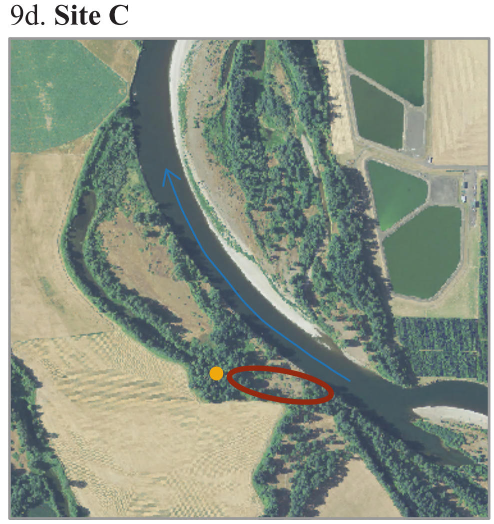

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Figure 9. a. Location of each analysis site within the study area; b,c,d, each site showing the general location of the analysis extent (the specific analysis extents are shown in Figure 12). The analysis extent is where the land surface is above the 2-year water surface elevation and obstructing side channel connection to the mainstem Willamette. Side channel elevation beyond the connection point (gold) is below the 2 year water surface elevation.

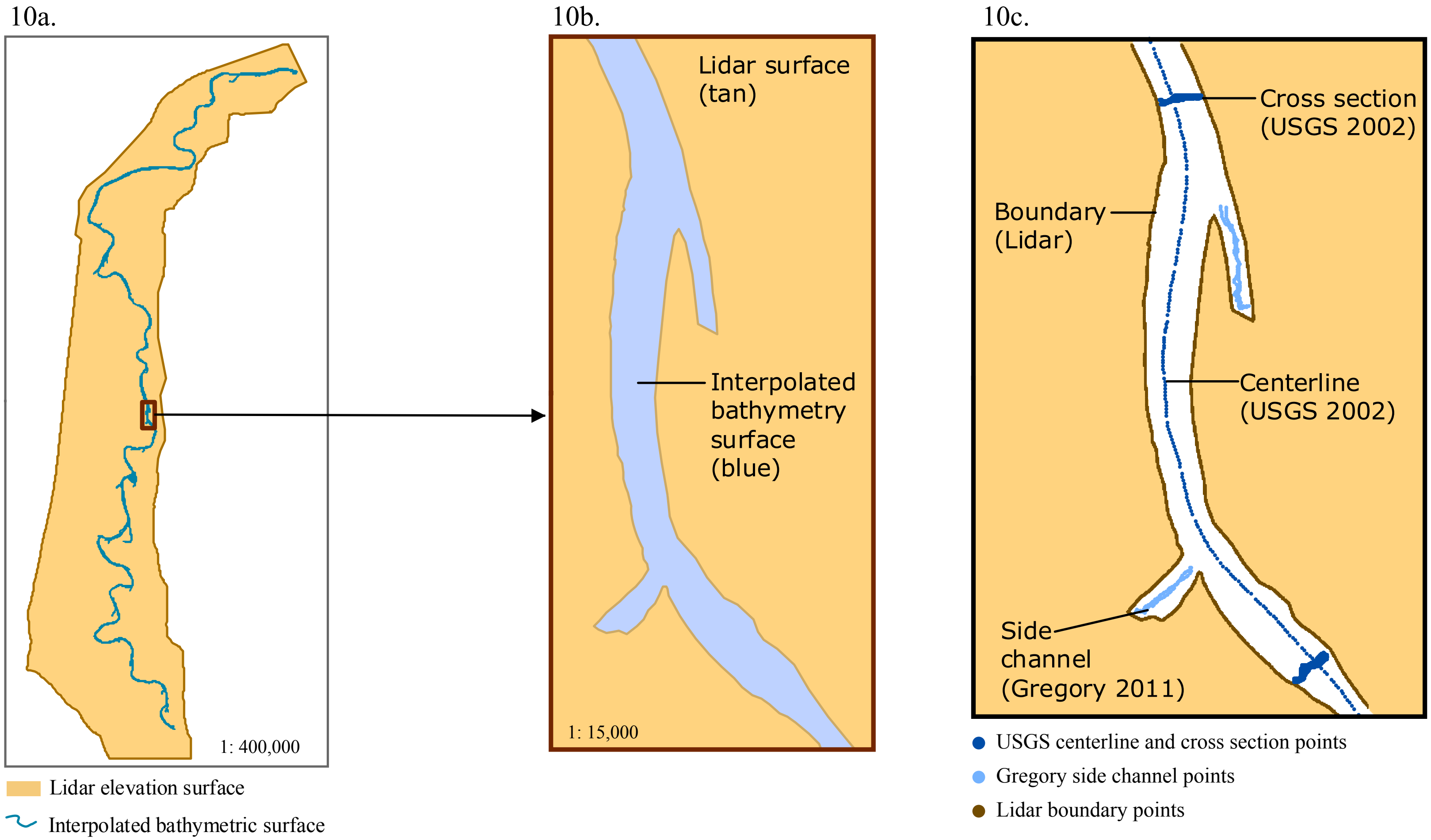


Figure 10. The Lidar/ bathymetry surface is created by integrating an interpolated bathymetric surface with the Lidar elevation surface (10a, 10b). Input elevation values for creating the interpolated bathymetric surface are from the USGS 2002 centerline and cross section data, the Gregory 2011 side channel data and channel boundary points selected from the Lidar data (10c).

area that integrates an interpolated bathymetry surface with the Lidar surface (Figure 10a, b). Data sources for creating the Lidar/ bathymetry surface are described in the following sections. Data processing for the bathymetric surface is described in Appendix D, data processing for the Lidar/ bathymetry surface is described in Appendix E.

Data sources for the Lidar/ bathymetry surface

Lidar

Light Detection and Ranging (Lidar) data were collected and processed by Watershed Sciences, Inc. through a contract with the Oregon Department of Geology and Mineral Industries (DOGAMI 2009, 2012). Lidar data were collected for multiple areas in Oregon; I used data from Willamette Valley Phase 1, deliveries 2, 3, 4, 5 and 7. Data acquisition for all of these deliveries began on August 31, 2008 and extended into September 2008 (deliveries 3, 5, and 7) or February 2009 (deliveries 2 and 4). Processed Lidar data were delivered for bare earth and highest hit elevations in ArcGIS floating point grid format with a 3 foot cell size. The bare earth data were used to create the surface for my analysis. Horizontal accuracy for the Lidar data is between 0.15 and 0.40 meters; the vertical accuracy is 0.04 meters.

Bathymetry data

Two data sets were used in conjunction with the Lidar data to create the interpolated bathymetric surface:

1) USGS 2002 bathymetry data

In 2002, The U.S. Geological Survey (USGS) collected bathymetry data for selected reaches of the Willamette and Santiam Rivers for the purpose of better understanding stream temperature processes (USGS 2003). Data covering the mainstem Willamette for my study area were collected between March 14, 2002 and March 25, 2002. The data include centerline elevation points with 10 - 20 meter spacing and cross section elevation points with one mile spacing. Data collection at each cross section location included multiple passes; all of these elevation values are reported for the cross section. The data were delivered as text files with northing, easting and elevation in meters for each data point. This data set covers only the mainstem Willamette, not side channels or alcoves. Refer to Appendix D2 for more information about the USGS 2002 data processing.

2) Gregory 2011 depth data

Stanley V. Gregory (Oregon State University, Department of Fisheries and Wildlife) collected depth data for the mainstem Willamette and selected side channels within my study area from July 25, 2011 through July 29, 2011. Spacing of the data varies but is generally between 10 and 30 meters. The data were delivered as a set of spreadsheets with latitude, longitude and depth in meters. Elevation values for Gregory's 2011 side channel points were calculated based on relationships between Gregory's 2011 depth data and the USGS 2002 centerline elevation values. The calculation is described in Appendix D3. Gregory's 2011 mainstem data were used only as a point of reference, not as an input to the Lidar/ bathymetry surface. The source of inputs for creating the surface are USGS 2002 for the mainstem elevation values and Gregory 2011 for the side channel elevation values.

Integrated Lidar/ bathymetry surface

The elevation values for the continuous Lidar/ bathymetry surface are from two sources: 1) the Lidar data and, 2) an interpolated bathymetric surface (Figure 10a, b). The interpolated bathymetric surface was created in a geographic information system (GIS) using point elevation from four data sets: 1) USGS 2002 centerline elevation points, 2) USGS 2002 cross section elevation points, 3) Gregory 2011 side channel elevation points and 4) point elevation derived from Lidar data at the channel boundary (Figure 10c). The interpolated bathymetric surface was integrated with the Lidar surface in a way that replaced the water surface elevation values from the Lidar with the elevation values from the bathymetric surface (see Appendix E for processing details). The result is a continuous surface that has land surface elevation from the Lidar and an interpolated bathymetric surface from the USGS 2002 and Gregory 2011 data (Figure 11).

Modeling reconnected side channels

Overview

A 2-year flood event is used to model the 2050 representation of reconnected side channels at Sites A, B and C (Figure 9). The Lidar/ bathymetry surface described in

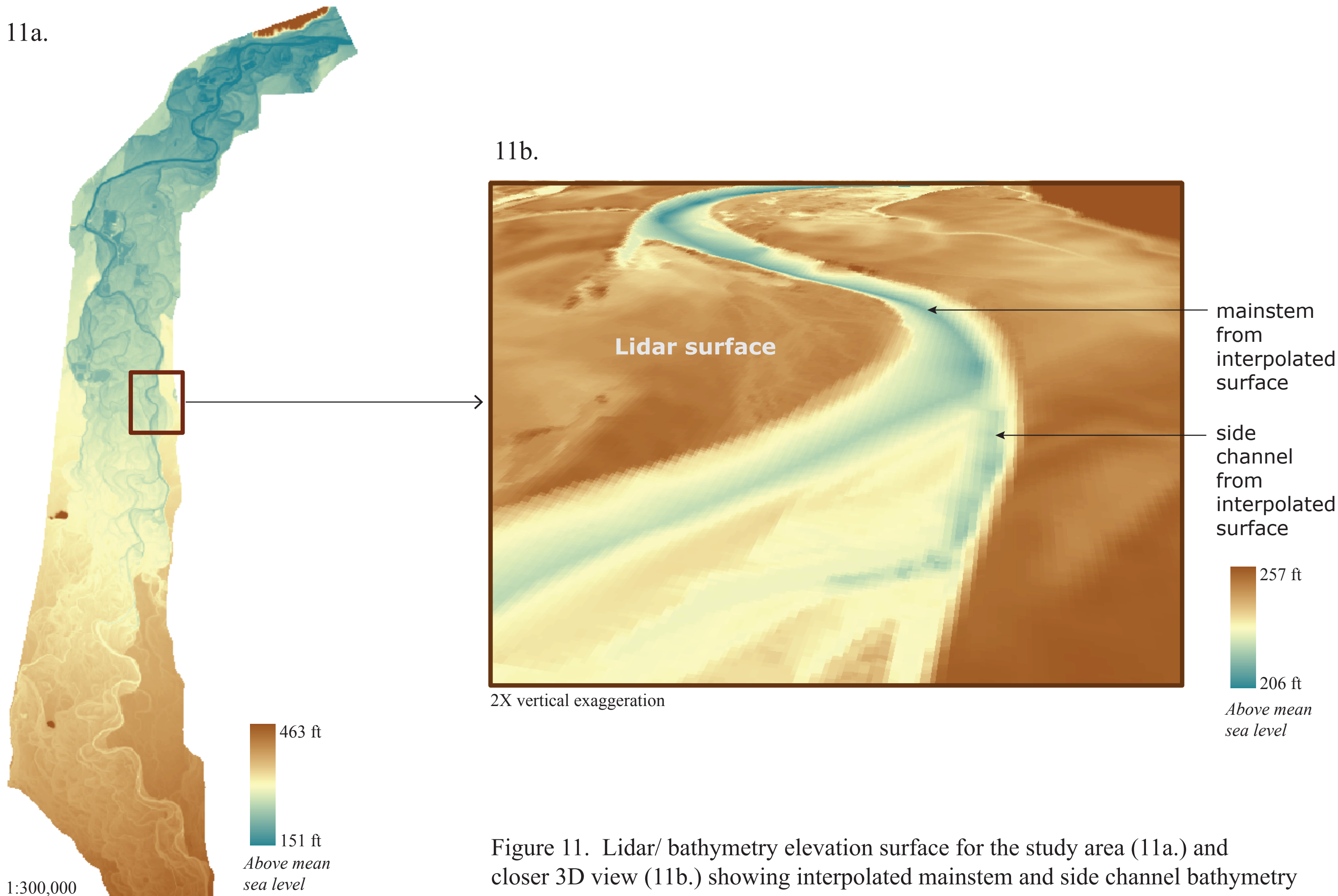


Figure 11. Lidar/ bathymetry elevation surface for the study area (11a.) and closer 3D view (11b.) showing interpolated mainstem and side channel bathymetry integrated with Lidar.

the previous section represents elevation in the current landscape (circa 2000) and this surface is modified to model changes in the 2050 landscape at the three sites. A raster representation (GIS) of water surface elevation in a 2-year flood event is used with the Lidar/bathymetry surface to determine where and how much to modify the land elevation surface at each site to allow water to flow from the mainstem into the side channel. The analysis compares the side channel volume before (circa 2000) and after modeled excavation (2050) and, the volume of the excavated side channel to the mainstem. I first describe the 2-year water surface elevation data and then present the two components of the analysis.

2-year water surface elevation

River Design Group, Inc. (RDG) developed a mapped representation of flood inundation for a 2-year regulated flow for the Willamette River floodplain from Eugene to Oregon City (River Design Group 2012). My analysis uses the 2-year water surface elevation data that RDG developed for their 2-year inundation map. RDG created water surface profiles with flood frequency curves from the Army Corps of Engineers, stream gage rating tables from the U.S. Geological Survey and Lidar data. In addition, field collected data from high water events in January 2012 were incorporated to refine and improve the water surface profiles. RDG's process and analysis are documented in their project report (River Design Group 2012). The data that RDG shared with me is an ArcGIS format floating point grid with a 6 foot cell size. The floating point values for each grid cell represent the modeled water surface elevation, in feet, for a 2-year regulated flow.

Modeling side channel excavation and change in side channel volume

<u>Methods</u>

The Lidar/ bathymetry surface, the 2-year water surface elevation and the 2009 NAIP imagery were used to determine the modeling and analysis boundary at each of the three sites (Figure 12). The side channel boundary was drawn manually as a GIS shapefile using the Lidar/ bathymetry surface and 2009 NAIP image as guides. The analysis extent was narrowed within this drawn boundary to locations where the difference between the Lidar/ bathymetry surface and the water surface elevation show

Site A

— revetment 1: 15,000

Site B

1: 15,000

Site C

1: 6,000

Analysis extent

Locations within the analysis extent where channel elevation values are modified to create the modeled excavated surface

Locations within the analysis extent where elevation values are more than 0.5' below the 2-year flood water surface elevation and are not altered in the modeled surface

Site	*Analysis extent*	*Water surface elevation (analysis extent)*	*Channel surface elevation before modeled excavation (analysis extent)*
A	2.7 acres	201.0' - 201.1'	195.8' - 206.9'
B	9.0 acres	206.0' - 206.8'	193.6' - 216.7'
C	1.4 acres	299.4' - 299.9'	293.0' - 302.4'

Figure 12. Analysis extent for each modeled excavation site showing locations where the channel surface elevation is within 0.5 feet below, or higher than, the 2-year flood water surface elevation (areas shown in brown). These are the locations where the channel elevation surface is modified with GIS processing to create a modeled excavated surface.

connection to the mainstem Willamette is obstructed by land surface above the 2-year water surface (Figure 12). Modeled excavation occurs within each analysis extent where the Lidar/ bathymetry elevation is above, or within 6 inches below, the 2-year water surface elevation. A new surface is created for each of the three analysis extents that modifies (excavates) the existing surface to allow side channel connection to the mainstem Willamette in a 2-year flood event (Figures 13, 14, and 15). For each of the three sites, a change in volume between the existing surface (before) and the modified surface (after) is calculated in ArcGIS with the cut/ fill operation.

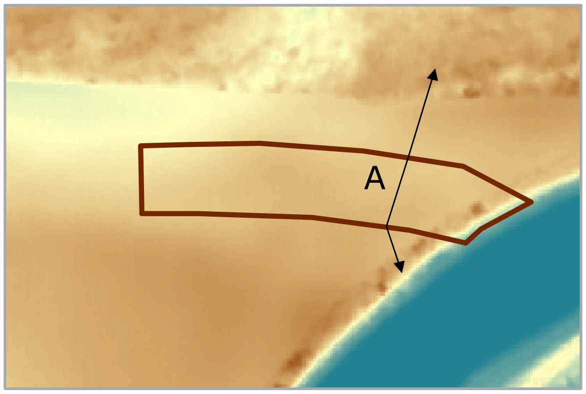
At sites B and C, there is land surface above the 2-year water surface elevation that obstructs the side channel's upstream connection to the mainstem Willamette (Figures 9 and 12). At these two locations, data processing is a series of subtractions from the Lidar/ bathymetry surface using a GIS operation to incrementally lower the surface below the 2-year water surface elevation. The process is intended to lower the surface in a way that is similar to field excavation; the modeled excavation removes more from the highest starting elevations (more is subtracted) and less from starting elevations that are closer to, but higher than, the water surface elevation (refer to Appendix F for GIS processing details).

The channel reconnection at Site A required different processing due to the surrounding topography, much of which is near or just below the 2-year water surface elevation. At this site it is necessary to create a channel that is below the 2-year water surface elevation *and* the surrounding topography to direct water from the mainstem to the identified 2050 channel. It should be noted that there is a revetment along the mainstem Willamette at this location; any side channel modification such as the one modeled here would also require a modification to the revetment. At this site (A), a new surface was created for the extent of the analysis boundary using GIS buffer and raster processing. The elevation values for the new surface were determined from the 2-year water surface elevation and the surrounding topography; the lowest elevation is at the center of the new channel with gradual increases in elevation that tie into the topography surrounding the analysis boundary (refer to Appendix F for GIS processing details).

The change in side channel volume was calculated for the analysis extent at each site in ArcGIS (3D Analyst > Surface analysis > Cut/ Fill) using the current (2000) surface as the 'before' input and the modeled excavation (2050) surface as the 'after' input.

Site A

Surface elevation before modeled excavation



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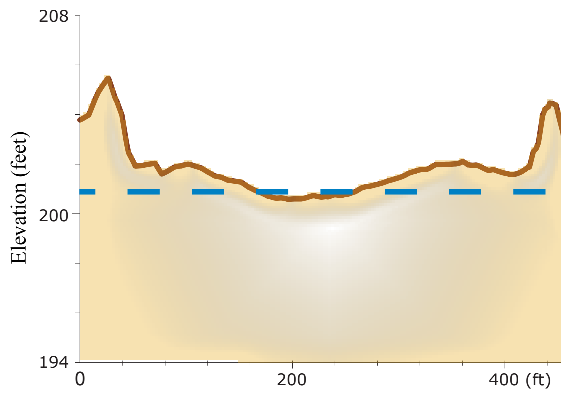
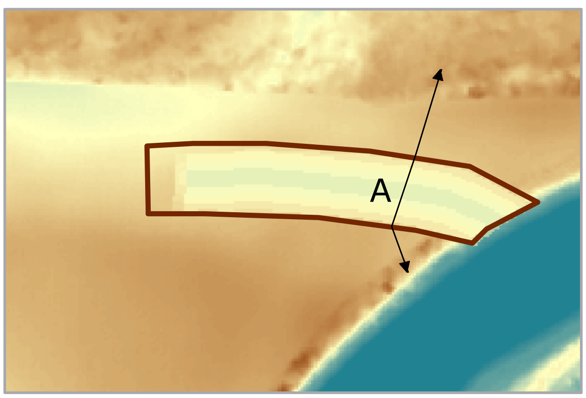
Cross section A before modeled excavation



Surface elevation after modeled excavation



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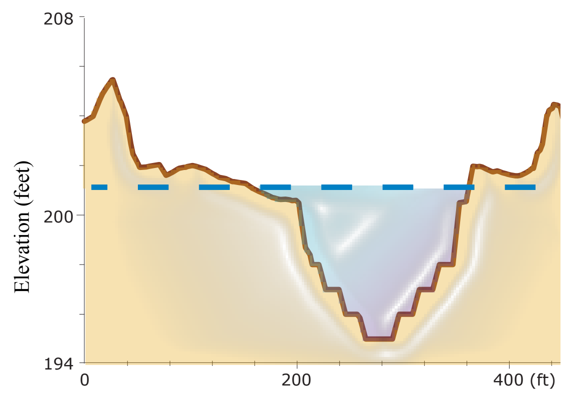
Cross section A after modeled excavation



Surface elevation

211 ft

AMSL

161 ft

Analysis extent

Water surface at 2-year flood

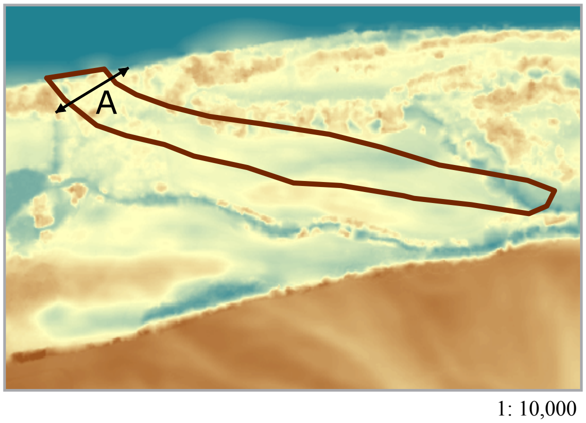
Water surface elevation range within analysis extent	*Water surface elevation average within analysis extent*	*Land surface elevation before modeled excavation (range within analysis extent)*	*Land surface elevation after modeled excavation (range within analysis extent)*	*Change in volume within analysis extent*
201.0' - 201.1'	201.0'	195.8' - 206.9'	195.0' - 201.4' *	10.2 ac. ft.

* The higher than water surface elevation values in the 'after' surface are at the top of the bank where the channel surface joins the surrounding topography.

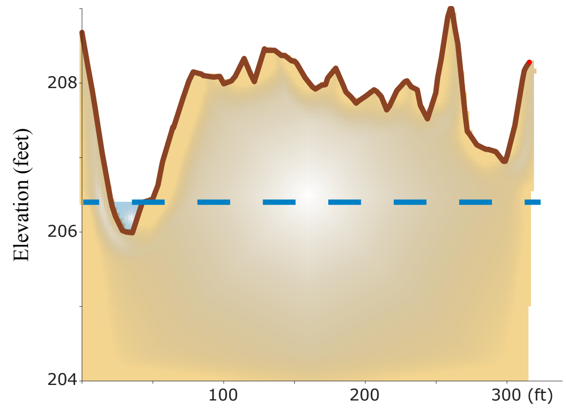
Figure 13. Site A analysis results and example cross section showing the side channel elevation surface before and after modeled excavation. *AMSL - Above Mean Sea Level*

Site B

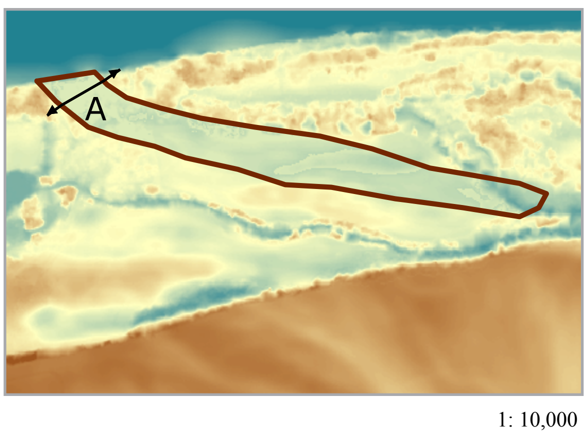
Surface elevation before modeled excavation



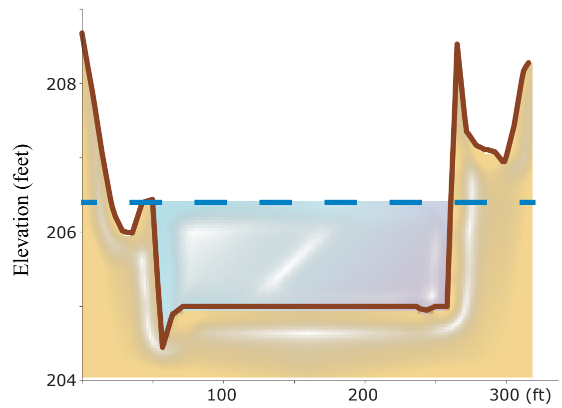
Cross section A before modeled excavation



Surface elevation after modeled excavation



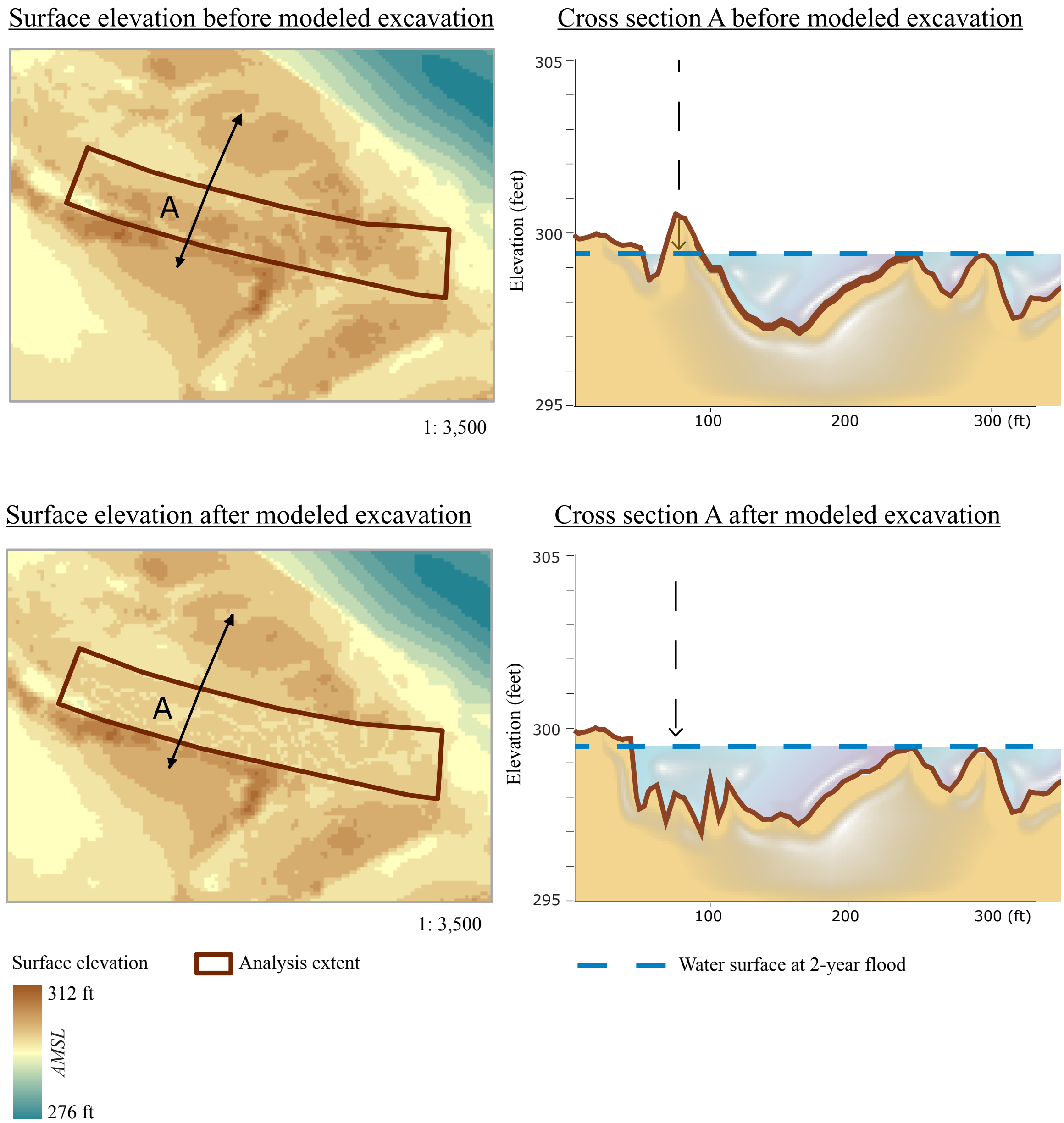
Cross section A after modeled excavation



Water surface elevation range within analysis extent	*Water surface elevation average within analysis extent*	*Land surface elevation before modeled excavation (range within analysis extent)*	*Land surface elevation after modeled excavation (range within analysis extent)*	*Change in volume within analysis extent*
206.0' - 206.8'	206.4'	193.6' - 216.7'	193.6' - 205.0'	20.4 ac. ft.

Figure 14. Site B analysis results and example cross section showing the side channel elevation surface before and after modeled excavation.

Site C



Water surface elevation range within analysis extent	*Water surface elevation average within analysis extent*	*Land surface elevation before modeled excavation (range within analysis extent)*	*Land surface elevation after modeled excavation (range within analysis extent)*	*Change in volume within analysis extent*
299.4' - 299.9'	299.6'	293.0 - 302.4'	293.0' - 298.5'	1.7 ac. ft.

Figure 15. Site C analysis results and example cross section showing the side channel elevation surface before and after modeled excavation.

Results

Figures 13, 14 and 15 show the results of channel modification at the three sites. In comparing the existing side channel surfaces with the modeled excavations, the greatest increase in volume is at Site B (20.4 acre feet) which also has the largest analysis extent (9.0 acres). The smallest of the three sites, Site C (1.4 acres), showed the least increase in volume (1.7 acre feet). As previously noted, Site A (2.7 acres) required more excavation than the other two sites due to surrounding topography. Here the increase in volume is 10.2 acre feet. Although Site B shows the greatest increase in total volume, Site A shows the greatest change per unit area (average 3.8 feet/ acre) compared to Sites B (2.3 feet/ acre) and Site C (1.2 feet/ acre).

Comparing volume between modeled side channel and mainstem Willamette

Methods

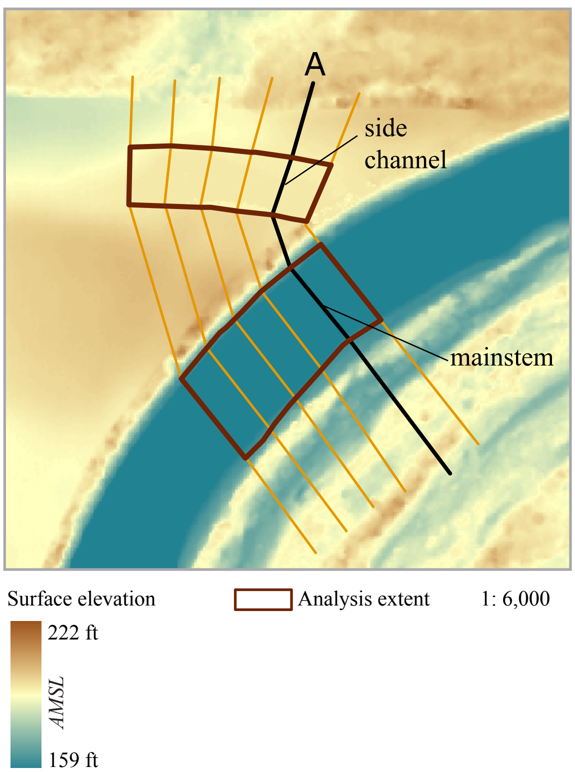
To compare the storage volume between the modeled side channel and the mainstem Willamette River, a set of cross sections was constructed at each analysis site (Figures 16, 17, 18). The number and spacing of cross sections is site specific. At each site the side channel and its mainstem counterpart share the same set of cross sections and these cross sections span the same centerline distance in the side channel and the mainstem. There are mainstem and side channel analysis extents at each site; these extents are defined by the side channel and mainstem boundaries (determined with the Lidar elevation surface and 2009 NAIP images) and the outer (upstream and downstream) cross sections. For each site (A, B and C) the volume below the water surface elevation is calculated for the modeled side channel and the mainstem with an Area/ Volume calculation in GIS (ArcMap's 3D Analyst > Surface Analysis > Area and Volume).

Results

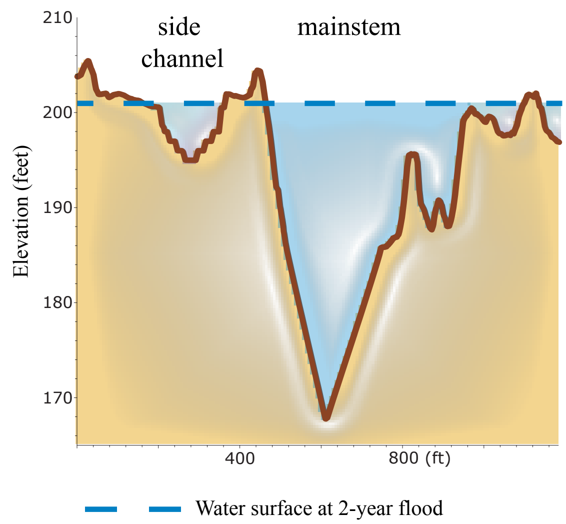
The comparison of side channel and mainstem Willamette volume for Sites A, B and C are shown in Figures 16, 17, 18 and Table 4. Although the centerline distance is the same for each site's side channel and mainstem, the greater bank-to-bank width of the mainstem (compared to the side channels) results in a larger mainstem analysis extent at all three sites. The mainstem is also deeper than the side channel at each site as shown in the cross sections in Figures 16, 17 and 18 (all cross sections are shown in Appendix G). The calculated volumes at the three sites show significantly greater volume in the mainstem compared to the side channel due the greater width and depth of the mainstem. At Site A, the side channel volume is 10% of the mainstem, at site B it is 6% of the mainstem and at Site C it is 4% of the mainstem.

<u>Site A</u>

Analysis extent for comparison of side channel and mainstem volume at Site A.



Side channel and mainstem at cross section A.

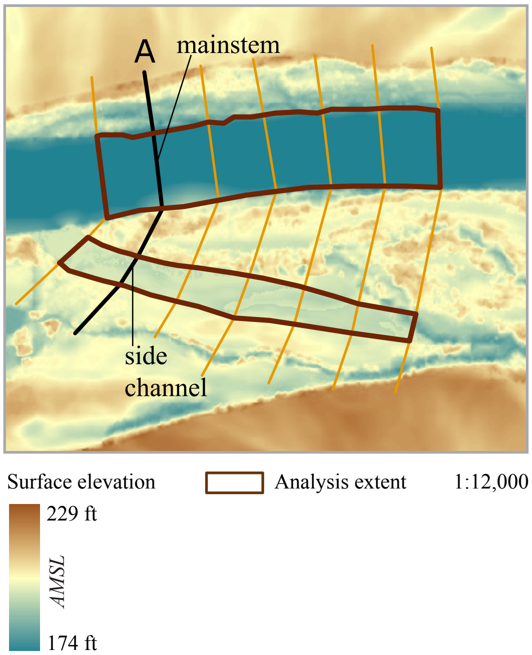


Water surface elevation (WSE)	*Cross section spacing*	*Centerline distance (analysis extents)*	*Mainstem analysis extent (surface area)*	*Side channel analysis extent (surface area)*	*Mainstem volume below WSE*	*Side channel volume below WSE*
201.0'	100'	500'	3.0 ac	1.8 ac	69.9 ac ft	7.2 ac ft

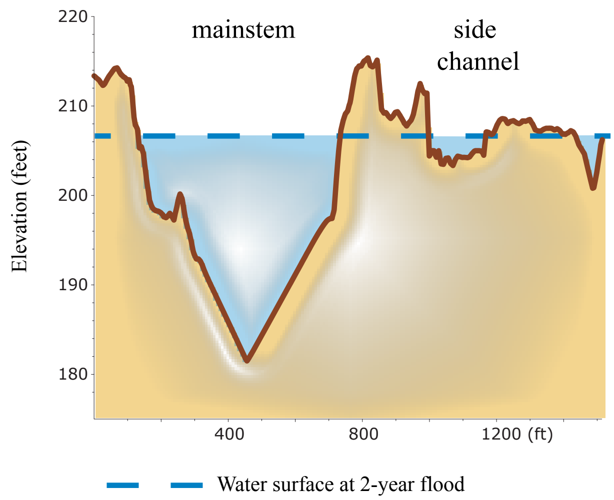
Figure 16. Site A comparison of volume in modeled side channel and mainstem Willamette River. All cross sections for Site A are shown in Appendix G1. *WSE - Water Surface Elevation*

Site B

Analysis extent for comparison of side channel and mainstem volume at Site B.



Side channel and mainstem at cross section A.

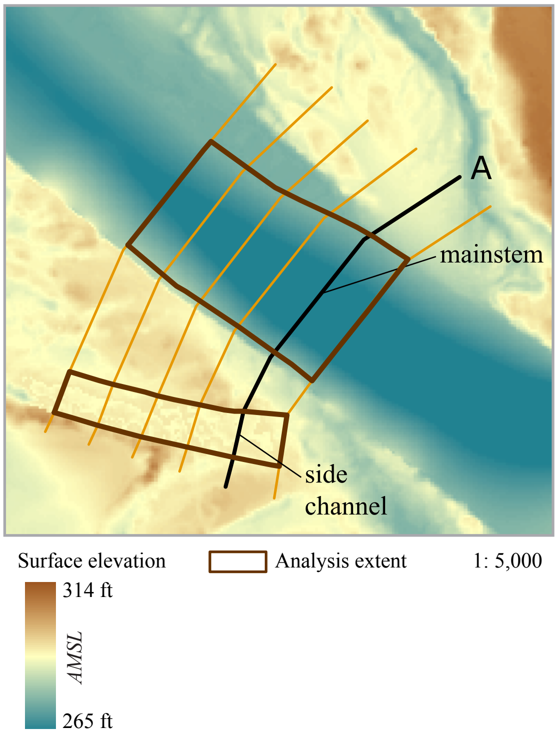


Water surface elevation (WSE)	*Cross section spacing*	*Centerline distance (analysis extents)*	*Mainstem analysis extent (surface area)*	*Side channel analysis extent (surface area)*	*Mainstem volume below WSE*	*Side channel volume below WSE*
206.4'	300'	1,800'	16.2 ac	7.7 ac	314.9 ac ft	17.7 ac ft

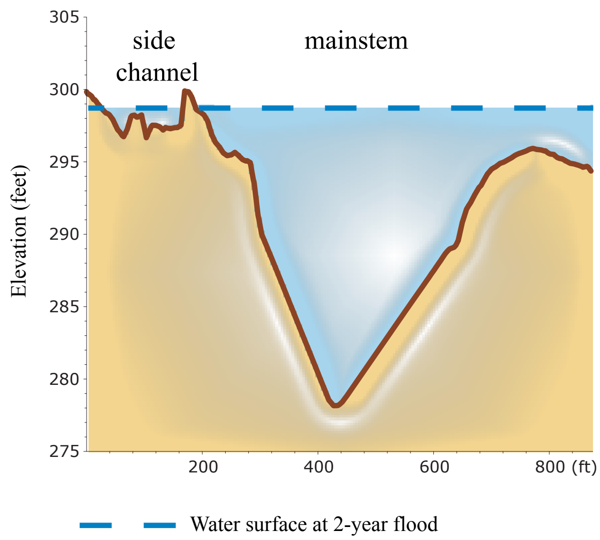
Figure 17. Site B comparison of volume in modeled side channel and mainstem Willamette River. All cross sections for Site B are shown in Appendix G2. *WSE - Water Surface Elevation*

Site C

Analysis extent for comparison of side channel and mainstem volume at Site C.



Side channel and mainstem at cross section A.



Water surface elevation (WSE)	*Cross section spacing*	*Centerline distance (analysis extents)*	*Mainstem analysis extent (surface area)*	*Side channel analysis extent (surface area)*	*Mainstem volume below WSE*	*Side channel volume below WSE*
299.6'	100'	500'	3.5 ac	1.1 ac	50.8 ac ft	2.2 ac ft

Figure 18. Site C comparison of volume in modeled side channel and mainstem Willamette River. All cross sections for Site C are shown in Appendix G3. *WSE - Water Surface Elevation*

Site	*Water surface elevation (WSE)*	*Cross section spacing*	*Centerline distance (analysis extents)*	*Mainstem analysis extent (surface area)*	*Side channel analysis extent (surface area)*	*Mainstem volume below WSE*	*Side channel volume below WSE (2050 conditions)*
A	201.0'	100'	500'	3.0 ac	1.8 ac	69.9 ac ft	7.2 ac ft
B	206.4'	300'	1,800'	16.2 ac	7.7 ac	314.9 ac ft	17.7 ac ft
C	299.6'	100'	500'	3.5 ac	1.1 ac	50.8 ac ft	2.2 ac ft

Table 4. Comparison of side channel and mainstem volume for Sites A, B and C.

Inundation over land surface

During a high water event such as a 2-year flood, ground outside of the channels becomes inundated. In this section I map the depth of water outside of channels to look at inundation patterns on land.

Methods

The representation of depth of water in a 2-year flood event is created by subtracting the Lidar/ bathymetry surface from the water surface elevation in ArcGIS. The two surfaces are floating point grids with a 6 foot cell size; the cell values represent elevation in feet. In the resulting grid, all values greater than zero are depth of water, in feet, above the land surface.

To focus on the patterns of inundation on land, water surfaces have been excluded from the inundation maps in Figure 19. The cells that are excluded are those classed as water in land use/ land cover circa 2000 and 2050, and the territory inside of the polygonal channel boundary created for the side channel modeling.

Results/ Limitations

In Figure 19, locations where the depth of water is less than 0.5 feet are mapped separately (Figure 19a, 19c) from locations where the depth of water is 0.5 feet or greater (Figure 19b, 19d). Figure 19a and 19c show that grid cells with values less than 0.5 feet are present throughout the study area. These values are mapped separately because the coarse nature of the methods used to derive the data suggest that these locations are less reliable indicators of flood water storage than greater depths. Two limitations of the 2-yr flood inundation model are particularly relevant: 1) there is no consideration of the movement of water across different land cover types, for example a fallow agricultural field versus a forest (the forest has a greater 'roughness' coefficient, i.e. more resistant to the flow of water) and, 2) there is no consideration of water infiltration based on soil characteristics. At shallow depths, land cover roughness and infiltration are particularly important in determining whether, and how long, water remains on the land surface.

Figure 19b and 19d show patterns of water depth over 0.5 feet and identify general locations in the study area where the land surface has the potential to temporarily

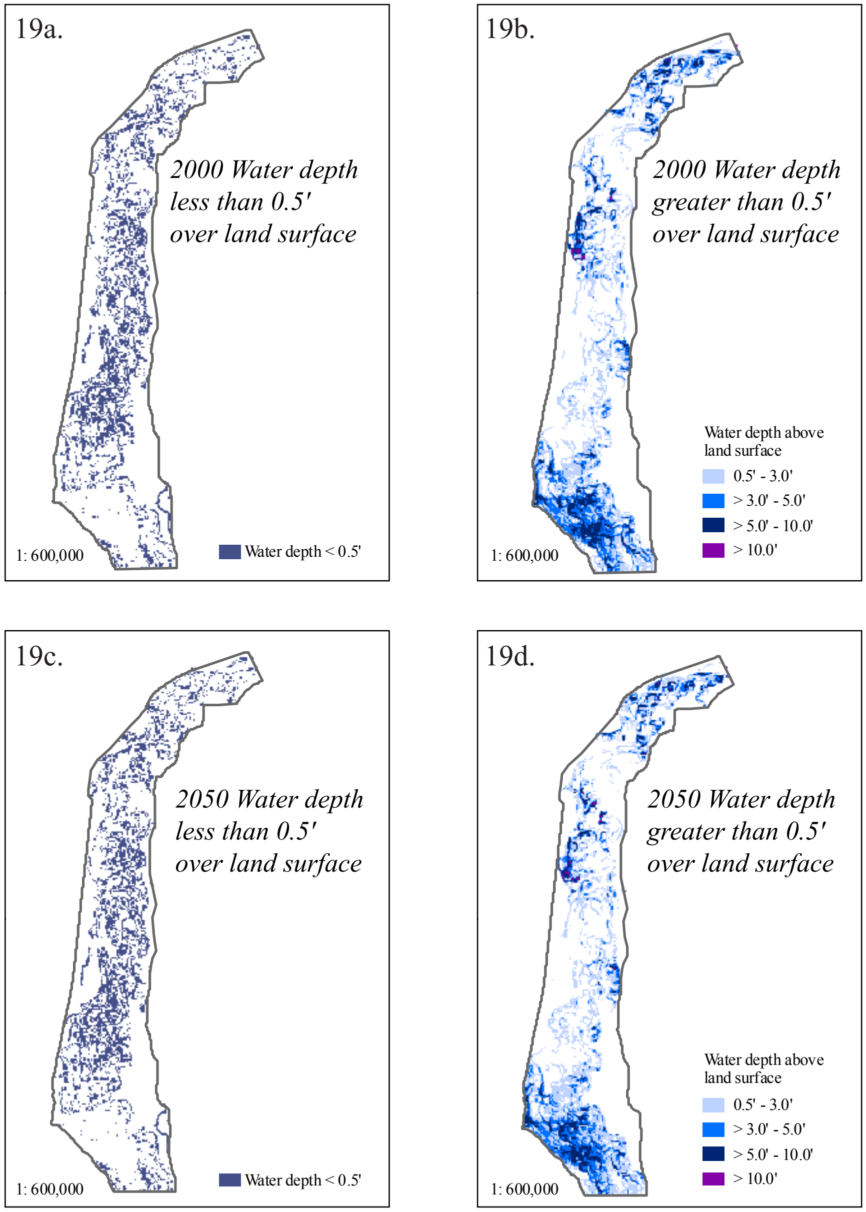


Figure 19. Inundation over land surface for a 2-year water surface elevation. 19a, 19c show locations where the depth of water is less than 0.5' for 2000 (a) and 2050 conditions (c). 19b and 19d show locations where water depth is 0.5' or greater for 2000 (b) and 2050 conditions (d).

store flood water. Locations shown in Figure 19a and 19c also have the potential to temporarily store flood water but, for reasons stated in the previous paragraph, are considered less indicative. The interpretation of water depths greater than 0.5 feet is also limited by the methods used to derive the data. In addition to the previously noted limitations, water depth is calculated as the elevation difference between the water surface and the land surface; there is no consideration of the *flow* of water. Depending on the pathways available, water may or may not be conveyed to a lower elevation. The classes shown in Figure 19b and 19d are intended to generalize the data and show patterns that indicate locations in the study area with the potential to store flood water outside of the mainstem Willamette and side channels in a 2-year flood event. Areas identified with water depths greater than 0.5 feet in Figure 19b and 19d represent 28% (2000) and 25% (2050) of the land surface in the study area. The estimated storage volume outside of channels in the 2000 landscape is 69,000 acre feet.

Discussion

The results of the analyses comparing the 2000 side channels with the 2050 side channels and the 2050 side channels with the mainstem suggest that the contribution of side channel reconnection to the volume of flood water storage is minimal. Although the three analysis sites represent a small sample of the study area's side channels and alcoves, the comparisons at the three sites show the same relationships: 1) the increase in side channel volume resulting from excavation is relatively small (Figures 13, 14, 15) and, 2) the volume of water in the mainstem overshadows the volume in the excavated side channel (Figures 16, 17, 18 and Table 4).

The volume of water that can be stored is one aspect of assessing how side channel reconnection might contribute to mitigating the effects of a 2-year flood event. Another important aspect is how channel reconnection might affect the pattern of inundation locally and, by extension, how the cumulative effect of these local changes might affect inundation patterns at the landscape scale. It is possible that small changes in the flow of water and pattern of inundation from a channel reconnection could sufficiently alter conditions to, for example, avoid flooding of an agricultural field. This is an important future research question in any effort to achieve multiple ecosystem service benefits from frequently flooded agricultural land near the Willamette River.

Figure 19b and 19d suggest that land outside of channels plays a significant role in the temporary storage of floodwater in a 2-year event. This representation is consistent with what I heard from farmers during my interviews. Some of the farmers pointed out particular fields where flooding during high water events, sometimes for consecutive days, limits their crop options. So, although farmers are not currently compensated for it, parts of the agricultural landscape are currently providing an ecosystem service in the form of temporary flood water storage. A more detailed analysis including information about soil infiltration characteristics and field collected data would be required to begin to quantify this form of storage as an ecosystem service.

From the perspective of flood storage as an isolated ecosystem service, my analysis indicates that the channel reconnection explored here would not be a worthwhile undertaking. However, a landscape approach to ecosystem services considers the landscape and its processes as a whole rather than an itemized list of separable components. Restoring side channel connections has the potential to provide a suite of ecosystem services including aquatic habitat, nutrient cycling, sediment transport and flood storage. If the benefits are evaluated from an economic perspective with each ecosystem service as an isolated component, it may turn out that none are providing the maximum benefit possible. An alternative approach is to evaluate the benefits of the suite of ecosystem services resulting from channel reconnection. Each component in the suite can still be assessed individually but the evaluation considers the suite as a whole rather than striving for maximum benefit from individual components. Although flood storage from channel reconnection is minimal, it may contribute to the suite of ecosystem services that can be provided by channel reconnection.

Limitations and uncertainties

I have previously noted limitations associated with the 2-yr flood inundation data and the report from River Design Group (2012) offers a more detailed discussion of these data and their limitations. I focus here on the limitations and uncertainty associated with the bathymetric surface.

In the Willamette's dynamic river system, data such as the USGS 2002 and the Gregory 2011 record a moment in time. River processes such as sediment transport, erosion and avulsion are continuous and points of reference are not stationary. Channel bottom elevation, the location of channel centerline and banks, and the configuration of gravel bars and side channels are ever changing. The study area's river processes have been working for a decade since the USGS 2002 mainstem data were collected. Some of the changes such as gravel bar location and side channel configuration could be seen with the 2009 NAIP images. Where the images showed significant changes, such as the formation of a new gravel bar in the channel, the data were adjusted by moving the centerline and interpolating centerline depth from upstream and downstream locations. To include side channels in the model, it was necessary to combine the USGS 2002 mainstem data with the Gregory 2011 side channel data. There are two primary sources of uncertainty in this pairing: 1) there is a nine year difference in the collection dates and, 2) the data collection protocol was different for each data set. The USGS 2002 data report channel bottom elevation and the Gregory 2011 data report depth to river bottom. The integration of these two data sets is discussed in Appendix D.

The purpose of my dissertation model is to provide a first pass assessment of flood storage for the study area landscape. Although there have been site specific channel changes since 2002, it is not unreasonable to assume that these are shifts in the location of channel characteristics and not major differences in overall river processes at the landscape scale. The site specific inaccuracies need to be considered within the overall context of the study area landscape and model intentions.

CHAPTER V

BIOPHYSICAL COMPONENT:

CARBON SEQUESTRATION

Introduction

Due to widespread concerns over climate change, carbon sequestration has recently gained traction as an ecosystem service. The immediate concern is that the increase of greenhouse gasses (GHG) in the atmosphere is driving current and projected increases in Earth's average annual temperature (Rosenzweig et al. 2007, Freedman et al. 2009). Carbon dioxide (CO_2) is a major constituent of greenhouse gasses and maximizing carbon storage in soil and plant biomass is recognized as one mitigation measure that can offset climate warming due to carbon emissions and land use change (McCarl and Schneider 2001, Eve et al. 2002, Freedman et al. 2009, Gorte 2009, Yadav 2009).

Carbon storage and sequestration

The terms storage and sequestration can vary in meaning with different authors and particular aspects of carbon cycling and accounting. The term storage is generally applied to the amount of carbon within particular systems, for example soil or vegetation. However, the carbon is in flux and not stored as a static, contained, fixed amount. The term storage is also applied to carbon capture and storage in man-made systems. In this use of the term, carbon is actually captured (for example from industrial uses) and stored in enclosed containers. The term sequestration generally refers to mitigating carbon dioxide in the atmosphere by intentionally holding carbon in other systems, for example forests. The state of knowledge about carbon sequestration makes it difficult to verify the amount of carbon in living systems that is over and above what would otherwise be present. Some authors argue that the term sequestration should only be used if the change in carbon can be verified. In this chapter, I use the term storage to refer to the amount of carbon within systems (for example oceans and soil) with the understanding that the amount is in flux and variable. I use the term sequestration to refer to additional carbon storage within systems resulting from intentional change, without need for verification. When discussing the work of others, I use their language.

Carbon markets

In response to likely regulations limiting carbon emissions, carbon exchange markets are developing worldwide (Sandor and Walsh 2001, Victor and Cullenward 2007, Freedman et al. 2009). Whether this type of a market can achieve the objective of mitigating carbon emissions is yet to be determined. In the United States, the most hopeful effort was the Chicago Climate Exchange which established a voluntary program for trading carbon credits in 2003. The program closed in 2010 because the price of carbon credits had dropped so dramatically that trading was no longer economically viable. According to Nathanial Groenwold (2011), the downfall of the Chicago Climate Exchange was triggered by an overabundance of carbon credits and a corresponding drop in price. Others point to the lack of action by policy makers in the United States on cap and trade policies and link the success of carbon markets to government policies that would motivate or compel participation. According to a report by Peters-Stanley et al. (2011), voluntary carbon markets in the United States continue to make progress in the form of smaller regional markets in the west.

Carbon sequestration - simple concept, complex process

Conceptually carbon sequestration is simple: increase the amount of carbon that is stored in plant biomass and soil to offset or reduce the amount of carbon dioxide that is released into the atmosphere. Ways to increase stored carbon include changes in forest and agricultural management practices (for example longer forest rotation periods and no-till in agricultural fields) and, changes in land cover (for example from row crop to forest). At a very basic level, these changes increase stored carbon by retaining or increasing plant biomass and reducing carbon that is released from the soil. Research thus far shows that the science of carbon sequestration is quite complex and the current state of knowledge makes it difficult to develop general characterizations. The biogeochemical processes involved are highly interdependent (Schlesinger 1997, Post and Kwon 2000, Gruber et al. 2004, Schmidt et al. 2011) and the importance of ecosystem specifics makes it difficult to draw transferable conclusions (Sun et al. 2004, Luyssaert et al. 2007, Keith et al. 2009). Developing economic accounting systems for carbon storage is complicated, in part, because living systems do not store carbon as a static entity (Jacobs et al. 2000, García-Oliva and Masera 2004, Dhanda and Hartman 2012). The amount of carbon in a system changes over time and varies with factors such as forest age, climate and disturbance history (Dixon et al. 1994, Goodale et al. 2002, Hendrickson 2003, Pregitzer and Euskirchen 2004).

In the following sections, I provide a brief background of carbon in a global context and use forests as an example to illustrate the spatial and temporal variability of carbon and the complexity of carbon related ecosystem processes.

Global and terrestrial carbon pools

Global carbon pools, global flux

Global carbon pools are often divided into three classes: oceanic, atmospheric and terrestrial. Lal (2008) presents finer distinctions in his characterization of five carbon pools, listed here in descending order of size (1Pg = 1 petagram = 10^9 metric tons):

1) the oceanic pool is 38,000 Pg
2) the geologic pool (comprised of coal, oil and gas) is 4,130 Pg
3) the pedologic pool (comprised of soil organic and inorganic carbon) is 2,500 Pg
4) the atmospheric pool is 760 Pg
5) the biotic pool is 560 Pg

Together, Lal's pedologic and biotic classes are what is commonly referred to as the terrestrial carbon pool. Global carbon pools, however they are classed, do not function as discrete systems; carbon is exchanged across systems and is variable within pools. The burning of fossil fuel (from the geologic pool) and land cover conversion (for example from forest to agricultural crops) have altered the global flux of carbon (Dixon et al. 1994, Sabine et al. 2004, Canadell et al. 2007a, Lal 2008).

Since the industrial revolution in the mid-nineteenth century, the geologic carbon pool has diminished and the oceans, the atmosphere and terrestrial systems show net increases. There is general agreement that the atmospheric carbon pool has increased by 3.2 - 3.5 Pg per year and the oceanic pool by 2.0 - 2.4 Pg per year (Schlesinger 1997, Houghton 2003, Lal 2008, Gruber et al. 2009). The degree of change reported for each pool depends on when the research was conducted, the research methodology and the time period considered (Houghton 2003, Sabine et al. 2004). Canadell et al. (2007a) investigate the growth rate of carbon dioxide in the atmosphere and show that the estimates can be significantly different depending on the chosen time period. For example, their estimate of atmospheric increase from 1959 - 2006 is 2.9 Pg per year but their estimate from 2000 – 2006 it is 4.1 Pg per.

Terrestrial carbon pools

There is a great deal of overall uncertainty associated with estimates for changes in the terrestrial carbon pool due to multiple sources of uncertainty in methodology, data and knowledge (Goodale et al. 2002, Houghton 2005, Canadell et al. 2007b, Arora and Boer 2010). Houghton (2003) compares methods that estimate terrestrial carbon based on atmospheric concentrations of carbon dioxide (he calls these top-down) with methods that use forest inventories and land use change (he calls these bottom-up). He states that the two top-down methods yield similar estimates of an average increase in terrestrial carbon storage of ~ 0.7 (+/- 0.8) Pg per year but estimates from the bottom-up methods are much less definitive. In a more recent publication, Dolman et al. (2010) do not provide a global value for terrestrial carbon flux. Instead they emphasize the importance of regional and land cover variations by discussing estimates for China, Europe, Africa and old-growth forests.

The details of global carbon flux may be disputed, unfolding and uncertain; but, the overall assessment of the trend is clear: human activity has caused a shift in the global carbon flux in ways that have increased the amount of carbon in the atmosphere, oceans and terrestrial systems. Uptake of CO_2 by oceans and terrestrial systems serves, in effect, as a buffer by reducing atmospheric concentrations. There is disagreement and uncertainty in assessments of the amount and rate of change in the oceans and terrestrial systems, and also in forecasts regarding future trends. Dolman et al. (2010) conclude that there is insufficient knowledge to confidently predict whether oceans and terrestrial systems will continue to maintain current rates of uptake, accommodate even greater amounts of CO_2 or may have already begun to decline their uptake.

Given the uncertainty in the continued capacity of oceans and terrestrial systems to accommodate carbon emissions caused by human activity, strategies are needed to intentionally influence carbon flux in ways that reduce the amount of carbon dioxide in the atmosphere. There is on-going research that may eventually provide options to sequester large quantities of carbon in oceans and underground (Lal 2008). However, these are only possibilities and, if viable, will take time to develop. There are two broad categories of near-term, practical strategies directed at decreasing the amount of carbon dioxide in the atmosphere: 1) reduce the amount of carbon released from the geologic pool and land use conversion and, 2) increase the amount of carbon stored in terrestrial systems by protecting existing resources and creating new ones. The carbon sequestration component of my dissertation addresses the second strategy and in the following section I provide a brief overview of carbon within terrestrial systems.

Terrestrial systems

Lal's (2008) previously discussed classification of global carbon pools provides a high-level division of terrestrial carbon pools: soil and biotic. Even at this coarse level, the carbon pools are not distinct. Soil properties are influenced by their associated biotic systems (particularly those underground) and biotic systems are influenced by their soils. The effect of these interactions on carbon storage is not well understood and appears to vary in different ecosystems (Weishampel et al. 2009, Schmidt 2011).

Soil carbon

At a global scale, the current stock of soil carbon is estimated to be more than three times the biotic stock (Janzen 2004, Lal 2008, Schmidt 2011). At finer spatial scales, researchers report considerable variation in the ratio of soil to biotic carbon. Sundquist et al. (2009) compare total soil organic carbon with total forest biomass for the United States and find that the soil component contains more than 80% of the carbon from these two sources. In a synthesis of carbon in United States forests, Ryan et al. (2010) state that "live and dead trees contain about 60% of the carbon in a mature forest, and soil and forest litter contain about 40%". In a study of forest and peatland ecosystems in Minnesota, Weishampel et al. (2009) report that 35 – 40% of the upland forest carbon is in the soil and forest floor litter. They compare this with the peatland ecosystem which has 90 – 99% of its carbon in the soil.

Inventories of current stocks of terrestrial carbon discussed in the previous paragraph are important for knowing where to protect existing resources. Researchers differ in their assessments of what the current stocks indicate about future increases in stored terrestrial carbon. Although the current global stock of soil carbon is at least three times the global stock of biotic carbon, there are differing assessments of the potential for increasing this pool in a way that significantly influences carbon flux. Yadav et al. (2009) acknowledge that increasing carbon in soils is not a permanent solution but state, "…soils are the largest pool of terrestrial carbon that can be increased through land management practices". Subak's (2000) qualitative assessment is, "In the long run, the worldwide potential for carbon sequestration in agricultural soils is significant…". Lal's (2004) quantitative assessment is that it is possible to increase global soil carbon stocks by 0.4 – 1.2 Pg per year for the next twenty to fifty years. At some point, an equilibrium will be reached and there will be no further net gain in the soil carbon stock. Desjardins et al. (2005) present similar estimates of average soil carbon increases of 0.2 – 0.8 Pg per year over the next fifty to one hundred years. There are questions about the degree to which increasing soil carbon is a practical and tractable strategy for mitigating atmospheric carbon dioxide. Hendrickson (2003), Smith (2005) and Bangsund and Leistritz (2008) discuss the challenges of verifying net increases in soil carbon from intentional land management practices. Paustian et al. (2000) also point out that increases in soil carbon can be reversed if management practices are not carefully maintained.

Biotic carbon

Biotic systems use carbon dioxide (they are sinks for CO_2) and also produce carbon dioxide (they are sources of CO_2). Sequestration to offset atmospheric CO_2 requires that the amount of carbon taken in and used by the system is greater than the amount produced. The two main processes associated with the biotic exchange of CO_2 are: 1) photosynthesis which removes CO_2 from the atmosphere and uses it to produce other compounds (for example sugars) and, 2) respiration which releases the CO_2 produced by biological activity into the atmosphere. A measure of an ecosystem's overall productivity can be expressed as net ecosystem productivity (NEP) which is the gross ecosystem photosynthesis minus ecosystem respiration (Schlesinger 1997, Baldocchi and Valentini 2004, Pregitzer and Euskirchen 2004). There are many factors such as climate, water availability and light that influence photosynthesis and respiration. Rates of biotic processes also vary across multiple spatial and temporal scales (Dixon et al. 1994, Baldocchi and Valentini 2004, Olsrud and Christensen 2004, Pregitzer and Euskirchen 2004, Houghton 2005). For example, rates of photosynthesis and respiration will vary depending on the time of day, season of the year and age of the vegetation. There can be considerable fluctuation in the overall amount of carbon in a system depending on the point in time (or span of time) and the particular ecosystem conditions (Post and Kwon 2000, Hendrickson 2003, Schmidt et al. 2011). In the following paragraphs, I use "forest" as a general ecosystem type to illustrate some of the complexity associated with characterizing and quantifying carbon storage and sequestration.

Carbon Pools in Forests

Carbon cycling in forests takes place across multiple pools. There are variations on the characterization of carbon pools within forests which depend on the nature of the research. For example, in a study of world forests, Pregitzer and Euskirchen (2004) define four forest carbon pools: vegetation, coarse woody debris, organic soil horizons and soil. In a field based study of upland forest and peatland, Weishampel et al. (2009) define six classes of carbon: above ground vegetation, belowground vegetation, forest floor, soil, snags and coarse woody debris. These pools are not isolated from one another but are useful for understanding and comparing carbon cycling in ecosystems. Weishampel et al. showed that the majority of carbon in the upland forest is in the aboveground vegetation and compare this with the peatland whose largest carbon pool is the soil. In a study of Pacific Northwest forests, Sun et al. (2004) compare western mesic forests, central arid forests and Cascade Mountain forests. They report significantly different quantities of carbon in soil and forest floor in the three different forest ecosystems.

Influences on carbon storage in forests

The factors and relationships that influence forest carbon storage are complex and not yet well defined and characterized. What is becoming apparent from the research to date is the need to understand the factors and relationships in the context of particular ecosystem properties (Norby et al. 2007, Oke and Olatiilu 2011, Schmidt et al. 2011). Luyssaert et al. (2007) find that, at a global scale, climatic variables of temperature and precipitation are the major influences on gross primary production (the gross uptake of CO_2 for photosynthesis) and that this is highest in humid tropical evergreen forests. However, they conclude that global patterns of net ecosystem productivity (gross primary production minus respiration) are not correlated with climatic variables. They hypothesize that net ecosystem productivity is determined by nonclimatic factors such as successional stage, management, site history and site disturbance. When comparing specific forests from global environments, Keith et al. (2009) report that, of the sampled forests, moist temperate forests had higher average site biomass than either tropical or boreal forests. These authors hypothesize that forest carbon biomass is the result of interactions and feedbacks among environmental conditions, life history attributes, morphological characteristics, disturbance regimes and, land use history. Pregitzer and Euskirchen (2004) show that forest age is a major influence in carbon flux and conclude with a general statement that for all forest biomes in their study, net ecosystem productivity peaked at intermediate age classes and declined in older age classes. However, they also discuss the importance of understanding disturbance history and land use as it affects the variability of biotic processes in different forest carbon pools. For example, as new forests establish after a disturbance, rates of respiration can be higher than rates of photosynthesis which results in the forest serving as a source of atmospheric CO_2 rather than a sink.

Landscape estimates of carbon storage based on vegetative biomass and soil carbon

The discussion of forest carbon flux illustrates the incomplete scientific understanding of carbon storage and potential sequestration. Research is on-going and in the coming years there will be new knowledge to guide the implementation of terrestrial carbon sequestration. In the meantime, currently available data and knowledge can be used to provide initial landscape estimates of current and potential carbon. These landscape assessments have been done at national scales (Eve et al. 2002, Bradley et al. 2005, Egoh et al. 2008, Kirschbaum et al. 2012) and at finer statewide and regional scales (Ney et al. 2002, Chan et al. 2006, Nelson et al. 2009). Because the science of carbon storage and sequestration is still early for most ecosystems and land use types, these landscape scale assessments generally rely on estimates of the carbon content of vegetative biomass and soil. The carbon content of vegetative biomass serves as a coarse assessment of ecosystem productivity and this can be derived from available land use/ land cover data. The carbon content of particular soil classes provides an estimate for the soil component of terrestrial carbon. The current state of scientific knowledge is insufficient to provide comparable information about biotic processes that influence carbon storage for the multiple ecosystems and land uses that occur in a landscape (for example, native forest, row crops, residential). The estimates based on plant biomass and soil carbon content have limitations but do provide an approach that enables inclusive landscape scale assessments.

Agriculture and carbon sequestration

Agriculture is broadly recognized as a land use with significant potential to influence terrestrial carbon sequestration (Lal et al. 1999, Subak 2000, Srivastava et al. 2012). There has been considerable emphasis on alternative management practices to protect and improve carbon held in soils (Paustian et al. 2000, Eve et al. 2002, Lal 2004, Desjardins et al. 2005). Practices such as no-till and cover cropping can reduce the amount of carbon that is released from the soil during cultivation and also increase the carbon content of soil organic matter. It is acknowledged that the carbon sequestration potential of agricultural soils is limited in both capacity and longevity but it is considered an important short-term strategy to mitigate increased atmospheric CO_2 (Lal 2004, Wander and Nissen 2004).

Terrestrial carbon sequestration can also be achieved through changes in agricultural land cover to increase vegetative biomass. Converting from an annual to a perennial crop will result in relatively small increases in carbon storage; conversion from an annual crop to an orchard or other woody vegetation will, over time, sequester relatively higher amounts of carbon. My dissertation research is based on changes in vegetative biomass and does not include carbon sequestration that can be achieved through alternative management practices.

Carbon sequestration as a variable ecosystem process

Literature associated with carbon in ecosystems is dominated by quantitative approaches that report global flux in petagrams, compare the carbon content of soil and biotic systems and, discuss carbon production in terms of megatons per hectare per year. Research is showing that these narrowly focused characterizations, although necessary and informative, are insufficient to fully explain carbon cycling. Studies at multiple spatial and temporal scales find that the particular qualities of an ecosystem can significantly influence carbon related processes, and it is important to understand carbon cycling within this context (Canadell et al. 2007b, Olsrud and Christensen 2004, Sun et al. 2004, Keith et al. 2009, Oke and Olatiilu 2011, Schmidt et al. 2011).

The pressing need to implement measures to mitigate atmospheric CO_2 has put the emphasis on quantifiable and tractable ways to increase carbon storage in terrestrial systems. However, the research to date supports a broader ecosystem approach to carbon where the quantitative assessments of storage are one aspect of overall ecosystem function and health. As stated by Janzen (2004), "… ecosystems are much more than tanks for excess CO_2". Janzen, Lal (2004) and Srivastava et al. (2012) put forth the idea that carbon sequestration is one of the benefits of healthy ecosystems but it is not necessarily more important or essential than others. Furthermore, managing an ecosystem for the single purpose of maximum carbon sequestration could have a negative effect on other ecosystem services such as biodiversity and water quality (Catovsky et al. 2002, Huston and Marland 2003, Jackson et al. 2005, Freedman et al. 2009). An approach that seeks to increase carbon in terrestrial systems as one measure of ecosystem health and productivity rather than maximize absolute quantities of sequestered carbon could prove to be both easier to achieve in the short-term and more beneficial in the long-term.

Analysis

Overview

My analysis compares the difference in carbon storage between the 2000 and 2050 landscapes based on changes in land use/ land cover and the resulting changes in vegetative biomass. There are two components in my estimates of carbon storage: 1) organic carbon stored in soil to a depth of one meter and, 2) carbon stored in plant biomass (above and below ground) based on land use/ land cover classes. Data for the soil component are from the Natural Resources Conservation Service (NRCS). The biomass component is based on a project by Nelson et al. (2009) in which they developed estimates of carbon for the land use/ land cover classes in my study area. Carbon storage estimates for the two components (soil and biomass) are calculated separately and then combined to provide overall estimates for the study area in 2000 and 2050. The soil carbon component remains constant from 2000 to 2050. Changes in carbon storage for the study area are based on changes in land use/ land cover classes from 2000 to 2050 and the corresponding changes in the biomass carbon component.

Soil carbon

<u>Data sources</u>

Two datasets are used for estimates of soil carbon: 1) Spatial data representing soil map units from the Soil Survey Geographic database (SSURGO); these files are available on-line for individual counties as zipped GIS vector files (NRCS 2010a) and, 2. a tabular database with organic carbon estimates for SSURGO map units within Oregon. I obtained the tabular database through personal contact with Steve Campbell at USDA-NRCS in Portland, Oregon (NRCS 2010b). The tabular database was delivered as a Microsoft 2003 Access database with two tables. The values reported in my work are from the table OR_SSURGO_oc_wtavg in which organic soil carbon is based on a weighted average of all soil components within a map unit. The spatial territory of a single map unit may contain more than one soil component and the soil organic carbon value in OR_SSURGO_oc_wtavg is the average value based on the percentage of each soil component within the soil map unit.

<u>Data processing</u>

Data processing began with the SSURGO coverages (a GIS vector file format) for each of the three counties in my study area (Benton, Lane and Linn). Each file was clipped to the study area boundary and the attributes from OR_SSURGO_oc_wtavg were joined to the attribute table for each county's coverage. The attributes were joined using the mukey (map unit key) attribute field which is common to both the Access database table (OR_SSURGO_oc_wtavg) and the SSURGO spatial data. A single soil coverage for the study area was created from the three clipped county coverages (each with the joined attributes) using the Append command in ArcInfo. The OR_SSURGO_oc_wtavg table contains multiple attributes; each attribute reports the amount of soil organic carbon in kilograms per square meter (kg/m^2) at a specified distance below the soil surface. My analysis uses the attribute that quantifies soil organic carbon to a depth of one meter. Three additional processing steps were applied to create a GIS file that is compatible with the biomass carbon estimate data:

1) The coverage was re-projected to UTM, Zone 10N, NAD 27 from its original projection of UTM, Zone 10N, NAD 83.

2) The carbon reporting unit was converted from kg/m^2 to metric tons per hectare (mT/ha).

3) The coverage was converted to a grid (raster file) with a 30 meter by 30 meter grid cell size. The value reported for each grid cell is the organic carbon to a depth of one meter in mT/ha.

Biomass carbon

<u>*Data and estimates*</u>

Values for biotic carbon are based on estimates associated with above and below ground vegetative biomass for the different land use/ land cover classes in the 2000 and 2050 study area landscapes. The methods and biomass estimates are based on work by Nelson et al. (2009) which uses spatial data from the Willamette River Basin and the same land use/ land cover classes as my study area. The 2000 and 2050 study area land use/ land cover classes (presented in Chapter 3 and shown in Figure 7) are associated with quantities of carbon in Nelson et al.'s Appendix Table 2. The values in Nelson et al.'s Appendix Table 2 are maximum carbon values in mT/ha for each land use/ land cover class. For some of the land use/ land cover classes (for example forest), the amount of biomass carbon is age dependent; a mixed hardwood forest does not reach the maximum carbon value reported in Appendix Table 2 until it is 125 years old. Nelson et al. provide a supplementary table (Table 4) to adjust the maximum biomass carbon value based on vegetation age. There is a lack of published research to guide decisions about vegetation age in my study area. For land cover classes with age dependent biomass carbon, I consulted with local experts (Stanley V. Gregory at Oregon State University and, Bart Johnson and David Hulse at University of Oregon) to determine an appropriate age for the calculation. I provide a table in Appendix H (Table 21) with the study area's land use/ land cover classes, the maximum biomass value from Nelson et al., an age estimation when necessary and, the adjusted carbon biomass value used for my dissertation analysis. Appendix H also describes my modifications to Nelson et al.'s estimates for mixed forest and natural shrub.

Data processing

The biomass carbon content of each land use/ land cover class, expressed in metric tons per hectare (mT/ha), is shown in Table 5. These carbon values were used to create GIS maps for the 2000 and 2050 landscapes using a 30 meter by 30 meter grid cell size. Total biomass carbon for each landscape was calculated from the number of hectares associated with each carbon value. To determine the total study area carbon in 2000 and 2050, the previously discussed soil organic carbon map was added to each of the biomass carbon maps with a GIS operation. As with the biomass maps, the total study area carbon was calculated from the number of hectares associated with the values in the summed 2000 and 2050 maps (biomass + soil).

Results and discussion

Figure 20 shows soil organic carbon to a depth of one meter for the study area; the amount of soil carbon (4,307,370 mT) is the same in the 2000 and 2050 landscapes. Figure 21 shows the amount of carbon associated with vegetative biomass in the 2000 (1,133,682 mT) and 2050 (1,580,711 mT) landscapes. Figure 22 shows combined soil and vegetative biomass carbon for the 2000 (5,441,052 mT) and 2050 (5,888,081 mT) landscapes and Table 6 provides a quantitative overview.

The amount of soil organic carbon is significantly greater than the amount of carbon associated with vegetative biomass in the 2000 and 2050 landscapes. In the 2000 landscape, 79% of the carbon is stored in soil and 21% in vegetative biomass. Land cover changes in the 2050 landscape increase the amount of carbon stored in vegetative biomass and a corresponding increase in total stored carbon (soil + biomass). In the 2050 landscape 73% of the carbon is stored in soil and 27% is stored in vegetative biomass. The relative amounts of soil and biomass carbon in the 2000 and 2050 landscapes are

Land use/ land cover	***Carbon estimate (mT/ha)***
Residential 0 - 4 DU/ac	23
Residential 4 - 9 DU/ac	21
Residential 9 - 16 DU/ac	17
Residential > 16 DU/ac	12
Commercial	0
Commercial/Industrial	0
Industrial	0
Residential and commercial	0
Urban non-vegetated unknown	0
Rural structures	23
Railroad	0
Secondary roads	0
Light duty roads	0
Rural non-vegetated unknown	23
Main channel non-vegetated	0
Stream orders 5 - 7	0
Water	0
Topographic shadow	0
Urban tree overstory	23
Forest semi-closed mixed	333
Forest closed hardwood	333
Forest closed mixed	333
Upland semi-closed conifer	333
Conifer 0-20 yrs	75
Forest closed conifer 21-40 yrs	167
Forest closed conifer 41-60 yrs	263
Forest closed conifer 61-80 yrs	345
Forest closed conifer 81-20	555
Forest closed conifer >200y	630
Hybrid poplar	75
Grass seed rotation	2
Irrigated annual rotation	0
Grains	0
Nursery	0
Caneberries & Vineyards	37
Double cropping	0
Hops	0
Mint	0
Sugar beet seed	0
Row crop	0
Grass	2
Burned grass	2
Field crop	0
Hay	4
Late field crop	0
Pasture	4
Natural grassland	8
Natural shrub	111
Bare/fallow	4
Flooded/marsh	0
Irrigated field crop (perennial)	32
Turfgrass/park	0
Orchard	37
Christmas trees	20
Woodlot	383
Oak	69
Wet shrub	48

Table 5. Biomass carbon estimates based on land use/ land cover class.

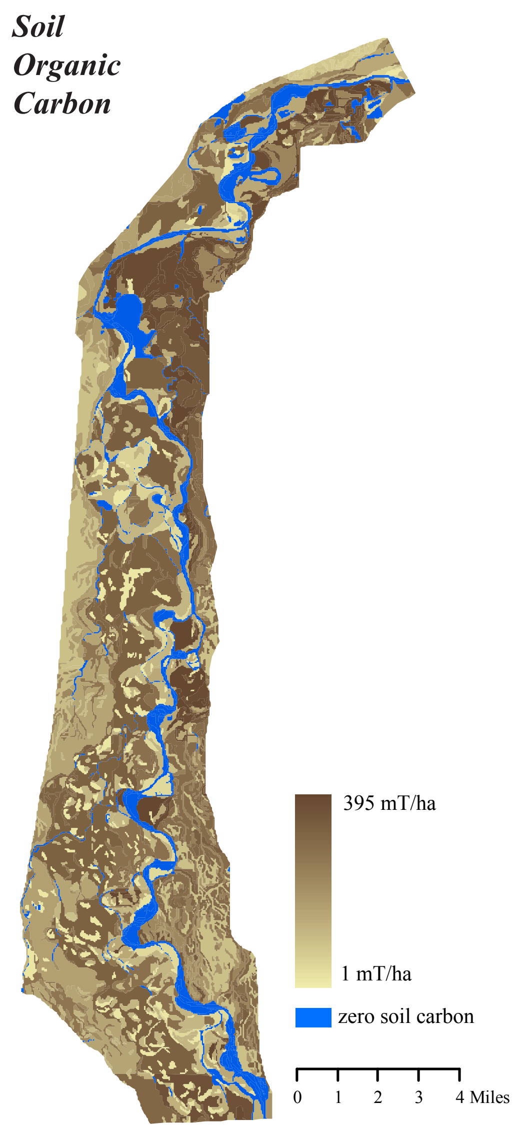


Figure 20. Soil organic carbon to a depth of one meter in 2000 and 2050. The estimate of soil organic carbon in the study area is 4,307,370 mT.

consistent with general statements found in published research (Janzen 2004, Lal 2004).

Although there is a net increase in the amount of stored carbon in the 2050 landscape relative to the 2000 landscape, Figure 23 shows that both increases and decreases occur within the study area. An increase in carbon, totaling 634,357 mT, occurred in 6,992 hectares. Much of the overall increase in carbon in the 2050 landscape occurs over a relatively small area and is due to land cover changes that significantly increase vegetative biomass. Over fifty percent of the carbon increase can be attributed to changes from a conventional agricultural crop in 2000 to forest or natural shrub in 2050. Changes from zero or low carbon biomass land cover (for example, grain or grass seed) to a forest land cover account for 44% (277,143 mT) of the total carbon gain in 2050. This 44% increase in stored carbon covers a relatively small area of 823 hectares because the carbon biomass value of forests (333 mT/ha) is significantly greater than that of agricultural crops. Similarly, changes from agricultural crops to natural shrub account for 14% of the carbon increase (86,904 mT) over an area

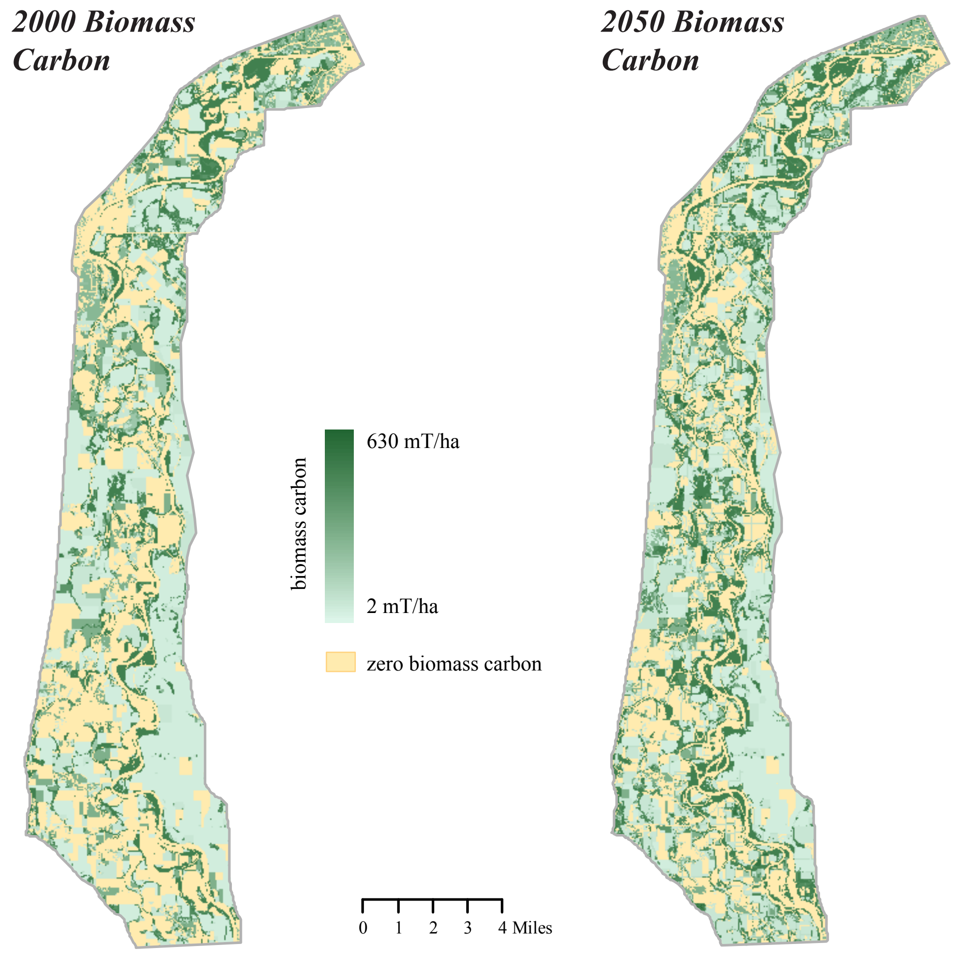


Figure 21. Biomass carbon associated with land use/ land cover classes in 2000 and 2050. Estimates of biomass carbon are 1,133,682 mT in 2000 and 1,580,711 mT in 2050.

2000 Landscape

	mT of C	*% of total C*
Soil organic carbon	4,307,370	79%
Biomass carbon	1,133,682	21%
Total carbon	***5,441,052***	

2050 Landscape

	mT of C	*% of total C*
Soil organic carbon	4,307,370	73%
Biomass carbon	1,580,711	27%
Total carbon	***5,888,081***	

Table 6. Overview of study area soil and biomass carbon in 2000 and 2050.

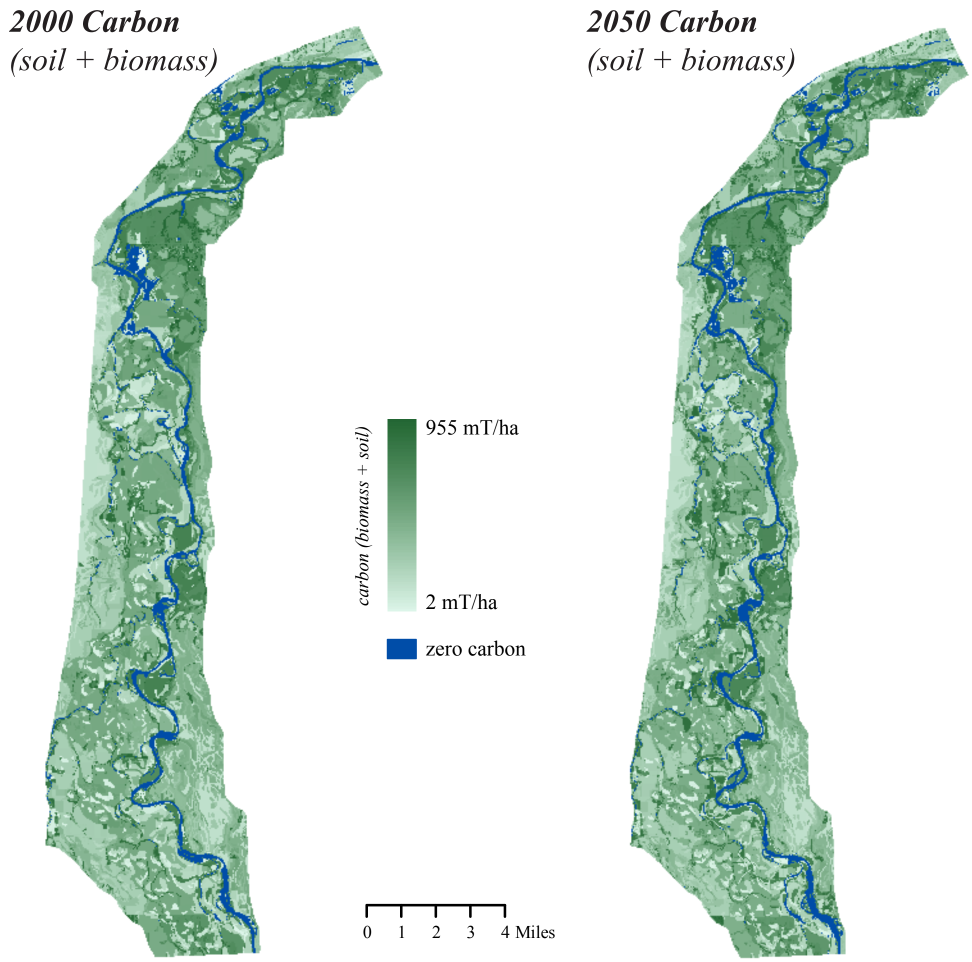


Figure 22. Total study area carbon (soil + biomass) in 2000 and 2050.
Estimates of total carbon are 5,441,052 mT in 2000 and 5,888,081 mT in 2050.

of 795 hectares. Due to the lower carbon content of natural shrub (111 mT/ha) compared with forests, the conversion from agricultural crops to natural shrub results in smaller gains in stored carbon over a greater spatial extent.

The majority of the carbon decrease from 2000 to 2050 is due to 2050 channel reconnections and a corresponding change from a vegetative land cover (with carbon biomass) to water (no carbon biomass). Sixty-four percent of the total carbon decrease is due to a 2000 vegetative land cover becoming water in 2050. More specifically, 58% of the total carbon decrease is due to the conversion of 328 hectares of forest in 2000 to water in 2050. Smaller fractional decreases in carbon are distributed throughout the study area where land cover changes result in lower carbon biomass values (for example from orchard to natural grassland).

The study area's overall stored carbon increases from 5,441,052 mT in 2000 to 5,888,081 mT in 2050 due to changes in land use/ land cover that increase vegetative biomass and therefore biotic carbon. Carbon associated with vegetative biomass increases by 39% from 2000 to 2050 and total carbon (biomass + soil) increases by 8%. These estimates are likely at the low end of what might actually be achieved because they only account for increases in stored carbon due to changes in land cover. Managing the land with practices that are reported to improve terrestrial carbon storage (for example, no-till and extended rotation) should provide greater increases in sequestered carbon.

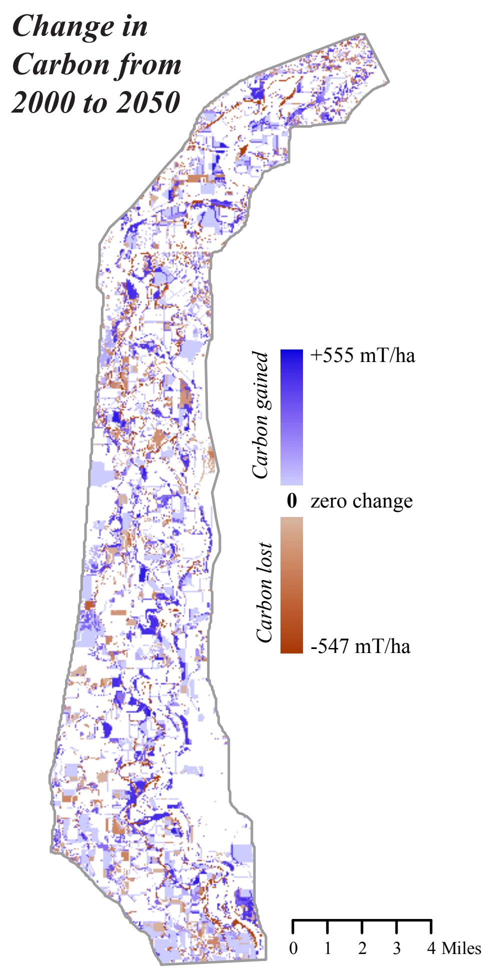


Figure 23. Changes in landscape carbon from 2000 to 2050 resulting from changes in land use/ land cover. Soil carbon remains constant; the map shows where carbon has been lost (brown) or gained (blue) in 2050 due to changes in vegetative biomass. The carbon loss from 2000 to 2050 is ~187,000 mT, the gain is ~634,000 mT and the net increase is ~447,000 mT.

The land has the potential to store significantly more carbon than is represented in the 2050 landscape. As previously discussed, changes in forested land cover account for relatively large changes in carbon and this could be used as a pathway to increase sequestration. My 2050 future scenario explores the potential to incorporate multiple ecosystem services within the agricultural landscape, not to maximize a particular ecosystem service. I present one alternative scenario for the landscape; a different future would be to manage the system for maximum carbon sequestration. In a scenario with this intention, more acreage would be converted from conventional agricultural crops to forest, and historic side channels would not be reconnected where forest would be lost to water. This is a different future, one in which farming and other ecosystem services are secondary to carbon sequestration.

Given the current state of knowledge and the uncertainties associated with terrestrial carbon storage, there are questions about the prudence of managing landscapes for the single purpose of carbon sequestration (Janzen 2004, Jackson et al. 2005, Freedman et al. 2009). There is sufficient research to know that terrestrial carbon storage can be increased and to lay the groundwork for practical implementation. However, for landscapes such as my study area, there is insufficient knowledge to predict with confidence how much carbon can be stored and, over what period of time. If maximum carbon sequestration is the objective, landscape productivity will be geared to and evaluated through this narrow lens and, the outcome of this endeavor is uncertain. In my 2050 landscape, carbon storage is increased as one aspect of a productive social/ ecological system. The focus here is on the system as a whole, not maximizing individual ecosystem services. Approaching carbon sequestration as one aspect of ecosystem process and function rather than a property to be maximized provides the flexibility to acknowledge and accept the uncertainty and variability of working with ecosystems. The landscape can be intentionally set on a path of increased carbon storage based on the currently available data and knowledge but it should be done so in conjunction with a research agenda. Research is necessary to better understand and characterize the factors that influence terrestrial carbon storage in this particular landscape. The research would benefit local land management decisions and contribute to the broader understanding of terrestrial carbon storage that is emerging from the growing number of landscape specific studies worldwide.

Limitations and uncertainties

The purpose of this narrowly defined analysis is to compare changes in stored landscape carbon due to changes in vegetative biomass that result from changes in land use/ land cover. This characterization excludes significant influences on terrestrial carbon storage such as land management, disturbance history and biotic processes. I do not address the permanence of stored carbon, leakage outside of the study area or loss of carbon that may be associated with increases in land cover biomass (for example, loss of soil carbon resulting from cultivation to plant a forest).

Within the bounds of the defined analysis, there are limitations and sources of uncertainty associated with data and assumptions. I briefly discuss three of these in the following paragraphs.

1) Land use/ land cover representation

The 2000 land use/ land cover representation is derived from satellite data and although the representation was refined with supplementary data such as color aerial imagery and county agricultural statistics, the data are a less than perfect representation of on-the-ground conditions. Quaife et al. (2008) discuss how the data, methods and uncertainties associated with land classifications influence estimates of terrestrial carbon flux. There is also a temporal aspect of accuracy in the landscape representation. Landscapes are continually changing and even the most accurate representation can only represent a brief moment in time. The 2000 land use/ land cover representation is now more than a decade old.

2) Estimates of biomass carbon associated with land use/ land cover classes

The estimates of carbon associated with each land use/ land cover class have not been derived specifically for this study area. The source data vary depending on the specific land use/ land cover class. For example, Nelson et al.'s (2009) values for the residential and grass seed classes come from the 2006 Intergovernmental Panel on Climate Change (IPCC 2006). These are generalized values that can be used globally when more specific, and appropriate, local data are unavailable. Nelson et al.'s forested carbon estimates are from a study by Smith et al. (2006) which is specific to forests in the United States and accounts for regional (for example Pacific Northwest) differences in species composition and biomass. Even here, generalizations are required and Smith et al. state, "... the uncertainty of results obtained by using representative average values may be high relative to other techniques that use site- or project-specific data."

3) Assumptions regarding vegetation age

Vegetation age, particularly in woody species, can significantly influence the amount of stored terrestrial carbon. In my analysis, the increase in stored carbon from 2000 to 2050 is primarily due to changes in the mixed forest and natural shrub classes and the corresponding changes in biomass carbon. In Nelson et al.'s (2009) methods and data, the carbon biomass estimates for mixed forest and natural shrub are dependent on vegetation age and it was necessary to determine an age for these classes. Lacking empirical research for guidance, I have calculated biomass carbon for mixed forest and natural shrub using an average age that does not vary with time (see Appendix H). This is a modeled representation of on-the-ground age distribution and has the potential to be a source of error in the calculated landscape biomass carbon. Nelson et al.'s method to adjust biomass carbon based on age uses a proportional distribution across time; i.e., the value for mixed forest increases by the same amount every 5 years until the maximum value is reached at 125 years. Research shows that the influence of age is more complex and nuanced than this linear relationship (Pregitzer and Euskirchen 2004).

CHAPTER VI

BIOPHYSICAL COMPONENT:

FLOODPLAIN FOREST

Introduction

Floodplain forest is an important feature of the Willamette Valley landscape whose extent has been significantly reduced since EuroAmerican settlement in the mid-nineteenth century (Gregory et al. 2002d). The portion of the Willamette River's floodplain within my study area has been recognized for its high potential to restore channel complexity (Gregory et al. 2002a, Wallick et al. 2007) and the forest is an integral part of the river's floodplain processes. Floodplain forest can be placed in multiple ecosystem service categories: it provides a cultural service in the form of scenic beauty and a sense of place, it is a component of the river's recreational network and, it serves as an umbrella for the complex and multifaceted qualities of floodplain forest-related biodiversity. In my dissertation, floodplain forest is comprised of specific land use/ land cover classes and my analysis compares the amounts of floodplain forest in the 2000 and 2050 landscapes.

The Willamette Valley floodplain forest (see images in Figure 24) is sometimes referred to as riparian forest, gallery forest or bottomland forest. These four terms have been used by different authors but all refer to the same assemblage of species and ecological function. Riparian and gallery are broad categories for forests that are adjacent to water but these are not necessarily in a floodplain. Naiman and Décamps (1997) define riparian as "biotic communities on the shores of streams and lakes" and note that the word derives from the Latin riparius which means "of or belonging to the bank of a river". In a discussion of the term gallery forest, J.S. Beard (1955) describes these as forests that "commonly follow the watercourses through savanna regions …". The term bottomland forest may come from characterizations in the 1850s General Land Office survey which made reference to the "low bottom" lands of the Willamette River floodplain, "The bottoms along the Willamette are heavily timbered with fir, maple, ash and a dense undergrowth of vine maple, hazel and briers…" (from Benner and Sedell 1997).

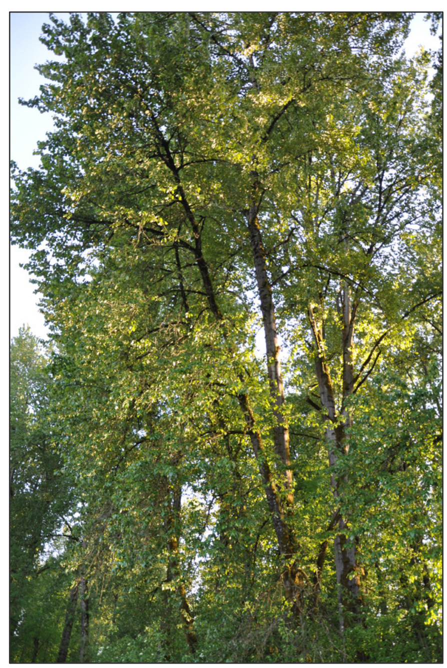
24a.

24b.

24c.

Figure 24. Contemporary floodplain forest.
a) aerial view from 2009 National Agriculture Imagery Program
b, c) view of river and vegetation
d, e) black cottonwood

24d.



24e.

Riparian forests occupy an important and unique ecological niche at the interface of terrestrial and aquatic ecosystems. River and land processes are intertwined and riparian environments have been characterized as landscape mosaics that are particularly dynamic and diverse with a high degree of spatial and temporal variability (Gregory et al. 1991, Naiman et al. 1993, Olson et al. 2007, Yang et al. 2011). The forest provides habitat for terrestrial species and can be particularly important for aquatic species in reducing stream temperatures and providing nutrients. The forest contributes to bank stabilization and also serves as a source of wood for river processes. The ecological value of large, in-stream wood in the form of broken limbs and downed trees (also referred to as woody debris) is often noted (Gregory et al. 1991, Naiman et al. 1993, Benner and Sedell 1997, Cline and McAllister 2012) but Opperman et al. (2008) point out that living wood in streams also plays a unique and significant role.

Floodplain forest history and species composition

The earliest written descriptions of floodplain forest in the Willamette Valley date to Europeans and EuroAmericans in the first part of the nineteenth century; trappers and traders came first and they were soon followed by early settlers. These accounts are narrative descriptions incorporated into broader depictions of experience and impressions of the Willamette Valley landscape. Boag (1992) quotes an 1837 report by William A. Slacum, "In ascending this beautiful river, even in midwinter, you find both sides clothed in evergreen, presenting a more beautiful prospect than the Ohio in June". Field notes from the mid-1850s General Land Office Survey (GLO) have made it possible to construct a spatial representation and quantitative characterization of the vegetation at that time (PNW-ERC 2002b). This representation is generally referred to as pre-settlement vegetation although Towle (1982) and Titus et al. (1996) note that EuroAmerican settlement began more than a decade before the survey.

The characterization of pre-settlement vegetation communities in the Willamette Valley varies with different authors. Towle (1974, 1982) describes three vegetation categories: gallery forest, prairie and oak and, hillside forests. Titus et al. (1996) describe six vegetation categories and make finer distinctions in forest, prairie and wetland. Towle describes the gallery forest as "a wooded strip of varying width and continuity bordering stream corridors". Gregory et al. (2002e) provide a similar description of dense gallery forests lining the Willamette River and its tributaries. Adjacent to and sometimes intermingled with the gallery forests were large expanses of open prairie grasslands interspersed with isolated groves of oak and fir. Early settlers found the prairie grasslands particularly striking and commented on the height of the grass which could be 'as tall as your saddle' (Gibson 1985). Since the 1850s, the open prairie and oak savanna vegetation community has almost disappeared due to land conversion for agriculture and urbanization. Gregory et al. (2002e) report that the area of prairie grasslands in the Willamette Valley is currently about three percent of its mid-nineteenth century extent.

The floodplain forest tree species have changed little since the mid-nineteenth century: black cottonwood, alder, Oregon ash and willow dominate in the most saturated soils with bigleaf maple, Douglas fir and Oregon white oak becoming part of the species mix on higher ground with better drainage. Titus et al. (1996) report an historical understory mix of dogwood, ninebark, Indian plum, vine maple and hazelnut. Bruce Campbell (2003) adds Oregon grape, serviceberry, rose, elderberry and hardhack to the

Scientific name	**Common name**
Trees	
Acer macrophyllum	Bigleaf maple
Alnus rhombifolia	White alder
Alnus rubra	Red alder
Fraxinus latifolia	Oregon ash
Populus trichocarpa	Black cottonwood
Pseudotsuga menziesii	Douglas fir
Quercus garryana	Oregon white oak
Salix spp.	Willow
Shrubs	
Berberis aquifolium	Oregon grape
Cornus sericea	Creek dogwood
Corylus cornuta var. californica	Hazelnut
Oemleria cerasiformis	Indian plum
Physocarpus capitatus	Ninebark
Rhamnus purshiana	Cascara
Rosa nutkana	Common wild rose
Salix spp.	Willow
Sambucus sp.	Elderberry
Spiraea douglassii	Hardhack

Table 7. Floodplain forest tree and shrub species. This is a compilation of species listed by Titus et al. 1996 and Campbell 2003.

25a.

25b.

Figure 25. Visualization looking east toward the Coburg Hills near Eugene, Oregon.
a) circa 1850 landscape using data from the 1850s Government Land Office survey,
b) circa 1990 landscape from land use/ land cover data. The visualization was created by David Diethelm for the Pacific Northwest Ecosystem Research Consortium (Hulse et al. 2002)

list of understory species. Botanical and common names for floodplain forest species are provided in Table 7.

Although there has been little change in floodplain forest species since the mid-nineteenth century, there has been significant change in its spatial extent and pattern during that time. The GLO survey from the 1850s describes a floodplain forest of varying widths depending on the particular characteristics of the river and floodplain (Benner and Sedell 1997). At that time, the average forest width was one to two miles on either side of the river and reached a maximum width of seven miles where the Willamette and Santiam rivers converge (Towle 1982, Gregory 2002e). In their assessment of floodplain forest for the entire Willamette River system, Gregory et al. (2002e) find that only about twenty percent of the area covered by floodplain forest in the 1850s currently remains as such. They also report that the width of floodplain forest has been greatly reduced, in come cases it is down to the width of one or two trees. See Figure 25 for a comparison of the circa 1850 landscape with the circa 1990 landscape just south of my study area. This visualization is based on the 1850s GLO survey data and land use/ land cover data circa 1990.

Floodplain forest as an ecosystem service

Cultural and recreational services

For many within the Willamette Valley, floodplain forest is both a familiar and valued vegetation community. Oregon's statewide planning goals specifically include riparian corridors (Oregon Department of Land Conservation and Development 2010, Goal 5) and groups active within the state, for example Defenders of Wildlife, The Nature Conservancy and the Willamette Partnership, have worked to foster public appreciation for this and other native ecosystems. At local levels, watershed councils have been particularly effective with outreach, community education and actively involving landowners in restoration projects. Riparian habitats are part of Oregon's Conservation Strategy for the Willamette Valley (Oregon Department of Fish and Wildlife, 2006) and there are resources for private landowners to participate in efforts to restore and monitor native habitats (Campbell 2003, Defenders of Wildlife 2012). As a result of Oregon's policies and advocacy by non-governmental groups over the past few decades, many residents of the Willamette Valley have an appreciation for the region's native habitats. There is already a sense that these places have value without the need to enumerate the specific ecosystem services they provide.

Floodplain forest is a component of the Willamette Valley's recreational assets. Walks through the forest and camping are recreational amenities of the forest itself but the primary recreational value of floodplain forest comes from its contribution to the Willamette River network. The forest is an integral part of the overall river network and whether fishing from the banks or floating down the river, the forest is significant in a visitor's experience. In the *Willamette River Field Guide*, Travis Williams (2009) describes a view from the river, "The area is very scenic. Looking toward river right you can view the broad bottomlands with cottonwoods and willows…".

Cultural services such as spiritual, aesthetic and cultural heritage are present in most ecosystem service classification systems (Daily 1999, de Groot et al. 2002, Millennium Ecosystem Assessment 2003, Boyd and Banzhaf 2007). However, cultural ecosystem services are particularly problematic in terms of definitive characterization and value assignment (Daniel et al. 2012). The task is easier where cultural ecosystem services have a tangible aspect, for example sacred or culturally significant sites that can be located and mapped by a community (Raymond et al. 2009, Bryan et al. 2010). It is more difficult to characterize cultural services within an ecosystem services framework when they lack specific spatial and physical qualities. Perhaps future research will develop adequate characterizations for the more elusive cultural services such as spiritual and aesthetic but, at present, they are more conceptual than operational. Although a case could be made for the aesthetic and spiritual qualities of floodplain forests, the case for its contribution to a sense of place as an ecosystem service (Harrison et al. 2010) is perhaps less vague and more persuasive. At a landscape scale, floodplain forest is a physical reference to the environment. This is a particular assemblage of species that is adapted to the climate and geology of the Willamette Valley floodplain. The sense of place does not necessarily come from a logical thought progression linking the specifics of the environment to the vegetation. Rather, it is a visceral connection to place that can be felt but not necessarily articulated. Floodplain forest also provides a sense of place in the experience of landscape at a human scale. In this particular landscape there is a temporal aspect to the sense of place. The frequent transitions from agricultural field to floodplain forest to river are not just locational cues but speak to the evolution of this place since the mid-nineteenth century.

Biodiversity

Biodiversity is: *"the full range of variety and variability within and among living organisms and the ecological complexes in which they occur, and encompasses ecosystem or community diversity, species diversity, and genetic diversity*" (from the US Congressional Biodiversity Act, 1990).

This is one of numerous published definitions of biodiversity and no single definition is universally cited. At the core of the various definitions is the holistic nature of biodiversity; the whole is more than the aggregation of individual components. These narrative descriptions which serve to communicate the concept of biodiversity are necessarily broad and lack the specificity that is required for operational approaches to biodiversity. Johnson et al. (1996) aptly describe the research challenge associated with biodiversity, "The problem ultimately encompasses all questions about how species coexist and how communities of populations influence ecosystem performance". While the concept and problem itself are holistic, research approaches require biodiversity to be compartmentalized. Isolating individual aspects of biodiversity allows for characterizations that can be quantified, assessed, monitored and tracked over time. For example, species richness and species diversity have been used as indicators of biodiversity (Noss 1990, Poiani et al. 2000). Species richness is the number of species in an ecological community and species diversity is an indicator of community complexity with several indexes of measurement. It is important to note that species richness and diversity are *indicators* of one isolated aspect of biodiversity and not metrics that characterize biodiversity itself.

Hierarchical frameworks for organizing biodiversity have been proposed by Noss (1990), Poiani et al. (2000) and, Nunes and van den Bergh (2001). These organizational structures provide a connection between research based understandings of biodiversity and conceptual definitions such as the one from the Congressional Biodiversity Act. Nunes and van den Bergh have an economic perspective and propose a four level biodiversity framework of functional, ecosystem, species and gene. Noss and Poiani et al. have ecological perspectives and base their frameworks on the spatial hierarchy associated with levels of biodiversity. Poiani et al. propose an inverted pyramid structure (see Appendix I) with four geographic scales: regional (the width of the pyramid), coarse, intermediate and local (the tip of the pyramid). The authors provide general ecosystem characteristics and a range of appropriate spatial extents for each scale. Noss proposes a nested hierarchy of three ecosystem attributes, each one with four spatial levels of organization (see Appendix I). The ecosystem attributes are: composition, structure and function and, each of these contain four spatial scales: regional landscape, community-ecosystem, population-species and genetic. Floodplain forest can be placed within the hierarchy of each of the three frameworks: ecosystem in Nunes and van den Bergh's, intermediate in Poiani et al.'s and, community-ecosystem in Noss's. Floodplain forest is one level in a biodiversity hierarchy; it is a component of coarser levels, for example the regional Willamette Valley landscape, and floodplain forest also serves as an umbrella for finer scale biodiversity such as species and genetic. A hierarchical framework allows specific aspects of biodiversity to be studied through research in a way that does not lose sight of the whole. This type of framework also makes it possible to develop characterizations (quantifiable and otherwise) at the various levels that can be used as indicators of biodiversity for monitoring and tracking change over time.

ANALYSIS

For my analysis, floodplain forest is defined by particular land use/ land cover classes and represented in a Geographic Information System (GIS) for the 2000 and 2050 landscapes. The analysis compares the amount and patch size of floodplain forest in the two landscapes.

Methods

Floodplain forest is derived from the GIS land use/land cover representations for 2000 and 2050 that are presented in Chapter III. The set of cover classes defining floodplain forest, shown in Table 8, was developed by the Pacific Northwest Ecosystem Research Consortium for their alternative futures analysis. This set of cover classes is mapped with a 30 meter by 30 meter grid cell size to represent floodplain forest in 2000 and 2050. To characterize patch size, the floodplain forest grids are converted to GIS vector files (polygons). Patches of floodplain forest are created with a GIS *Dissolve* operation which merges individual contiguous polygons into a single polygon feature.

Value	***Land use/ land cover***
53	Forest closed hardwood
54	Forest closed mixed
55	Upland semi-closed conifer
56	Conifer 0-20 yrs
57	Forest closed conifer 21-40 yrs
58	Forest closed conifer 41-60 yrs
59	Forest closed conifer 61-80 yrs
60	Forest closed conifer 81-20 yrs
61	Forest closed conifer >200 yrs
86	Natural grassland
87	Natural shrub
89	Flooded/marsh
98	Oak
101	Wet shrub

Table 8. Land use/ land cover classes that define floodplain forest for 2000 and 2050. The numeric value was assigned by the PNW-ERC to uniquely identify each land use/ land cover class.

Results and discussion

The representation of floodplain forest in 2000 and 2050 is shown in Figure 26 and an acreage comparison is shown in Table 9. The 10,900 acres of floodplain forest in

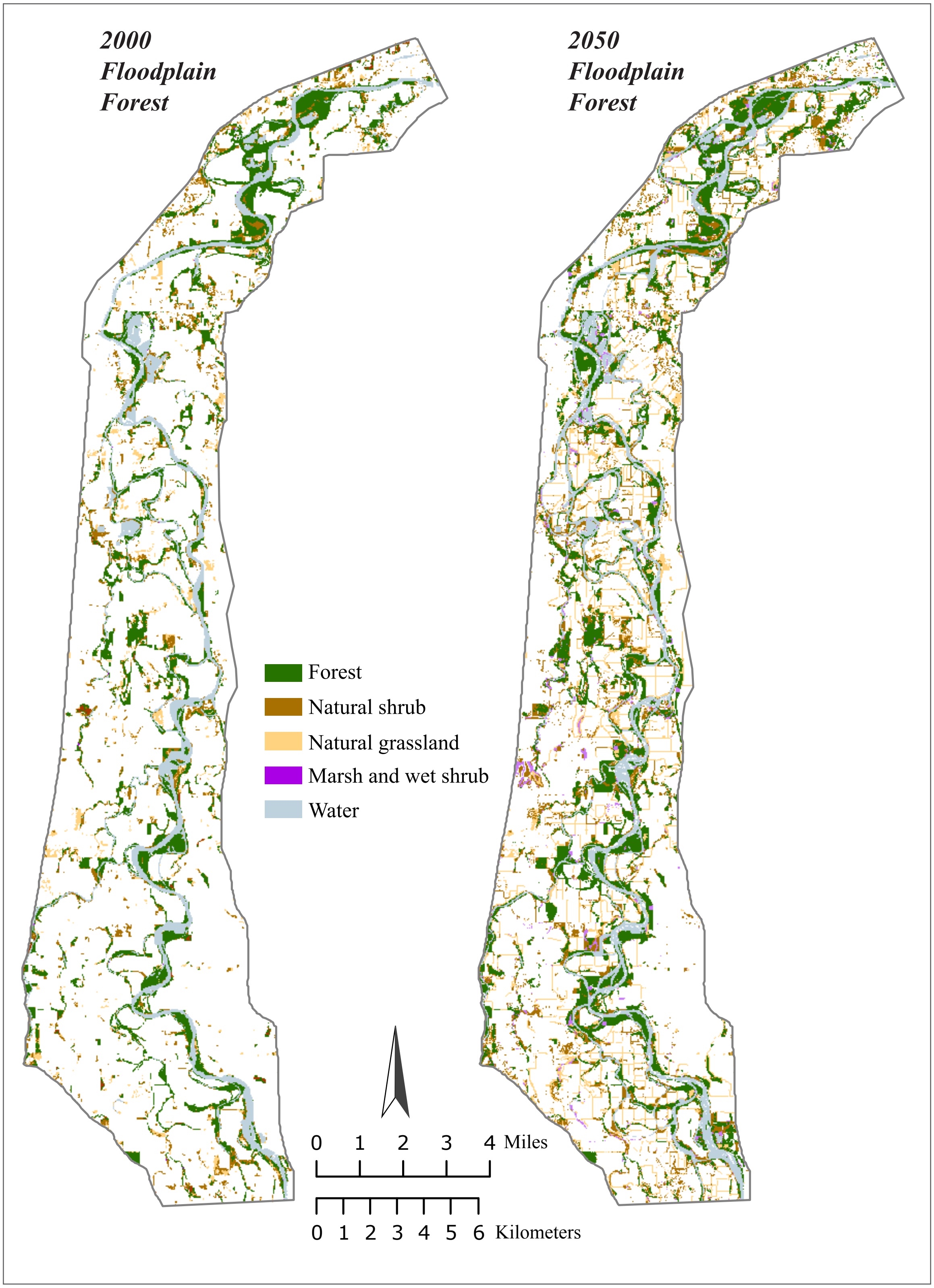


Figure 26. Floodplain forest in 2000 and 2050.

Floodplain Forest (aggregated classes)	***2000 (acres)***	***2050 (acres)***
Mixed forest (classes 53 - 55)	6,198	8,594
Conifer forest (aged, classes 56-61)	115	49
Natural grassland	1,541	3,940
Natural shrub	2,880	4,791
Other natural vegetation (classes 89, 98, 101)	167	989
Total acres	***10,900***	***18,363***

Table 9. Comparison of floodplain forest acreage in 2000 and 2050.

2000 covers 17% of the study area. In 2050, the amount of floodplain forest increases to 18,363 acres (a 68% increase) which covers 28% of the study area. The increase of 7,463 acres of floodplain forest is the net result of a loss of 2,013 acres from the 2000 landscape and an increase of 9,476 acres in the 2050 landscape. Much of the floodplain forest loss from the 2000 landscape can be attributed to the reconnection of side channels in 2050. One thousand acres of the 2000 floodplain forest become water in 2050. Smaller losses to multiple land use/ land cover classes (for example hay and pasture) account for the remaining loss of floodplain forest between 2000 and 2050.

Consistent with assumptions driving the 2050 landscape (the assumptions are discussed in Chapter III and details are provided in Appendix C), the 9,476 acre increase in floodplain forest is primarily due to the conversion of conventional agricultural crops in 2000 to floodplain forest cover in 2050. Eighty-eight percent (8,350 acres) of the new 2050 floodplain forest was an agricultural crop in 2000. Two agricultural classes account for more than half of the 8,350 acres: grass seed rotation (2,640 acres) and irrigated annual crops (2,250 acres). Another 30% of the conversion can be attributed to the combination of irrigated perennial crops (790 acres), hay (720 acres), grains (600 acres) and pasture (450 acres).

Floodplain forest patch size is shown in Figure 27 and quantified in Table 10. The increase in the total amount of floodplain forest from 2000 to 2050 is accompanied by an increase in patch size. From 2000 to 2050, the percentage of floodplain forest in the three smallest patch size classes decreased while the percentage in the 100 acre to 1,000 acre class doubled. There was also one patch greater than 1,000 acres added by 2050.

The increase in amount of floodplain forest and the change in patch size distribution between 2000 and 2050 do not necessarily equate to biodiversity enrichment. However, there is reason to believe that this is an improved set of circumstances with increased

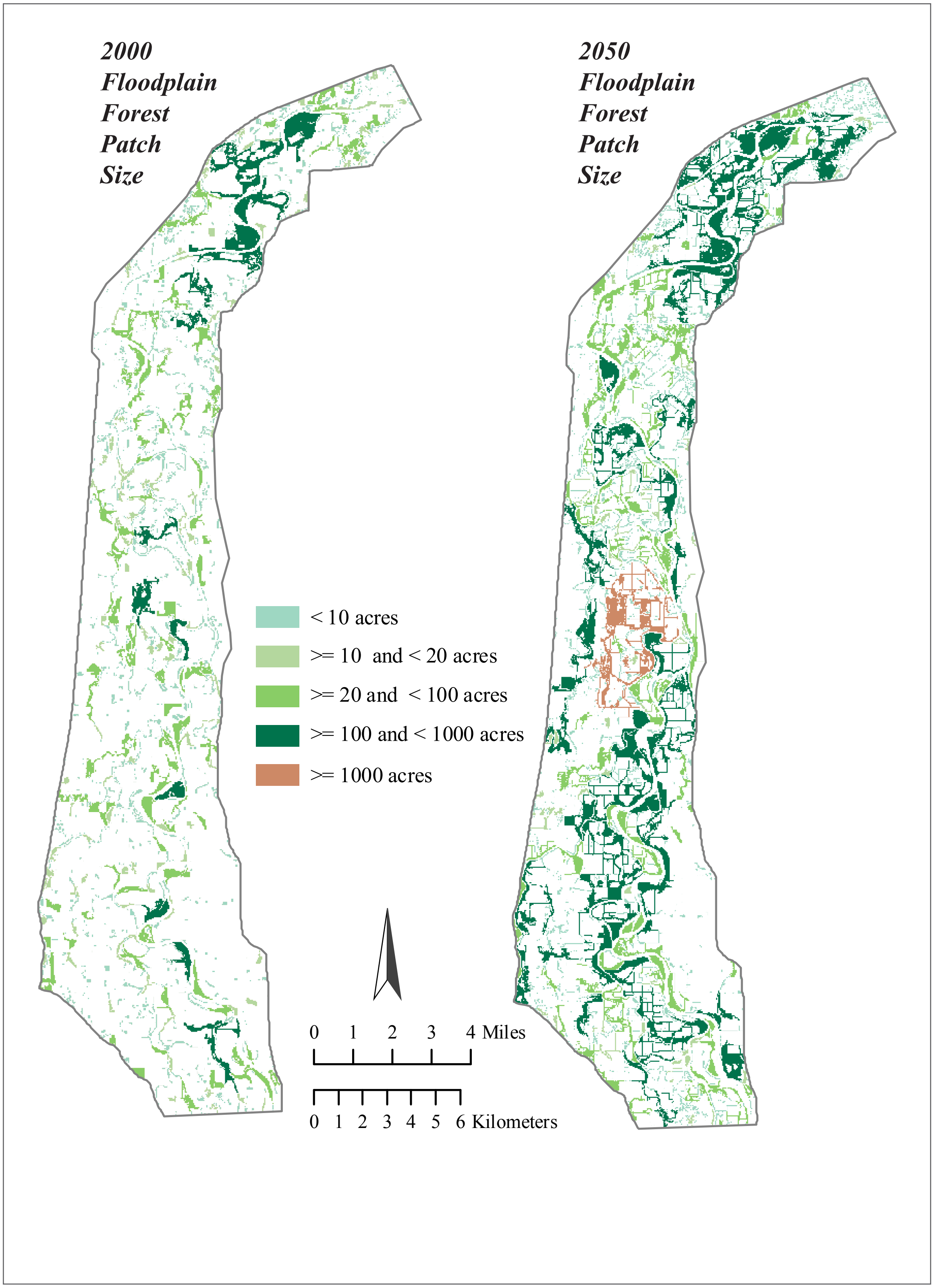


Figure 27. Floodplain forest patch size in 2000 and 2050.

	Number of patches		Total number of acres in patch size		Percent of total floodplain forest in patch size	
Patch size	***2000***	***2050***	***2000***	***2050***	***2000***	***2050***
< 10 acres	2,372	3,377	2,751	2,800	25%	15%
>= 10 < 20	102	55	1,445	742	13%	4%
>= 20 < 100 acres	88	97	3,929	4,413	36%	24%
>= 100 < 1000 acres	14	35	2,773	9,379	25%	51%
>= 1000 acres		1		1,029		6%
Floodplain forest acres			***10,900***	***18,363***		

Table 10. Comparison of floodplain forest patch size in 2000 and 2050.

opportunity for biodiversity. There are exceptions to any general statement about patch size and configuration but in his presentation of general principles of landscape and regional ecology, Forman (1995) states, "We may hypothesize that an optimum landscape has large patches of natural vegetation, supplemented with small patches scattered throughout the matrix [the non-patch part of the landscape]." As yet, there is insufficient empirical evidence to prove or disprove Forman's hypothesis and this approach of addressing the widest range of needs by including large patches with a supportive network of smaller patches still provides general purpose guidance in landscape ecological planning. If it is necessary to choose between numerous small patches and one to a few large patches then the needs of specific species and the qualities of the matrix need to be considered (Yates et al. 1997, Lindenmayer and Franklin 2002, Bender and Fahrig 2005, Prugh et al. 2008). The change in floodplain forest between 2000 and 2050 is not a choice between small patches and large patches. Rather, it is an expansion of the patch network and although there is a shift to a higher percentage of larger patches, Table 10 shows that small patches are still plentiful.

My purpose in the earlier description of pre-settlement vegetation was to provide historical context for understanding the evolution of this landscape, not to set the stage for re-establishing landscapes of the past. The purpose here is to explore the potential for floodplain forest, as an ecosystem service, to be part of a farm operation. The increase in floodplain forest from 17 percent of the study area in 2000 to 28 percent of the study area in 2050 could be a significant shift in the landscape's resources. The establishment and maintenance of floodplain forest habitat would require inputs of materials and labor. However, once established, this land cover should be considerably less resource intensive than the agricultural crops occupying the same territory in 2000. I use the term 'resource intensive' broadly to include the specific monetary costs to a farmer (labor, fuel, chemicals, equipment) as well as natural resources such as soil erosion and fertility, water quality and quantity and, fossil fuel extraction. From an ecosystem services perspective, the shift of conventional agricultural crops to floodplain forest is not taking away from agriculture to give to habitat. Rather it is a conversion that considers and seeks to make better use of broader landscape resources.

Limitations and uncertainties

The foundation for defining floodplain forest is a representation of land use/ land cover which was developed for the circa 2000 landscape. The land use/ land cover representation is at a 30 meter by 30 meter resolution and, although refinements were made, the primary source of the data was Landsat TM imagery. There is low confidence associated with identifying some of the floodplain forest classes (for example, natural grassland) from the Landsat data. Since the circa 2000 representation was developed, there have been new sources of data (color aerial images, Lidar elevation data) that have highlighted inaccuracies in the overall representation of floodplain forest. Using these more recent data sources in conjunction with the Landsat data results in a representation of floodplain forest that more accurately reflects on-the-ground conditions. The more recent data (including a 2-year flood inundation map) also allow for an assessment of whether or not there is a 'riparian relationship' between the vegetation and the river channels, i.e. is there frequent interaction between the vegetation and river processes?.

The 30 meter grid cell representation based on Landsat data has limited utility for understanding important qualities associated with floodplain forest. Figures 26 and 27 show the 'salt and pepper' nature of the grid cell representation and this likely accounts for the large number of small area patches (< 10 acres) within the study area. Some ground truthing is necessary to know whether these small patches exist and, if so, whether they function as floodplain forest. The representation of floodplain forest in my analysis considers only what can be seen from above the forest. There is no consideration of vertical forest structure or habitat quality and these can be important for certain kinds of biodiversity assessments.

CHAPTER VII

SOCIOCULTURAL COMPONENT:

INTERVIEWS WITH FARMERS

Purpose and expanded study area

To better understand the southern Willamette Valley's agricultural landscape and farmers' perspectives, I conducted in-person interviews in 2009 – 2010. To expand the pool of potential interviewees, the geographic boundary for this component of the research, shown in Figure 28, includes and extends beyond the boundary for the biophysical component of the research. This broader territory is still within the Willamette River floodplain and therefore, farming practices and crops remain the same. There are two primary purposes for this part of the research: 1) to gain a better understanding of the agricultural landscape through the histories and perspectives of farmers who work with the land and, 2) to gauge the interest of farmers to produce ecosystem services as part of their agricultural operation.

Background and context

The roots of EuroAmerican agriculture in the Willamette Valley trace back to the early part of the 19th century. Retired French-Canadian and American fur trappers were farming in the valley prior to 1840 (Blok 1973) and their success with crops encouraged an influx of new settlers in the early 1840s. By 1845, the Willamette Valley's EuroAmerican population had reached five to six thousand (Boag 1992) largely due to migration from the American Midwest (Bowen 1978). Settlers made the long and difficult trip for a variety of reasons: the promise of a better life, reports of the ease of agricultural production, access to markets, better prices for agricultural products than in the Midwest and, a healthier environment. Settlement of agricultural lands was rapid and by the mid-1850s the most desirable land had been claimed (Boag 1992). Since that time farming has been an integral part of the Willamette Valley landscape and today the region is recognized for its prime soils and diverse agricultural production.

The farmers who participated in the interviews for this project are located at the southern end of the Willamette Valley within the historic river floodplain between the urban centers of Eugene and Albany (Figure 28a,b). Agriculture accounts for 64% of the

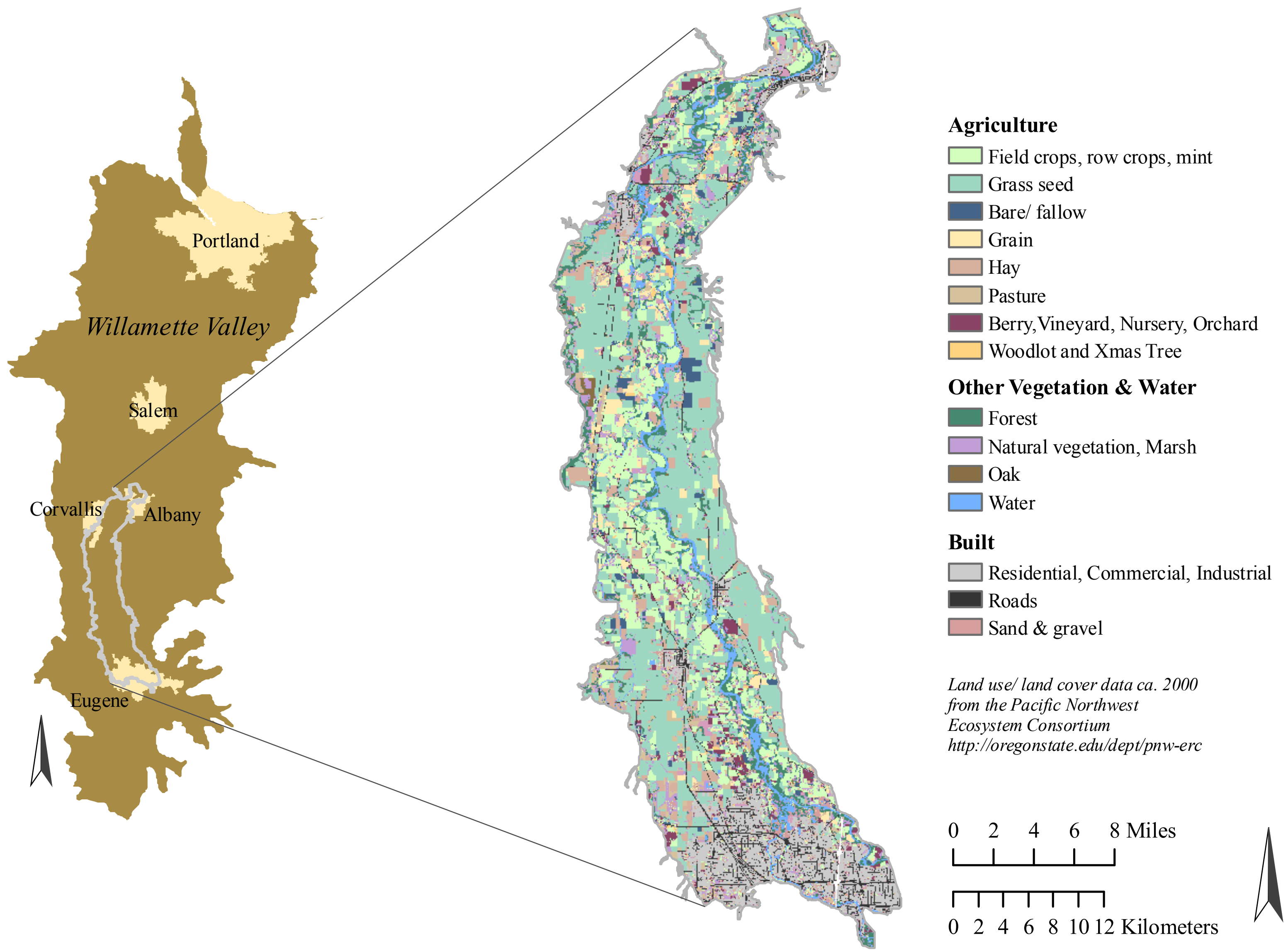


Figure 28. Expanded study area for interviews with farmers.

land use within the area (Figure 28c).   As of 2000 when the land use/ land cover data were collected, grass seed production accounted for 48% of the agricultural land use.

At the time of my interviews, the Willamette Valley grass seed market had reached a significant low point and this was a common thread in the conversations. The market had been in decline for multiple years and the farmers I talked to were not expecting much improvement in 2010. The nation's general economy was not doing well and this was affecting activities that drive the grass seed market. Farmers noted that the decline in new housing starts and homeowners with little money to spend on landscape upkeep had reduced the demand for residential lawns. They also noted that in tough economic times, golf course and pasture renovations are likely to be deferred. There was a general sense of uncertainty about the grass seed market across my conversations with farmers. The uncertainties ranged from near-term questions about the price of grass seed in 2010 - 2011 to concerns about the long-term prospects for the grass seed market.

Methods

Methods overview

I conducted ten in-person interviews with farmers selected using snowball type sampling (Hay 2005) and made initial contact with a telephone call. I met with the farmers who agreed to an interview at a place of their choosing and most of the interviews took place at an office or residence on their farm. All of the farmers agreed to an audio recording of the interview and these were transcribed for my analysis.

Methods description

In preparation for the interviews, I contacted professionals who work with farmers. These professionals included agricultural extension agents, the manager of an irrigation district and, conservation specialists from the Natural Resource Conservation Service and the Oregon Department of Fish and Wildlife. Through phone conversations and meetings with these professionals I became more familiar with the local agricultural landscape and gained a better understanding of cropping, growing conditions and agricultural markets. A few of these professionals became my link to the farming community and provided contact information for potential interviewees. The initial group of potential interviewees was designed to include both farmers who are early in their careers and more experienced farmers as well as variety in the size and type of farming operation.

As specified in my approved University of Oregon Human Subject's agreement, I made initial contact with potential interviewees by phone and in some cases followed up via email. I introduced myself and told the farmer who had referred me and how I had secured their contact information. This personal referral by someone the farmer trusted and respected was key in the initial conversation. This vetting by a trusted professional meant that farmers would at least hear me out and made them less leery about my motives and intentions.

Ten in-person interviews were conducted between November 23, 2009 and February 26, 2010. They ranged in length from forty minutes to two hours and each interview was audio recorded. I guaranteed farmers anonymity and have used pseudonyms in the following pages. The interviews were semi-structured with a common set of question categories (see Appendix J) that were covered during the course of the interview. Interviews were conducted as an informal conversation so the questions were not always asked in the same order or with exactly the same wording. This allowed farmers to tell their own stories and provided the opportunity for new topics to emerge. I started the interview by giving the farmer an overview of my question categories and I then asked specific questions during the conversation. To keep the tone of the interview conversational, I kept the questions in my head rather than reading them from a written list.

I transcribed the audio recording of each interview from beginning to end. The purpose of this transcription was to listen again to each farmer's story in context and produce a written document of the entire interview. I then used the four question categories shown in Appendix J (farmer, farm, farming in the Willamette Valley and ecosystem services) to begin organizing and classifying the narratives. I started this process by listening again to each audio recording, this time annotating the written transcript to note where a farmer's comment related to one of my questions. I also noted recurring themes, for example risk and diversity, that came from the farmers but had not been one of my questions. I produced a second document for each farmer with specific comments from the full narrative placed into categories and themes in the conversation. The following analysis is based on the two sets of documents for each farmer: 1) the

Farmer	Stage in farming	Crops	Farm size	Farm origin	Irrigation	Farm ownership
Jim	later in career	primarily grass seed	~8,000 acres	grandfather	some	owned and rented
Jack	early in career	primarily grass seed	~700 acres	grandfather	little to none	family owns most
Frank	later in career	primarily grass seed	~3,000 acres	homesteaders	some	~50% owned by family
Wade	later in career	primarily grass seed	~2,000 acres	homesteaders	little to none	owned and rented
Luke	early in career	primarily grass seed	~2,000 acres	grandfather	little to none	~75% rented
Kyle	early in career	primarily grass seed	~1,200 acres	1895	none	family owns most
Zach	early in career	primarily grass seed	~2,700 acres	grandfather	some	~50% owned by family
Gary	retired	mint, corn, wheat	~1,000 acres	grandfather	no current operation	no current operation
Ben	later in career	market produce, filberts	< 1000 acres	new	some	mostly rented
Morgan	early in career	market produce, filberts	400 acres	grandfather	yes	family owns all

Table 11. Overview of farmers and farm operations.

annotated full transcript and, 2) the narrative categories which include my original four (farmer, farm, farming in the Willamette Valley and ecosystem services) and those that emerged during the interview.

A narrative profile for each farmer is provided in Appendix K. These profiles are organized into my four original categories of questions and the farmers are identified with a first name pseudonym. This appendix offers a more in-depth understanding of each farmer and their operation than can be presented in an analysis. Reading Appendix K before the analysis section will provide an introduction to each farmer, their stories and their farm. Table 11 identifies each farmer with their pseudonym and provides an overview of each farm operation.

Analysis

The farmers

With one exception, all of the farmers interviewed for this study are at least third generation Willamette Valley farmers. Frank and his wife both have family histories in Oregon that trace back to homesteaders as early as the 1840s. Another farmer, Wade, has personal family stories of each generation that date back to migration from Iowa in 1846:

> My great granddaddy, my grandfather used to say, liked to say that he came across the plains on the hurricane deck of an Indian cayuse. He was in a basket over the withers of the horse - that's the way he says he came across. That's the family lore anyway. (Wade)

Kyle is still early in his career but his family's farm has been in the same location since 1895. Five of the farmers (Zach, Jim, Jack, Luke, and Morgan) are carrying on operations that were started by their grandfathers. In 1998 Gary, now retired from farming, and his brother sold the family farming operation that had been started by their grandfather. Since his retirement from farming, Gary has been working professionally with other farmers. Ben came to the Willamette Valley from eastern Oregon when he was 21 and started his farming career with hand picked pole beans.

The farms

The farms range in size from 400 acres to 8,000 acres (Table 11). Two of the farms at the small end of the range grow fresh market produce and commercial filberts (also known as hazelnuts). Both of these operations (Morgan's and Ben's) have farm stands that sell their fresh produce directly to retail customers. When Gary's family sold their farm in 1998 their main crops were corn, wheat and mint. The other seven farms are seed producers, primarily grass seed. At the time of the interviews the grass seed market was at a significant low point and the degree to which grass seed would continue to be the main crop was in question:

> There was a time when every acre was grass for seed. Now I tell people we are seed producers. (Wade)

> The grass seed is the primary [income producing crop] – well this year I don't know what will be the primary – but normally it has been. (Luke)

Eight of the farms operate on a combination of family owned and rented land. I use the term *family owned* because it is common for farmers to rent land from a family member (for example a father or grandfather). Morgan's farm is completely family owned. As fresh market producers, "a lot of the stuff we grow is perennial crops like berries and orchards – that fits into our whole rotational scheme. If you don't own the land, you can't make those kind of improvements." (Morgan) Ben is also a fresh market producer but says, "I rent almost all of my properties. I probably have 30 landlords. Most of my rents are automatically renewed every year."

The degree to which farms are irrigated varies (Table 11). Growing for fresh market requires irrigation but most of the grass seed production is done without irrigation. The farms with little or no irrigation farm this way because they do not have water rights to irrigate their crops. The lack of irrigation water limits cropping options and is a source of frustration, "Getting water rights is impossible." (Zach)

> People in the valley say you can raise anything here – which is true to an extent. This is the extent – you have to have water rights. We have like 14 acres [of water rights] out of 700 acres. It is a little bit frustrating for me because I hear a lot of – why don't they raise food crops, that is so much more efficient and people want local. I would love to have water and raise these crops. (Jack)

Seed farmers with some irrigation use it strategically for specialty crops or to get things off to a good start. "We have a little [irrigation], it's very minimal. It has pretty much been on our native stuff. We've done some sugar beets and some kohlrabi seeds and some specialty type stuff." (Luke) "We're going to plant clover here next year and I'm sure we will irrigate that up." (Zach)

All of the farms are family operations. Ben's operation is small; he is the only farmer but his daughter helps run the farm stand. Jim's family has a more extensive operation with two farms and a warehouse. Their operation is a partnership among him, his wife, his parents, his sister and brother-in-law. Jim's two sons and nephew are also part of the operation and will eventually come into the partnership. "So anyway – we're just a good ol' family farm." (Jim) Kyle, Zach, Jack, Luke and Morgan are all part of operations that include fathers, grandfathers, uncles or brothers. Wade farms with his son, Frank with his son-in-law. Gary and his brother were farming together when they sold their operation and were originally in business with their father and grandfather.

Cropping and diversity

"Diversity has kind of been the key to our existence." (Jim)

All of the farms have some degree of crop diversity and a few also have diversity in their agricultural operation. Examples of operational diversity include cleaning and storing seed for other farms, hiring out equipment and trucking to markets.

<u>Soil and irrigation limitations</u>

Kyle's farm is one of the least diverse. Their main crop is perennial ryegrass seed; this year they have 360 acres of wheat, 50 acres of pasture and 6 head of cattle. Consistent with the trend in the southern part of the Willamette Valley this year, the wheat acreage is up a bit but, "not a big change" from the recent past. This is in part because many of their fields are not suitable for growing wheat. Their crop options are limited to "anything that can grow on damp, clay ground" and no irrigation.

Jack's crop options are also constrained by soil conditions and lack of irrigation. "The grass seed is mostly what we raise. We have in the past raised fresh strawberries, mint and corn, just a tiny bit for fresh eating, and then the grass seed." They have tried wheat in the past but,

> This year we didn't even put in wheat even though a lot of grass seed farmers did. A lot of our ground is wet enough that it will not grow wheat. About 60 acres out of our 700 would raise wheat. The last time we raised wheat, it cost us about as much as a trip to Hawaii. So we said next time I want to raise wheat, why not just go to Hawaii and call it even? (Jack)

Jack's primary crops are tall fescue and forage seed for grass fed beef pastures. This crop choice is based on the realities of their farm's growing constraints and trends that show promise for future markets. "We think it [tall fescue] is one of the good grasses for the future because it is going to fit more with the need to cut down on water use. Fescue will stay greener with less water." The forage fescue is good for them because "people want natural grass fed beef. Plus, the forage fescues we can grow them good. This wet ground is very tolerant of those." During our conversation Jack makes it clear that their crops have been selected out of necessity, not by choice. "We would raise food crops in a second if we had water. But without water and without high ground that you can raise wheat on, you're very limited." Although they are limited in crop diversity, they have diversified their operation because,

> There is so much volatility in the market, it'll just take you out if you don't have something to even out the bumps a little bit. So we try to do some service – we process, clean, package and store seed for other farmers. We have bought and sold some of the by-products that are used for animal feed. This year the service income that we got from doing the cleaning for other people is a big thing because the market is so messed up. (Jack)

Crop transitions and experimentation

When I asked about his crops, Frank said, "Everything is seed." He said this year the farm was one-third wheat but he did not say how this compared to past years. The conversation about crops was a bit fluid and short on crop acreage and chronology. Grass seed is the primary crop with other crops varying annually based on experimentation, trials on their farm and markets. This year they have about ten percent white clover which is down from twenty-five percent about a decade ago. But, "If things don't change, we might take some of that [white clover] out come spring." They have grown turnip seed, broadleaf mustard seed and, peas and radish for sprouting. "We had a new crop this year and it was the most profitable. It was a spring vetch. So we're going to try a couple of hundred acres next year." The experimentation and testing of new crops is an aspect of farming that Frank clearly enjoys. Their overall operation is strengthened because the family also owns facilities for processing and storing their own seed.

"Now I tell people we are seed producers." (Wade) The production on Wade's farm is in transition from all grass seed to a mix of seed crops. The shift is motivated in large part by the loss of field burning and a desire to increase the use of crop rotations. Meadowfoam was one of the first crops they added and now, "We plant as much meadowfoam as we can." They are in the trial and error phase of figuring out what crops work for them. "White clover – we tried it several years ago – didn't work too well. Now we're trying it again." Other seed crops they have or will try include turnip seed, wheat, rye, oats and radish seed for sprouting. A seed company that is run separately from the farm adds diversity to the family's overall operation. The company was started in 1976 by a group of farmers but over the years others have dropped out and Wade's family is now the sole owner. Although the seed company sells some of the seed from Wade's farm, "I realized if it is going to work – it is a seed company – their job is to sell seed, not necessarily just mine. By far and away, they buy more seed from other places, make blends and whatnot and market it."

Crop and operational diversity

Zach's farm features both crop diversity and operational diversity. They have a warehouse that is separate from the farm and large equipment which allows them to do work for other farms. "They [other farms] don't really have the equipment to do everything they need to do so they hire us to do a lot of stuff." This year their farm is one-quarter wheat (up slightly from the recent past), one-quarter clover and one-third ryegrass. "You can see that we are pretty diversified. We have a lot of different crops." The diversification includes crops that are a small percentage of their overall 2,700 acres but play a significant role in the farm's income. They have about 300 acres of meadowfoam which works well with their crop rotation and, "Turns out that this [meadowfoam] is probably our only crop that is actually going to pay money this year – and it pays really well." They grow turnips which "are kind of a neat crop to grow and they are real early. Usually we start harvest like the 25th of June on average. The turnips will be a couple of days before that so that fits our program pretty well." Their diversification includes grass fed beef. "Last spring, I sold hardly any seed but I sold all of our calves. That paid my fertilizer bill. The cattle really helps out a lot – just because it brings in cash flow at a different time of the year."

Jim's farm is also quite diverse in both cropping and operations. The family has two farms, a warehouse operation and a small trucking operation. They do custom hauling for seed companies but the real benefit of owning their trucks is the flexibility to manage the transport of their own products. "We don't make any money running those trucks. It is just kind of a convenience thing, we can get it done on our time frame." Of the farmers I interviewed, Jim had the greatest number of acres in production on a combination of owned and rented ground. They grow annual and intermediate ryegrass, fescue, wheat ("this year we have a ton of wheat"), peppermint for oil and sweet corn for processing. I asked if their diversity allowed them to ride out the rough times.

> Yes, absolutely. The corn has saved our bacon. The peppermint has been good to us. Yes, being diversified – when one thing is hot, usually something else is cold. The vegetables have been outstanding the past couple of years. (Jim)

During the interview, we looked at agricultural fields on air photos. His field by field knowledge was impressive; he knew about the soil, who owned the land and whether the land could be irrigated. The distribution of their fields gives them options in crop choices. "Diversity has kind of been the key to our existence. And we're fortunate we've got enough diversity in our soils that we can do that too." Jim said that decisions about cropping include more than just biophysical conditions:

> There are a few alternative crops we could go in there with but we are just not set up to grow those, like meadowfoam or clover. Every farmer kind of has his niche of what he grows and can grow good. Those aren't ones we do real well on, we're not set up to do them. We could do them but just don't like to if we don't have to. (Jim)

When Gary started farming they had three main crops: corn, wheat and peppermint:

> It was our feeling, and it was true to form, that if one of those crops had a good year, it would cover our costs. And if two of them had a good year, it was a decent year. If all three of them came through, it was a banner year. There were very few times that all three came through – very few. Often times we had two crops that did well in the same year. And then there were times when we only had one crop that made it work. You kind of have to live the lifestyle of what you bring in.

Diversity as a necessity

By the time Gary and his brother retired they were growing "just about anything we thought we could grow that would be economically profitable." They had added table beets, green beans, carrots, wheat, grass seed, dill and wine grape seedlings to their list. They were also raising sheep and livestock, selling irrigation parts and harvesting corn for other farmers. Even this high degree of diversity wasn't sufficient to cushion their operation when the closure of Agripac (a food processing facility in Eugene, OR) meant losing the market for their row crops. The loss would have necessitated revamping their operation to stay in farming. As they looked into the future, Gary and his brother decided to change careers rather than "run from crop to crop and kind of stay on top."

Initially, Luke only noted his farm's staple crops, "today currently we are in grass seed, sheep and cattle." During the conversation I learned that they also grow about 100 acres of wheat and for the past few years have been growing native plant starts for restoration work. The wheat and native plants help but their diversity is low. Luke sees potential in the native plants but says, "It has been a challenge, we're learning all the time with that one." He is hopeful enough that he has increased to 30 acres in native production, "There is that learning curve – which when you add it all up, I don't know if we're really ahead. But there is that potential when we learn the stuff."

Diversity in fresh market production

As fresh market growers Morgan and Ben have the highest crop diversity of the farmers I interviewed and both have farm stands to market their produce directly to consumers. They grow on high quality agricultural soils and therefore have a wider range of crop choices. They produce for a different market than the other farmers and both operations have an extensive list of fruits and vegetables that are produced over the growing season from spring into fall. Although diversity is high, these farmers are not free of limitations in production. As with the grass seed farmers, they are limited by wet soil and, they face management challenges such as crop rotation for disease control. Morgan and Ben both grow commercial filberts (hazelnuts) as a companion to their fresh market operation.

> It is nice to have a commercial crop like filberts. Because when the price goes up, if you've got enough pounds, it's a real shot in the arm. But the fruit stand is nice because you get your money a little bit at a time and you have a lot more control. You know what – it is just nice to have both. (Morgan)

> People don't realize that it's the filberts that buys all the stuff around here, buys all the fancy equipment. I knock on wood, I hope it keeps up. (Ben)

Management practices

The recent downturn in the grass seed market has been an added incentive for farmers to reduce tilled acres and look for new rotational crops, in part to reduce input costs. Six of the farmers talked about reducing their costs through management practices such as no-till, volunteering and crop rotations:

> Yeah – but what we are doing now is volunteering a lot of that. So we don't till the ground. So all we are doing is harvesting it and letting it come back. . . . And it saved us a lot of money because we don't have to till that ground. It costs a lot to plow and do all that. (Jim)
>
> We've been doing more no-till and volunteering because 1) it is cheaper because you don't have to work the soil and 2) we are trying to build up the organic matter. (Wade)
>
> That's why we are trying to do as many rotations as we can; because it cuts down on all of our inputs. (Zach)
>
> Yeah, so we've kind of had to learn to do the no-till and . . . try to tweak things to volunteer and that type of thing. (Luke)
>
> And it [forage fescue] cuts down on how much we have to use – I mean tractors, diesel, labor, fuel – everything is getting so much more expensive. So it is a way we can cut down on a lot of diesel and labor and have a crop. So we don't have to work the ground every year on most of our land. (Jack)

Farmers are looking for new crops to increase their overall diversity and improve crop rotations. An ideal crop would be marketable, tolerate wet soil, complement other crops and have minimum input costs. Meadowfoam is a crop that works for Wade and Zach:

> So we have been looking for more rotational crops, which we hadn't too much. Meadowfoam was one of the first ones. We plant as much meadowfoam as we can. (Wade)
>
> The best part of it [meadowfoam] is you can no-till it into high residue crops. (Zach)

Meadowfoam is an example of a crop that works well for some farmers but isn't an option for others because it doesn't fit with their operation (Jim) or can't be grown in their soil (Jack). Wet soil conditions in the southern Willamette Valley present a significant constraint for finding new crops, "There's not a lot of options. That's probably some of the hardest part about the south valley – we're just so wet." (Luke) Jim also noted the limited options, "There [aren't] a lot of alternative crops out there."

Risk and uncertainty

Collectively the farmers' comments indicate a general acceptance of risk and uncertainty in what they do. Uncertainty about the weather is a given and has always been part of farming but today's farmers are also faced with greater volatility in agricultural markets, capricious seed companies, and unpredictable input costs. Two of the farmers spoke of farming in gambling terms:

> It [farming] is basically legalized gambling with a purpose. . . . But it is crazy risks. (Jack)
>
> Yeah, we're rolling the dice all the time. . . . Farmers like to gamble, they like to roll the dice. Personally, I am a risk oriented personality. I don't like to take dumb risks but it's managed risk taking all the time. You just learn to factor it into everything you do. (Morgan)

On being a farmer

During our interview, Frank accurately asserted that I had "…run into very few farmers who aren't passionate about what they're doing." Most of the farmers were explicit in expressing how they felt about their work and the lifestyle. A few, like Ben, were less explicit but the pleasure of farming came through when they talked about their work:

> But peaches – how hard you prune them, how hard you thin them, or do you thin them? You got some stuff to decide. How to pick for quality. You've got lots of inputs you can do that affects the outcome. So I kind of like that kind of stuff – so, you're always learning something. (Ben)

Gary is glad to be retired from farming but has fond memories of the lifestyle and seasonal pleasures:

> And then, of course, our kids were with us – I mean any time I'd go to the farm, they had to go. And so, it was fun from that perspective. Farming was not a job. It's a lifestyle and; so, you incorporate your family within. (Gary)
>
> Because the smell of fresh dirt turning over and particularly if you've got a 40 or 60 or 100 acre field that you've just turned over – there's a distinct aroma to that. And the smells of harvest – the sweet smell of corn when you're picking corn, the distinct odor of peppermint when it's being distilled. Each crop has its own individual distinct odor – and I miss that. (Gary)

Jim, Wade and Zach communicated an overall satisfaction in farming:

> It's been good – it's a good life, can't complain. It is hard work for quite a few months out of the year and then sit back and watch everything grow. . . . But we just basically force ourselves to slow down this time of the year and enjoy things. (Jim)
>
> But it's a good life. I feel sorry for people sometimes. There's a lot of people doing stuff they don't like because they have to keep food on the table. It's too bad, I wish everybody could like what they are doing. (Wade)
>
> Because we enjoy farming and stuff. (Zach)

Jack summed up a common theme in the interviews:

> If you did it and looked at it on paper – it is insanity pretty much. But you do it because that's what you do. We feel really blessed . . . and to be out there and the land and the crops – if it is in your blood, you kind of like it. (Jack)

Willamette Valley - agricultural change

<u>*Past to present*</u>

"When I was graduating from high school, in our ag classes, they were telling us that farming was becoming a business – and boy, it did." (Wade)

The farmers' individual stories collectively depict a general pattern in Willamette Valley agriculture that moves from a focus on growing crops and raising livestock in the 1950s to today's more complex world of agricultural business. Being a farmer now means more than working with the land to produce crops and raise livestock. Now they must also make decisions in a global marketplace, keep up with regulations and negotiate contracts with seed companies.

Wade's personal story reflects the influence of technology on the evolution of Willamette Valley agriculture. Wade says when he was a small boy, "we were pretty much a general farm . . . you just kind of had a little bit of everything." His father originally didn't want to be a farmer "because it was just too much work." The introduction of mechanization changed his father's mind about farming. He thought that with mechanization "life on the farm – it would be better, he [Wade's father] could see a way forward to making farming work – he thought he had some ideas that would help out." Like his father, Wade initially wasn't going to be a farmer, "I used to tell people that if Dad was still milking cows when I got ready to do something, I wouldn't have come back to the farm – I would have been an insurance salesman." What changed Wade's mind was the trend to crop specialization and increased yields from commercial fertilizers. In particular he saw promise in grass seed production, "It got to be profitable to where grass seed production – you could make a living at it. Sometimes a good living and sometimes not so much. But it was a living and it has kind of gone from there."

Wade and Jack talk about their grandfather's generation as subsistence farmers:

> I should have mentioned my granddad – when they were farming, it was subsistence farming. Well they raised some grain as a cash crop and some livestock. The farm, being subsistence, had sheep, hogs, dairy cows – there was farming with horses but my granddad, being a mechanical engineer, was involved with some of the earlier steam equipment that was used. (Wade)

> My grandpa farmed – I'm like third generation, partially on the same land. My grandpa was – well you could do it differently then, a little more subsistence style meaning he would make just enough – have half a beef – then he would go down to the coffee shop and talk. It didn't seem like he really thought much about the future as far as building anything up that could sustain in a way. He still got us into it. (Jack)

Morgan and Gary tell of their grandfathers leaving other professions to start farming:

> My grandfather, my Dad's Dad, was a millwright and he farmed on the side. And he had a filbert orchard. When he was 55, he retired from being a millwright and farmed filberts full time. And he sharecropped orchards and had a couple hundred acres at one time. (Morgan)
>
> My grandfather was born and raised in Springfield. I think he was born in 1906. He worked in construction up until he was about 35 years old. Then he decided he wanted to do his own farming business. So he purchased some land out in the Coburg area and started his farm, I believe it was 1940. (Gary)

These accounts of subsistence farming and opportunities for new farmers are a contrast to the circumstances for the current generation of farmers. All but one of the farmers I interviewed came to farming through previous generations of farmers. These relationships make it possible for new farmers to learn *how* to farm in the southern Willamette Valley and also give them access to land and equipment. The cost of land and equipment is prohibitive for most new farmers and all of the young farmers I interviewed were working with family members, renting land and sharing the cost of equipment. Morgan was the only young farmer who owned some of his own land and during the interview he stressed that he had worked very hard to make this happen:

> Yeah, that was another reason I was able to buy land – because I knew early on what I wanted to do – very early. You figure out that it takes a lot of money to get into it and you have to build equity any way you can and as fast as you can to have a chance. So when I was in high school, I didn't spend any money. I started saving back then. (Morgan)

Morgan notes that the money to buy his farmland came from the stock market and a real estate investment, "The irony in that story is, I bought farm ground twice – both times with money I did not make in agriculture."

Technology, markets and policy have significantly changed agriculture since the 1950s and farming is more complex for the current generation. Willamette Valley agriculture now operates in a global economy; more than 80% of Oregon's agricultural production is exported and more than half of the exports are sent overseas (Oregon

Department of Agriculture 2007). While a global economy offers expanded market opportunities for Willamette Valley agriculture, it also presents uncertainty and competition. The farmers I interviewed talked about the benefit of expanded markets for their products (for example grass seed and filberts) but they also expressed concern that unknown global events or cheaper products from other countries could abruptly eliminate these markets:

> What's going to happen to the grass seed industry – if China ever starts raising grass seed, or down in Brazil or something like that – it will kill the market because they can't raise it as cheap here as they can there. And it will be no longer viable. (Ben)

> Well, the thing that worries me about that is, we are selling over 65% of Oregon's crop [filberts] to China. What happens when China . . . plants filberts or invades Taiwan and we get into a conflict. It's gonna just drop like a rock. When I was a kid they were 30 cents a pound and I think before I die, I think they will be 30 cents again. But this last year they were over 80 cents and that's a lot better. (Morgan)

Gary, now retired, reflects on changes he experienced in Willamette Valley agriculture:

> Then at about '85 [1985], things started to turn around and change . . . as agriculture expanded – not even globally but internationally. That changed the whole mentality as far as marketing was concerned. Then we started to see competition in the mint business, bringing in cheaper, less quality oil from other regions. We saw the wheat market drop down from where it was . . . (Gary)

Gary believes the signing of The North American Free Trade Agreement (NAFTA) in 1994 also influenced the trajectory of Willamette Valley agriculture:

> The other major factor, I think – and this is a personal opinion, was NAFTA. When we signed that NAFTA agreement, the consequences economically to agriculture I don't think were actually known. And they were more dire than what we thought they were going to be. And that put a dagger in a lot of production agriculture. (Gary)

When I conducted my interviews, the grass seed market had been weak for multiple years and there was considerable uncertainty about current and future production. At that time, the market price for grass seed was less than the cost of production and activity was on hold; no one was selling and no one was buying. Farmers were storing grass seed waiting for the market to return, hoping for at least break even prices. In most years grass seed is harvested, cleaned and bagged for sale but this year (2009 - 2010 season) farmers are storing bulk seed. Jim's account is typical of what I heard:

> Used to be the warehouse was running 24 hours a day, 7 days a week. You went in and you cleaned everything that you brought in. We bring in 12-15 million pounds of seed every summer. We would usually finish up around March cleaning everything. So we'd have everything bagged, ready to go. The way things are now, we don't even clean it. Just leave it in the bin, bulk. Because when you clean it, put it in the bags – you've got all the problems – you've got to move it, you're moving it around, mice are getting into it. Better off [to] leave it in the bin, clean it when you get an order. So then you don't have the damage and everything. That's what we're doing now. (Jim)

For some, this year is an extreme case of business as usual. Others are trying to be calm as they wait it out but, "another year or two of this and I'll be in trouble – it's not real pretty." (Luke) Two of the grass seed farmers who are early in their careers were particularly concerned about the near future:

> Yeah, it's not dire straits yet. If we can keep goin' at the rate we're doin' . . . within a couple of years, it's gonna get pretty serious. (Kyle)
>
> Of the cycles I've seen, this one is one of the worst I've seen in a long time. I think there is some big uncertainty on where we're headed totally. I can't tell you I'm terribly optimistic, I'm trying to be. (Luke)

The longer established farmers and those with family resources were less anxious about the near future but still uneasy:

> . . . how fast they all went down [grass seed prices]. And then when it came down, it was relentless – just kept coming down, coming down. We think we've bottomed now and we're starting to see a little bit of a rise in annual ryegrass is about the only thing that has come back. Everything has been hit and that's what's caught a lot of us. (Wade)

> This one here [agricultural cycle] is a little bit more disconcerting than some of them. . . . I don't know when we're going to come back. And I don't think that it is going to come back for a while. (Jack)

Jim's take on the current downturn is, ". . . we've seen this before, and we'll see it again. We're creatures of habit." While he says he has seen it before, he notes a difference and questions what will come down the road. "It is going to be interesting to watch because we are definitely in some type of a transition – I'm just not sure what direction it's going to go."

The fresh market growers, Ben and Morgan, are not experiencing the same cycle as the grass seed growers. Both farmers have, for the time being, a relatively comfortable income balance with the combination of fresh market produce and commercial filberts. The filbert market has been very good for the past few years and both farmers stated this has been a big boost to their operation. Just as the grass seed growers see themselves at the low point in a downturn, the filbert producers see themselves somewhere on an upswing. Ben and Morgan are enjoying it while it lasts but don't expect it to last forever.

Farmers' thoughts about the future

Whether up or down, the cyclical nature of agricultural markets is ever present for the farmers:

> That's what I say, it's a wave and you ride the high as far as you can and hope you don't fall off and get lost under water. (Gary)
>
> It's just a vicious cycle. (Jim)
>
> And it goes in cycles, 'bout every 3 – 5 years, you'll get a good year and then you'll have a couple of bad years – average year – bad year – good year – bad year. (Kyle)

My interviews suggest that this time farmers are more uncertain about where they are in the cycle and what comes next:

> Right now we're deep, I mean we've dug a ditch in the valley – we've got a canyon. We've got to crawl our way back out of that canyon. . . . It is going to be

> interesting to watch because we are definitely in some type of transition. I'm just not sure what direction it's going to go. . . . So when we come out the other side – what's going to be out there? (Jim)
>
> I think there is some big uncertainty on where we're headed totally. . . . I don't know, I think there's going to be some big changes . . . Obviously if the economy turns around some, I think it's going to help – it's gonna make the picture better but, I think there still needs to be some changes. (Luke)
>
> I don't know when we're going to come back and I don't think that it is going to come back for a while. . . . If we do have a recovery anytime soon, it is going to be slow and long. We're looking at worse than it was two years ago five years probably from now. (Jack)

Six of the seven grass seed farmers expressed uncertainty about the future of the grass seed industry. The source of the uncertainty varies from a general sense of unease to specifics such as a reduced demand for grass seed, the precariousness of grass seed companies and the management challenges of producing certified grass seed. Jack notes that changes in water availability, landscaping choices and golf course maintenance will impact the demand for grass seed:

> A lot of the better years were driven by golf courses – were driven by developers on the outside of the golf courses. The developer wanted to sell really expensive houses on the greens. So the developer told the golf course, you have to have this all watered and green all the way up to the edges and keep it nice. . . . So instead of having a fairway that is 100 yards wide, they might cut out the fairway to brown for a little while – then go to a 40 yard fairway. You know they just cut down. (Jack)

Jim comments on the shifting nature of grass seed companies:

> Because it used to be, back in the old days, there was 20 - 30 seed companies in the valley. So when you come out of it, you'd have these 20 - 30 companies all planting these varieties. Well you don't have 20 - 30 seed companies in the valley anymore. You've got, I don't know how many, maybe 5 - 10 major [companies] that have the capacity with their own production, research and development - developing new varieties. . . . So you're going to have to be a good salesman to get them to want you to grow their product. (Jim)

Wade and Jim remark on the growing restrictions imposed to produce certified seed varieties:

> . . . it is hard to move back and forth now. Certification demands that you are out of one species – if you are going to change varieties, you have to be out of that species for so many years before you can plant it again because you have to make sure that it is genetically pure. So there is getting to be a little less mobility in the grasses for us. (Wade)

Wade, Zach, Kyle and Jack all expressed concern about the consequences of the recent ban on field burning. They have all reduced their use of field burning over the past few years but Oregon Senate Bill 528 bans field burning altogether beginning in 2010. From the farmer's perspective, the ban removes one of their management options and will cause an increase in chemical use to control pests and weeds. They expect chemicals to be less effective than field burning and note that input costs will be higher with an increase in chemical use. In addition, Wade says the chemicals are damaging crop yields:

> When we started getting away from field burning – the first problems we have are weed problems. We have pretty much figured out what you can do and still get a crop. But to get a clean, quality crop – used to be we had field burning and chemicals. Then we were left with just chemicals. Now we are using enough chemicals that we are damaging our yields. (Wade)
>
> We burnt most of our wheat straw this year and we're done with that. We're pretty much going to have to pay to have it bailed or plow it under. We're not looking forward to that because our costs for working the ground are just out of control. (Zach)

Regulations on agriculture are seen as an onerous burden on current farming operations and, for some farmers, a potential means to undermine agriculture in the Willamette Valley. Both of the fresh market growers and four grass seed growers viewed regulations as an impediment to agriculture:

> I told them, well every time you add another regulation on us, you are putting the small farmer out of business. We have to get big enough that we can handle this extra burden of paperwork, if only paperwork, or expenses or all the other things that comes down on the farm. (Wade)

> That's just another one of those things – the ODA [Oregon Department of Agriculture] – I'm not really sure what they have done to help us; all they are is makin' rules and regulations against us. (Zach)
>
> My worry about the future is the regulations. We have no voting block. (Jack)
>
> I think the legislature is gonna shut us down farming – all the rules and regulations coming in for stuff. Shut us down where we can't do anything. (Ben)
>
> I'm frustrated with the government on tax policy and some regulations…(Morgan)

Although the future is uncertain, the nine active farmers expect to continue farming. For four of the farmers this extends to future generations; Morgan and Jack mentioned their small children, Jim and Frank mentioned their grandchildren. They all expect the family operation to be a viable option for the next generation. They were clear that it would be a choice, not an obligation:

> They [his children] wouldn't do anything else I don't think. And I have 3 grandsons coming up the pike. They're about yeah tall right now so they've got a ways to go. They can decide what they want to do. (Jim).

Farmers were not optimistic about the future of agriculture but there was an acceptance of change and a confidence in their ability to adapt. There is a tenacity and, in most cases a family legacy of farming in good times and bad. When I asked Zach if he expected to be farming in twenty years he responded that he would but, he expected to be dealing with an encroaching urban environment, "Yeah, I'm sure we'll find a way to do it but I'm going down the highway in a tractor goin' slow and everybody's pissed. Traffic is terrible."

Ecosystem services/ non-conventional crops

<u>*Terminology and overview*</u>

Ecosystem services is not a term in everyone's vocabulary and those who use it do not always have a common definition. To avoid introducing confusing terminology, I asked farmers for their thoughts about producing crops that are not now conventional agricultural crops. Most of the farmers had some knowledge of the basic idea of carbon sequestration and I used this as an example of what I meant by non-conventional crops.

The purpose of this part of the interview was to find out the degree to which farmers are receptive to the concept of ecosystem services. Given the early stages of understanding the production units and monetary value of ecosystem services, it is too soon to ask farmers if they want to produce a particular ecosystem service (for example, carbon sequestration). It is not, however, too early to hear the farmers' views and gauge their interest in moving the concept forward.

Farmers' openness to the concept of ecosystem services

"As I said, right now I think farming as a whole is pretty open to anything as long as it can be profitable. I think everybody would be willing for a little bit of risk." (Luke)

The seven active grass seed farmers are receptive to the concept of ecosystem services. Some are more interested than others and their reasons vary. In general the younger farmers with fewer financial reserves (Kyle, Luke, Jack) are open to any ideas that could provide new sources of income. The more experienced farmers with more financial cushion (Wade, Frank, Jim) were less anxious but still interested and open to the idea. The two fresh market producers voiced opposition to any activities that take land out of food production. Gary's perspective as someone who works with farmers is that the agricultural community is generally open to new ideas.

Luke and Kyle have fewer options than some of the other farmers. Kyle farms with his uncle, cousin and grandfather but they have very little crop diversity and no irrigation. Although Luke has a bit more crop diversity and is making progress in raising native plant starts, he doesn't have much financial cushion, (". . . another year or two of this and I'll be in trouble . . ."). Both of these farmers were open to the concept of ecosystem services:

> It [ecosystem services] is always a possibility – yeah. Your timing is right on with that [asking farmers about ecosystem services]. It is something that I have started to look into myself but I don't really know much about what my other options are. (Kyle)

> From my standpoint, we wouldn't hesitate if we thought there was profitability in it [ecosystem services]. . . . As long as they pay… (Luke)

Jack is also open to the idea of ecosystem services but his interest goes beyond the potential for economic gain. Throughout our conversation he expressed feeling disconnected from, and misunderstood by, the local non-farming community. When we talked about ecosystem services as a form of local agricultural production, Jack said, "It could be a good thing because, if nothing else it could build up an appreciation somewhat . . . it is not bad for them [non-farmers] to think about the fact that these people [farmers] are sequestering carbon for your community." He went on to express the need for a sincere partnership and recognition of the value of the service provided:

> Yeah, it would be just [fair] compensation and a level of – am I going to be on the team then, am I going to be respected for this or am I going to be like a welfare kid? . . . If there was a real coming together . . . can we do this community-wise and make it better?
>
> A lot of farmers would be open to that, I think. That idea of coming together . . . (Jack)

Jack has serious doubts about carbon sequestration, in part because of what he recently heard at meeting in Salem:

> The Salem guys said the price of your inputs would go so many times more, it is so disorganized on the carbon end and the acreage we're talking about. To make the carbon cap and trade thing effective, they have to use huge swaths of land. (Jack)
>
> I feel like the carbon credits are not going to be worth enough money to justify it. Unless the community decides that we want this kind of habitat and it's worth this much to us that we'll actually pay them fair market value to have it. Then I think people would do it. (Jack)

Zach's operation has considerable crop diversity and he would consider ecosystem services, "if it pays money." He notes that, ". . . it all depends . . . a couple of years ago I never would have planted meadowfoam . . . But as things become profitable and we can rotate them in – yeah, definitely." He was hesitant when we talked about ecosystem services requiring a longer time commitment than other crops:

> What are we doin' this for? Because we enjoy farming and stuff. Would we want to tie it up for 15 years? What would we get out of that, drivin' by for 15 years and watching stuff grow? I don't know… (Zach)

Zach also expressed the farmers' gambling spirit and wasn't sure he would trade a stable annual income from ecosystem services over the possibility of a big payoff from raising the right crop at the right time: "I guess if you had that set income, that would be great; but, when the stars line up with the moon, we can make a lot of money off some of our crops." (Zach)

Frank, Jim and Wade are open to the idea of ecosystem services with the underlying theme of the devil being in the details. Frank was not opposed to the longer time commitment of ecosystem services, ". . . we've got no problem waiting for it but at the end there has got to be a silver lining." He had questions about crops for sequestering carbon, "I'd like you to tell me what we would grow beyond grass seed that would store carbon any better than we already are." When I suggested trees, he responded, "I was one of the early ones in hybrid cottonwood and I'm not really sure that they store anymore carbon than the grass seed does." Although he expressed doubts, Frank was interested enough to say that he would like to hear more about my research as it progresses.

Jim acknowledges that ecosystem services could be advantageous to their operation and also benefit the land by relieving the pressure to continuously produce conventional crops:

> We've got some property that could be put into something on a long term basis if we were getting paid for it. I think it would work, I really do. That would be nice, it would take some pressure off of having to crop on that piece of dirt every year. That's what is hard – because back whenever, guys didn't worry about having to crop on that piece of dirt every year. They'd fallow it or do whatever and now – I don't know if we got ourselves into this box if it it's just the way it is but it seems like you've got to pull a crop off that piece of dirt every year . . . (Jim)

Jim also points out some real hurdles in incorporating ecosystem services into agricultural operations:

> Well it depends on the crop and it depends on – does it fit into our program? We'll play around with a lot of stuff on a small scale but it's got to fit into our program. (Jim)

> If there is a crop out there that I've never grown before or I know kind of how it works but it takes a lot of extra work – if I can make $600 an acre growing that but I can make $600 an acre growing straight-up annual ryegrass – Why not stick with the annual ryegrass? (Jim)

After our interview, Wade sent an email to clarify his thoughts on the idea of ecosystem services and their farm:

> . . . I don't mind changing crops on our farm, or even uses of the lands of our farms, as long as that change has hope, going in, of an economic gain to our farm enterprise. That gain can be as crass (and necessary) as cash profit or may be a benefit to soil condition or a future rotation.

When we talked about carbon sequestration, Wade expressed doubts about this fitting into the contract and crop rotation aspects of their operation, "I haven't seen where what we do is going to fit into the sequestration." He also brought up potential maintenance concerns regarding ecosystem services:

> . . . there needs to be some maintenance because we have a lot of weeds that can take over and threaten the neighbors as well – their livelihood. Too big of a weed bank blowing around is really hard when you are producing something you sell on purity. So there has to be some maintenance required. (Wade)

DISCUSSION

Farms, farmers and agricultural change

The interviews included two fresh market growers, seven seed producers (primarily grass seed) and one retired farmer. Crops grown on each of their farms are largely determined by soil conditions and the availability of irrigation water. The fresh market growers produce on high quality agricultural soils and have water rights to irrigate their crops. In contrast, the seed farmers work with soil that is less productive and most are further limited in their crop options by the lack of irrigation water during the growing season. Crop diversity is directly related to the soil conditions and water availability on each farm. The fresh market growers have the highest crop diversity, next are seed producers with irrigation water and variation in their soils and; at the low end are farmers without irrigation and low lying, poorly drained soils.

Nine of the farmers belong to families that have been farming in the southern Willamette Valley for generations; six of the families trace back more than fifty years and three of the families trace back more than one hundred years. This history provides a foundation for working with the biophysical environment and a multi-generational perspective on farming. The farmers had different perspectives on the recent downturn in the grass seed market; some called it business as usual, others thought it more significant. Although they had different ideas about the grass seed market, they were all drawing on more than their own experience and placing the downturn in the context of broader agricultural cycles.

For farmers, change and uncertainty are the norm and therefore, adaptation is a necessity. Agricultural markets fluctuate at multiple levels and are often unpredictable for farmers. There is uncertainty associated with annual market variation; crops that are in demand one year may not be the next. The farmers I interviewed told stories of grass seed and wheat prices varying significantly on a daily basis during the harvest season. Regulations are one form of unwelcome change for the farmers. During the interviews a number of farmers brought up the recent ban on field burning; all were dissatisfied but all were adapting with changes in management practices. Advances in technology are also a source of change in agriculture and these are generally seen as positive change by farmers. Mechanization made it possible for farmers to transition from what the interviewees referred to as subsistence farming, circa 1950, to more specialized agricultural systems. The introduction of chemical fertilizers and new plant varieties after World War II have increased yields and expanded markets for agricultural products. Farmers spoke with enthusiasm about recent technologies that offer more efficient use of farm equipment and enables more precise and limited application of fertilizers and other chemicals.

When asked about the future of agriculture in the Willamette Valley, farmers responded with a range of perspectives. For the most part, when talking about their personal circumstances, farmers spoke with confidence about their ability to bequeath a viable operation to the next generation. Two of the young farmers with limited diversity had a different perspective; they expressed concern for the future of their own operations if the grass seed market didn't improve in the next few years. One young farmer was confident that the family's operation would be strong and viable when his sons were grown but he expressed concern that the life of a farmer in the Willamette Valley might not be something he would want for them. Farmers spoke with less certainty about the future of Willamette Valley agriculture in general. Issues of concern include the previously noted competition and uncertainty presented by global markets, the future demand for grass seed, the configuration of seed companies, regulations on agriculture and the attitude of non-farmers toward agricultural operations and communities. Although farmers expressed confidence in their ability to adapt, they weren't sure what they would be adapting to.

Ecosystem services as part of agricultural systems

Based on my interview findings, the seven active grass seed farmers are open to the concept of ecosystem services. The perspective of the retired farmer who now works professionally in the agricultural community is that farmers are generally open to new ideas. The two fresh market producers expressed general opposition to anything that would convert land from food production to some other use and I did not press them about producing other types of ecosystem services.

The younger farmers with low crop diversity and fewer reserves expressed the greatest interest in exploring ecosystem services as crop options. The more experienced farmers with some financial cushion were interested but generally had more of a wait and see attitude. Although the conversation about ecosystem services was necessarily conceptual, the farmers were engaged and thoughtful in considering the pros and cons from their perspective. Even those who were skeptical about the feasibility of carbon sequestration specifically were willing to discuss general aspects of ecosystem service production. The idea of providing a service rather than producing a harvestable crop was one that gave farmers pause. As the production of ecosystem services moves forward, this will be a conceptual hurdle for both farmers and the rest of society.

One of the aspects of ecosystem service production that I thought would be problematic for the farmers is that of the longer time commitment for ecosystem services compared to most agricultural crops. None of the farmers balked at the longer time commitment as long as they were fairly compensated in the form of an annual payment for the service. The idea of a stable source of annual income from some portion of their land was an aspect of ecosystem services that appealed to farmers. However, establishing fair compensation will be complex. The value will need to consider the income that a farmer would earn from producing a conventional crop on the same ground. The income from a conventional crop can vary significantly from year to year; in a good year the farmer does well, in a bad year a farmer can lose money. The annual payment for an ecosystem service needs to take this into consideration. Producing an ecosystem service would smooth out the income stream; the farmer would be cushioned in a bad year but miss out on the high of a good year. On the other side of the equation is the potential for ecosystem service production to reduce the input costs for that portion of ground. The amount would vary with the specific ecosystem service compared to the previous crop but it could be a significant factor in what the farmer considers fair compensation.

The production of ecosystem services needs to be compatible with the overall agricultural operation in terms of the crops that are grown and the farm's management. The better the fit, the more likely farmers will be to incorporate ecosystem service production into their operation. Farmers are particularly interested in crops that allow them to reduce their inputs, increase no-till acres and expand crop rotations. If farmers have a choice between growing two crops with the same income potential, one that is known and reliable and one that is new and untested, they will grow what they know. If ecosystem services can offer benefits that are not necessarily reflected in market prices, for example reduced tilling, this could tip the balance in a farmer's willingness to experiment with ecosystem services. When planning for the future, farmers consider both short term economic gain and the long term wellbeing of their operation. Ecosystem services have the potential to offer long term benefits such as improved soil health and a steady income stream for part of their land. One of the farmers noted that he would welcome an option that would ease the pressure to "suck crops out of the land every year".

There are major questions about the management of ecosystem services in agricultural systems. There will necessarily be trial and error involved with the production and management of ecosystem services as crops. Farmers also have questions about how the production of ecosystem services may impact their conventional crops. Based on past experience with conservation reserve programs, farmers had specific concerns about weed management. Grass seed farmers are particularly wary about seed contamination because genetic purity is a requirement for many varieties. Farmers' management concerns went beyond their own property lines. They speak in terms of being a good neighbor and are cautious about taking on any activity that could cause problems for the neighboring community.

It is uncertain how much land farmers will commit to the production of ecosystem services and, whether the collective production acres will provide a societal good. For example, ten farmers each growing ten acres of trees for carbon sequestration are unlikely to provide enough sequestered carbon to be considered a societal benefit. Ecosystem services are new, experimental and require a longer time commitment than conventional agricultural crops. Therefore, farmers will be unlikely to devote significant acreage to their production at the outset. Another aspect of how much land will go into ecosystem service production has to do with what it means to be a farmer. For generations the production of conventional agricultural crops has defined what farming is about. The farmers I interviewed like being farmers and the management of ecosystem services will be different from what they know. In thinking about the production of ecosystem services one young farmer asked, "What would we get out of that, drivin' by for 15 years and watching stuff grow? I don't know . . ." Farmers may be willing to incorporate ecosystem services into their operations but not on a scale that would fundamentally change the nature of farming as they know it.

There is the potential for the production of ecosystem services to offer a bridge between the local farming and non-farming communities. Because fresh market growers are food producers and sell directly to their customers, they have a connection to nearby communities that the other farmers do not. The seed producing farmers market to brokers and seed companies and their products are shipped nationally and internationally. The sentiment from the grass seed farmers is that non-farmers do not appreciate what they do. Ecosystem services such as carbon sequestration or non-structural flood storage would serve nearby communities and have the potential to become a form of local agricultural production. This would offer grass seed farmers an option with tangible benefits to the local non-farming community and a connection that is currently lacking. One of the young farmers I spoke with emphasized that if ecosystem services are to be successful, everyone "needs to be on the same team." By this he means that there needs to be acknowledgment by farmers and non-farmers of the mutual benefits provided by ecosystem services and an appreciation for their production.

My interviews with grass seed farmers show an openness to the concept of ecosystem services and suggest farmers would participate in moving the idea forward. The farmers' histories portray a community that is adaptive and willing to experiment if there is a potential benefit. Farmers are looking for options that will reduce input costs, labor and tilling of the soil. There is potential for ecosystem services to offer these qualities and provide a stable annual income for some portion of the farmer's land. If the production of ecosystem services from farms in the southern Willamette Valley is to be successful, farmers need to be active participants in the implementation. Farmers made it clear that they are interested in ecosystem service production *if* they are fairly compensated and *if* production works with their operation. Ecosystem service research is still in its early stages regarding measurement, accounting and valuation. The production of ecosystem services in the near future will be, in essence, a societal and ecological experiment and require a willingness to accept some degree of uncertainty and risk. The farmers I interviewed indicated that they would be willing to accept some risk as long as the risks and potential benefits are shared by both farmers and non-farmers.

CHAPTER VIII
SOCIOCULTURAL COMPONENT:
CROP PROFILES

Introduction and overview

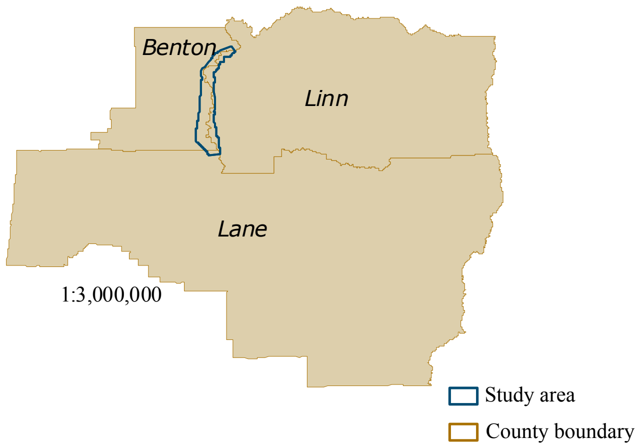
The results of my interviews suggest that a farmer's decision about whether or not to produce ecosystem services is multi-faceted and dependent on farm specific circumstances. A farmer will compare their current agricultural operation with ecosystem service production and assess the goodness of fit, the risks and the potential gains. During the interviews farmers cited potential non-monetary gains such as improved soil fertility and not having to work the ground every year. They also noted risks such as invasive weeds and the uncertainty associated with producing unfamiliar crops. One common aspect in the decision for all farmers will be the economic comparison of their current crop options with ecosystem services. Farmers are unlikely to choose an option that will decrease their current operation's per acre income. One farmer noted that given the choice between two crops with the same income potential, one familiar and reliable and the other experimental, he will choose the familiar. Ecosystem services need to be economically viable as a starting place. This does not necessarily mean that an ecosystem service needs to match or better the particular income for a specific crop in a specific year. As discussed later in this section, the income from a particular crop can be quite variable from year to year; there can even be a shift from highly profitable to a loss over the course of a few years (tall fescue for example). Compensation for ecosystem services in the form of a set annual payment would reduce the variability and uncertainty associated with crop prices. However, it would also eliminate the possibility of a highly profitable year. Ecosystem services are a longer-term investment than most conventional agricultural crops and the farmers I interviewed are not opposed to this aspect of production. Some indicated that a longer-term stable annual income for some portion of their land would be a welcome addition to their overall operation. For a farmer to choose ecosystem service production, the annual income needs to be sufficient enough that the longer-term stability is more attractive than the possibility of a banner year.

Arriving at a fair compensation value for ecosystem services needs to be an iterative process that includes farmers throughout. I offer the ideas in the following paragraphs as one way to begin thinking about the monetary value of ecosystem services. Rather than establish a price for a specific ecosystem service, my approach is to characterize a farmer's current crop income from land that could be used for ecosystem services. This provides a baseline range for the monetary compensation that ecosystem services will need to offer if farmers are to consider them as viable crop options. My discussion is limited to an estimated net per acre income from established crop production. I start by illustrating the variability in crop choices and also in annual market prices for specific crops. Understanding this variability is germane because it complicates establishing monetary value for ecosystem services and will be a factor in a farmer's decision-making. I then provide an example of how currently available data could be used to characterize per acre income of conventional crops as a place to begin discussions.

Crop variability

The study area's land use/ land cover class *grass seed rotation* is not one single crop; it is comprised of multiple grass seed varieties and other seed crops such as clover. The amount of a specific crop in the *grass seed rotation* class will vary from farm to farm and from year to year. I illustrate variability in cropping with data from 2005 through 2011 for the major crops in the *grass seed rotation* class. These data are from the Oregon Agricultural Information Network (OAIN 2011) which provides crop specific agricultural statistics for individual counties within Oregon. My study area contains portions of three counties: Benton, Linn and Lane (Figure 29) and I use data from Benton and Linn counties to illustrate my points since these two counties dominate my study area. The OAIN data are tabular statistics reported for an entire county; there is no spatial component or property identification that would allow the data to be narrowed to my study area. Therefore, my discussion and reporting of data in this chapter are for the entire counties of Benton and Linn, not just the territory within my study area.

Individual crops in the OAIN's data are aggregated into broader categories, for example grain, field crop and, small fruits and berries. The crops listed in Table 12 are in OAIN's category of grass and legumes and they are also correspond to the study area's land use/ land cover class of *grass seed rotation*. There are additional crops in OAIN's



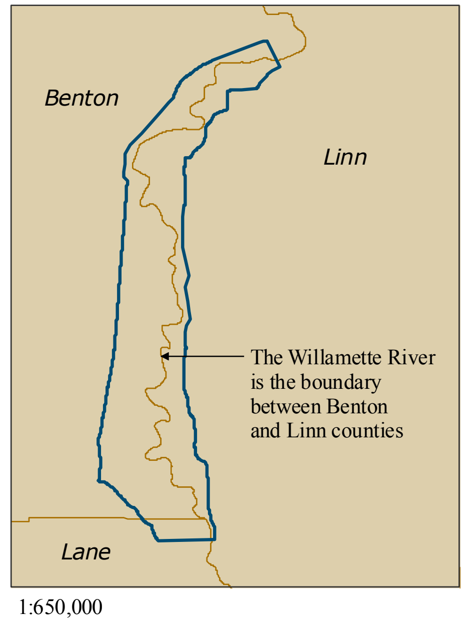


Figure 29. The study area contains portions of Benton, Linn and Lane Counties. The county boundary between Benton and Linn Counties is the Willamette River.

grass and legume category but the five listed in Table 12 represent the majority of the acreage in this category (94% in Benton, 97% in Linn). These data (Table 12) show spatial and temporal variability in cropping. The three primary grass seed crops in both Benton and Linn counties are tall fescue, annual ryegrass and perennial ryegrass but the distribution among these is different in each county. In Linn county, for the seven years reported, annual ryegrass is never less than 45% of the acreage in the grass/ legume category and, tall fescue is never more than 21% of the acreage. In Benton county, for the same seven years, annual ryegrass is most always below 35% and, tall fescue ranges from 27% to 47%. This variability between the two counties reflects differences in growing conditions on the west (Benton) and east (Linn) sides of the Willamette River (Figure 29). In particular, limited irrigation and poorly drained soils present greater limitations in crop choices in Linn County. The data in Table 12 also show the annual variability in cropping. From 2005 – 2011, both Linn and Benton counties show significant changes in perennial ryegrass. In Benton County there has been a significant drop in the grass/ legume proportion of perennial ryegrass from 24% in 2005 to 4% in 2011. In Linn County the change is less dramatic but still significant, from 31% in 2005 to 18% in 2011.

Benton County	2005	2006	2007	2008	2009	2010	2011
Tall Fescue	27%	28%	29%	44%	47%	42%	38%
Annual Ryegrass	32%	33%	34%	33%	29%	31%	38%
Perennial Ryegrass	24%	22%	20%	6%	5%	5%	4%
Orchard Grass	10%	9%	9%	10%	11%	11%	11%
White Clover	2%	2%	2%	2%	4%	4%	4%

Linn County	2005	2006	2007	2008	2009	2010	2011
Tall Fescue	17%	18%	19%	21%	20%	18%	15%
Annual Ryegrass	45%	46%	47%	48%	50%	52%	56%
Perennial Ryegrass	31%	28%	26%	22%	20%	20%	18%
Orchard Grass	2%	2%	2%	2%	2%	2%	2%
White Clover	3%	4%	4%	5%	6%	6%	5%

Table 12. Percentage (by area) of major grass seed and legume crops in Benton and Linn Counties from 2005 through 2011. The percentages are based on the total area in each county that is in the Grass and Legume category from the Oregon Agricultural Information Network (OAIN). There are other crops within the Grass and Legume category so the percentages in the table do not sum to one hundred. The crops listed here represent at least 94% of the acreage in the Grass and Legume category in Benton County and at least 97% in Linn County.

The crop option of wheat further complicates the variability discussed in the previous paragraph. In addition to shifting the percentage of their acreage among grass seed and legume varieties, some farmers have the option of growing wheat rather than grass seed in some of their fields. In general, wheat cannot be grown in very poorly drained soils and it can only remain in the same field for a few years. However, the drop in grass seed prices in 2009 and 2010 caused many farmers that could to decrease grass seed production and increase wheat production. Table 13 shows wheat acreage production from 2005 through 2011. The interaction between grass seed production and wheat production can be seen in the proportional changes of wheat acres over the same time period. Of the total summed acreage in the categories of grass/ legume and grain (this is almost exclusively wheat), the percentage of wheat in Benton County goes from 4% in 2005 to 20% in 2011. Linn County shows a greater change from 5% in 2005 to 29% in 2011.

Monetary income

To illustrate my approach to approximating net per acre crop income, I use data from two sources: 1) the Oregon Agricultural Information Network (OAIN 2011) and,

Benton County	2005	2006	2007	2008	2009	2010	2011
Acres of wheat produced	1,950	1,800	2,000	4,800	7,000	10,500	13,000
Percentage of wheat in the sum of grass, legume and grain acres	5%	5%	5%	11%	16%	25%	29%

Linn County	2005	2006	2007	2008	2009	2010	2011
Acres of wheat produced	8,000	7,500	7,000	14,000	27,000	38,500	40,000
Percentage of wheat in the sum of grass, legume and grain acres	4%	4%	3%	7%	13%	19%	20%

Table 13. Wheat acreage and comparison of the proportion of wheat acres to grass/ legume acres in Benton and Linn Counties from 2005 – 2011. The percentage of wheat is based on the summed area of two categories from the OAIN: 1) Grass/ legume and 2) grain. Wheat is the primary crop in the grain category in Benton and Linn counties. The calculations for the values in this table use wheat acres in the numerator and the summed acreage of grass/legume and grain in the denominator.

2) Enterprise Budgets produced by Oregon State University Extension Service (Oregon State University Extension Service 2010). The OAIN data provide an average per unit sales price (for example twenty cents per pound) that is paid to the farmer. As with the acreage data discussed in the previous paragraphs, this information is reported annually. The Enterprise Budgets are crop specific decision-making tools developed for farmers which allow them to estimate, in advance, their costs of production and potential income. The Enterprise Budget publications are only produced for certain crops and they are infrequently updated. For example, the publications I use are from 2010 and some of these had not been updated since 1995. The Enterprise Budgets include an itemized accounting of input costs (for example, the per acre cost of fertilizer and equipment) and also aggregated figures of direct expenses (annual expenses) and fixed expenses (longer term on-going expenses such as equipment replacement). The per acre income from a crop depends on a farmer's yield (pounds or bushels per acre) and the Enterprise Budgets provide yield estimates for each crop. Table 14 shows the price per unit (pounds or bushels) for the same set of crops shown in Table 12. The prices are directly from

Grass/Legume crops *(price per pound)*

	2005	2006	2007	2008	2009	2010	2011
Tall Fescue	$0.50	$0.75	$0.75	$0.67	$0.35	$0.32	$0.49
Annual Ryegrass	$0.28	$0.26	$0.28	$0.30	$0.18	$0.25	$0.30
Perennial Ryegrass	$0.55	$0.69	$0.66	$0.76	$0.50	$0.50	$0.62
Orchard Grass	$0.70	$0.93	$1.40	$1.85	$0.73	$0.58	$0.69
White Clover	$1.70	$1.35	$1.56	$2.25	$1.50	$1.23	$1.70

Wheat *(price per bushel)*

Wheat	$3.65	$3.95	$6.00	$6.00	$5.20	$5.60	$6.25

Table 14. Per unit prices paid to farmers for grass seed crops, white clover and wheat from 2005 – 2011. Prices are per pound for grass seed and clover and per bushel for wheat. The prices are from OAIN for Benton County, in a small number of instances, the prices in Linn County vary slightly from those listed here.

the annual OAIN data with no economic adjustment and no assumption that the values are directly comparable for the seven years. Even so, the annual variability in prices is apparent. From 2005 to 2011, tall fescue ranges from a low of thirty-two cents per pound to a high of seventy-five cents per pound. Average yields for tall fescue are more than one thousand pounds per acre so this variation in price is significant. Although white clover is a small percentage of overall acreage, the 2008 spike from an average of a dollar and a half per pound to two dollars and twenty-five cents per pound could provide a considerable boost to a farmer's income.

Table 15 combines data from OAIN and the Enterprise Budgets to derive a per acre income for the same set of crops shown in Tables 12 and 14. The direct expenses per acre and the assumed yield per acre are estimates from Enterprise Budgets dated November 2010. The budgets for annual ryegrass and wheat include expenses and yield estimates for both conventional and no-till practices. This is indicative of the current trend to shift to no-till when possible to reduce input costs. I use the direct expenses rather than the total expenses (direct plus fixed) as these are common expenses to all farmers on an annual basis. The fixed expenses are more variable from farm to farm. It should be noted that using total expenses rather than direct expenses can make a significant difference in the per acre net income calculation. For example, in 2010, using total expenses in the calculations results in a per acre loss for all crops except wheat.

Crop	Enterprise Budget publication	Direct expenses per acre	Yield per acre	Unit	2009 price per unit	2009 net income or loss per acre	2010 price per unit	2010 net income or loss per acre	2011 price per unit	2011 net income or loss per acre
Tall Fescue	AEB 0009	$483	1,350	pound	$0.35	-$10	$0.32	-$51	$0.49	$179
Annual Ryegrass (conventional)	AEB 0011	$401	2,000	pound	$0.18	-$41	$0.25	$99	$0.30	$199
Annual Ryegrass (no-till)	AEB 0011	$338	1,850	pound	$0.18	-$5	$0.25	$124	$0.30	$217
Perennial Ryegrass	AEB 0007	$478	1,350	pound	$0.50	$197	$0.50	$197	$0.62	$359
Orchard Grass	AEB 0014	$415	800	pound	$0.73	$169	$0.58	$49	$0.69	$137
White Clover	AEB 0021	$424	600	pound	$1.50	$476	$1.23	$314	$1.70	$596
Winter Wheat (conventional)	AEB 0015	$323	100	bushel	$5.20	$197	$5.60	$237	$6.25	$302
Winter Wheat (no-till)	AEB 0015	$302	100	bushel	$5.20	$218	$5.60	$258	$6.25	$323

Table 15. Estimated per acre net income for selected crops for 2009, 2010 and 2011. The direct expenses per acre and yield per acre are estimates from Enterprise Budget publications for the southern Willamette Valley, dated November 2010. The 2009, 2010 and 2011 price per unit amounts are from the annual OAIN statistics for Benton and Linn Counties. The per acre net income calculations for 2009, 2010 and 2011 use the same value for direct expenses and yield per acre (from the November 2010 Enterprise Budgets) and, gross income per acre based on price per unit for each year. The expense and income values are rounded to the nearest dollar.

Table 15 includes calculations for three years to show the annual variability in per acre net income. The estimates in the Enterprise Budget publications are based on the collective knowledge and forecasting of local experts at the time of the publication. As previously noted, the Enterprise Budgets are not updated annually but are used as planning tools for multiple years. I use expense and yield estimates from 2010 publications and these should provided reasonable approximations for 2009 through 2011.

The range of annual net income or loss shown in Table 15 illustrates some of the complexity in deriving a single per acre income value. The variability in crop options combined with the variability in annual prices complicates the task of making general assumptions about a farmer's income. The numbers do begin to suggest points for discussion. For example, some crops such as white clover may be unlikely candidates for conversion to ecosystem services. This crop has a relatively high per acre income (Table 15) and a relatively low percentage of harvested acres (Table 12). A potentially useful aggregation is to narrow the focus to the three main crops in Benton and Linn counties: tall fescue, annual ryegrass and perennial ryegrass. The net annual loss or gain for these three crops from 2009 through 2011 ranges from a loss of $51 per acre to a gain of $359 per acre. The average for these three crops over the three years is a gain of $122 per acre.

An example and comparator from Clean Water Services

A program developed by Clean Water Services to work with farmers in the northern Willamette Valley is relevant in my discussion of monetary compensation for ecosystem services. The program has been recognized for its success in meeting ecological objectives and also for its approach to working with the agricultural community (Abdalla 2008, Musengezi et al. 2012, Stuart 2010). In the following paragraphs I provide a brief background and overview of the program and then relate elements of the program to the agricultural statistics presented in the previous sections.

Clean Water Services (CWS) is a water resources management utility that serves communities in the Tualatin River Watershed near Portland, Oregon. As part of their plan submitted to Oregon's Department of Environmental Quality (DEQ), Clean Water Services proposed planting riparian vegetation as one method to offset excess thermal loads released into the river by their wastewater treatment plants. CWS is required to address the problem because the temperature of their treatment effluent exceeds standards in the federal Clean Water Act. Shading of waterways provided by riparian planting is one element in the overall plan which was developed as an alternative to cooling the released water with mechanical refrigeration. DEQ approved CWS's plan after considering the monetary and potential environmental costs of mechanical cooling of treated wastewater: between 60 and 150 million dollars to purchase and install the equipment, 2.5 to 6 million annually for maintenance and, potential negative impacts on salmon populations, air quality and climate warming.

In developing its programs to compensate private landowners for riparian plantings, CWS worked with an advisory committee (acronym SPOTAC) that included representatives from governmental agencies, environmental organizations, farming and forestry. From the outset, an objective was to design a program that would be attractive to private landowners as a means to encourage high rates of participation. To the degree possible, they also wanted to take advantage of existing programs and agency partnerships. Oregon's Conservation Reserve Enhancement Program (CREP) is an existing incentive program for private landowners that is administered cooperatively by the state and the USDA's Farm Services Agency. Although some Oregon farmers do participate in CREP, the terms of the program are not considered particularly attractive in the Willamette Valley. SPOTAC worked with farmers to identify aspects of CREP that discourage farmers' participation in the program. The committee used the farmer's input to develop one of the programs that CWS now offers to private landowners. The program, called Enhanced CREP, modifies the conditions and terms of the current CREP to address the problems identified by farmers. The second program that CWS offers to private landowners, called VEGBACC, was conceived by a farmer to provide an option with fewer benefits but greater flexibility than Enhanced CREP.

Enhanced CREP

Details of the Enhanced CREP and VEGBACC programs can be found in the Clean Water Services Revised Temperature Management Plan (2005), Appendix C and Appendix D respectively. I focus here on one aspect of the Enhanced CREP: the annual monetary compensation associated with converting from agricultural crops to riparian vegetation. The program makes a primary distinction between irrigated and non-irrigated cropland in the determination of monetary compensation. The compensation range for irrigated cropland is $391 to $394 per acre, the range for dry cropland is $104 to $264 per acre and, for pasture the range is $171 to $174 per acre (Tualatin and Multnomah Soil and Water Conservation Districts, no date). The wide range for dry cropland is due to the consideration of soil type in the amount of monetary compensation. One of the primary reasons farmers cited for not participating in CREP is the low annual payments which they find to be less than they can earn from crop production. In keeping with CWS's stated intention of developing a program that is attractive to farmers, the monetary compensation for Enhanced CREP is intentionally higher than the amount a farmer would earn from growing conventional agricultural crops on the land. SPOTAC considered net income per acre as one point of reference in determining monetary compensation. The committee's research determined that annual CREP payments are approximately equivalent to a farmer's net per acre income from crop production. There are multiple aspects to the Enhanced CREP incentives, for example technical assistance and maintenance costs, but consideration of net income per acre is a major factor in the program's annual monetary compensation. This annual payment is estimated to be an amount that is 64% higher than the per acre CREP amount and therefore, approximately 64% higher than a farmer's per acre net income from agricultural crop production.

Enhanced CREP, Linn and Benton Counties

Geographic proximity, common cultural norms and similarity in cropping make the Enhanced CREP a useful comparator for the Benton and Linn County agricultural statistics. Although there are many factors to consider in converting from conventional agricultural crops to ecosystem services (for example, planting, technical assistance and maintenance costs), I narrow the focus to annual monetary compensation as it relates to a farmer's current net crop income. For a comparison, I return to the net per acre estimate calculated for the three main crops in Linn and Benton Counties: tall fescue, annual ryegrass and perennial ryegrass. Calculating an average for the two counties over the three years from 2009 through 2011 resulted in a net income of $122 per acre. If Enhanced CREP's guideline of an annual payment of 64% above net income is applied, the per acre annual amount for these crops in Benton and Linn Counties is $200. As ryegrass and fescue are non-irrigated crops, these would be eligible for an Enhanced CREP annual payment between $104 and $264 per acre. The calculated $200 per acre for Benton and Linn Counties falls within the Enhanced CREP range.

ESTIMATES FOR THE STUDY AREA

Data availability enabled the calculation of net per acre income for grass seed, wheat and white clover in Benton and Linn Counties. Comparable data are not available for other crop types grown in my study area and so similar calculations are not possible for all crops. The calculated net income for the three main crops in Benton and Linn Counties compared well with the Enhanced CREP's non-irrigated annual compensation. This along with the previously noted geographic proximity, common culture and crop similarities suggest that it is reasonable to apply the annual monetary compensation for Enhanced CREP's irrigated cropland and pasture categories to my study area. Borrowing from the Enhanced CREP's numbers also takes advantage of the significant research and farmer input behind their monetary compensation values. For estimates of compensation in my study area, shown in Table 16, I use the annual per acre compensation ranges from Enhanced CREP with an adjustment for non-irrigated crops. The adjustment is based on my work with the OAIN data and the Enterprise Budgets. For the non-irrigated crops, I use the previously discussed estimate of $200 per acre annually as the bottom of the range because it is unlikely that farmers in my study area would consider less.

Crop type	*Annual per acre compensation range*
Irrigated crops	$391 - $394
Non-irrigated crops	$200 - $264
Pasture/ hay	$171 - $174

Table 16. Estimates of annual per acre income to compensate farmers in the study area for producing ecosystem services.

ECOSYSTEM SERVICES FROM AGRICULTURAL LANDS – BEYOND MONETARY EQUIVALENTS

The experience with Oregon's CREP, the background research of Clean Water Services and my interviews with farmers indicate that offering monetary compensation equivalent to net per acre crop income will not make ecosystem services an attractive option for farmers. Two aspects of Clean Water Services's approach are useful lessons in moving forward with monetary compensation for ecosystem services from agricultural lands. The first is to include farmers throughout the process and to strive for monetary compensation that is fair and attractive rather than least cost. My interviews with farmers suggest that developing ecosystem services as a crop option will require a sincere effort to work with farmers in a way that is inclusive and considerate of their perspectives and concerns. The second lesson is to design a program for success rather than economic efficiency. Significant levels of participation will be required if ecosystem services are to be provided by individual private landowners. It is ultimately the aggregation of the individual contributions (for example carbon sequestration and floodplain forest) that will provide the expected societal benefits. Therefore it is important to initiate a program that encourages broad participation and establishes a positive relationship with the agricultural community. Ecosystem services are experimental and, in the Willamette Valley, it will be difficult to recover if the experiment gets off to a poor start with farmers.

Looking beyond monetary bottom lines can offer a broader perspective on the potential benefits of incorporating ecosystem services into the agricultural landscape and I offer one example here. The difference in input requirements between conventional agricultural crops and ecosystem services is currently difficult to assess due to a lack of data. However, it is likely that chemical inputs (fertilizers, herbicides and pesticides) and the amount of fuel for farm equipment and transportation will be significantly less for ecosystem services than for agricultural crops. A farmer's monetary costs for these inputs is included in the crop specific Enterprise Budgets (OSU Extension 2010). The budgets also contain a per acre estimate of the amount of each input, for example gallons of herbicide, and it would be possible to quantify these inputs. A potential societal benefit that is not included in any monetary evaluation is the reduction of chemical inputs to the soil and the environmental costs of their production and transportation. These non-monetary environmental costs and benefits are part of the essence of an ecosystem services concept and although difficult to evaluate, they should not be overlooked.

CHAPTER IX

INTEGRATED RESULTS

Introduction and overview

In preceding chapters I have presented the analysis for each component shown in my dissertation diagram (Chapter I, Figure 3). Results of the analysis for each biophysical component: non-structural flood storage (Chapter IV), carbon sequestration (Chapter V) and floodplain forest (Chapter VI), provide estimates of the quantity of each that could be provided by the landscape as an ecosystem service. The analytic foundation for the biophysical components is a geographic information system (GIS) with data representing land use/ land cover, elevation and water surface elevation for a 2-year flood event. For the sociocultural component, I consulted with those most knowledgeable about the study area's agricultural landscape: farmers and professionals who work with farmers. The results of my in-person qualitative interviews with farmers (Chapter VII) directly inform my scenario assumptions for change in the 2050 landscape (Chapter III and Appendix C). In Chapter VIII, I offer an approach for developing a first approximation of monetary compensation for the production of ecosystem services. The monetary estimates are based on providing farmers with an annual per acre income for ecosystem service production that is, at a minimum, equal to what they currently earn from conventional crop production.

The answers to my two dissertation sub-questions have been presented in previous chapters. The answer to the biophysical question (*What quantities of ecosystem services are available from the landscape?*) can be found in the results sections of Chapters IV, V and VI. These sections provide a quantitative answer about the availability of each ecosystem service. The answer to the sociocultural question (*What are the perspectives of agricultural landowners that influence their willingness to produce ecosystem services?*) can be found in Chapter VII's qualitative analysis of my interviews with farmers. Up to this point, each ecosystem service has been evaluated and presented in isolation from the others. A key point in a landscape approach to ecosystem services is to understand the landscape as an integrated system; therefore, it is important to understand how the individual ecosystem services would function together in the landscape. In this chapter I synthesize the individual components in an integrated landscape evaluation.

The analysis combines results from the individual biophysical components to identify locations in the 2050 landscape that could simultaneously provide two or three ecosystem services. For these locations, I apply the monetary estimates presented in Table 16 (Chapter VIII) to provide a landscape scale first approximation of the annual monetary cost of compensating farmers for their production. The monetary value is intended to provide farmers with an annual compensation that is in the range of their current income from conventional crop production.

Data processing

The mapped results from the biophysical components are combined with a GIS raster operation (multiplication) to locate places in the landscape where more than one of the three ecosystem services could be provided. The biophysical criteria are as follows: 1) for non-structural flood storage, inundation greater than zero in a 2-year flood event, 2) an increase in carbon sequestration in 2050 relative to 2000 and, 3) new floodplain forest in 2050, i.e. locations that are floodplain forest in 2050 and were not floodplain forest in 2000. The results of the analysis identify locations that meet all three of the criteria, and locations that simultaneously meet two criteria, namely carbon sequestration and floodplain forest. A subsequent GIS multiplication operation is used to identify the specific 2000 agricultural classes where two or three ecosystem services are produced in 2050. The 2000 agricultural classes are used in the estimates of monetary compensation for ecosystem service production.

Results and discussion

Figure 30 shows locations where more than one of the three ecosystem services could be provided in the 2050 landscape. All three ecosystem services could be provided on 2,981 acres, and increases in carbon sequestration and floodplain forest could be simultaneously provided on an additional 4,841 acres. The metric for floodplain forest and non-structural flood storage is the area of each and so, the quantity of each is the acreage presented (i.e. for the three ecosystem services: 2,981 acres of non-structural flood storage *and* 2,981 acres of floodplain forest). For carbon sequestration, the landscape quantity is metric tons (mT) of carbon which is estimated from the acreage associated with specific land cover types (see Chapter V). The quantity of sequestered

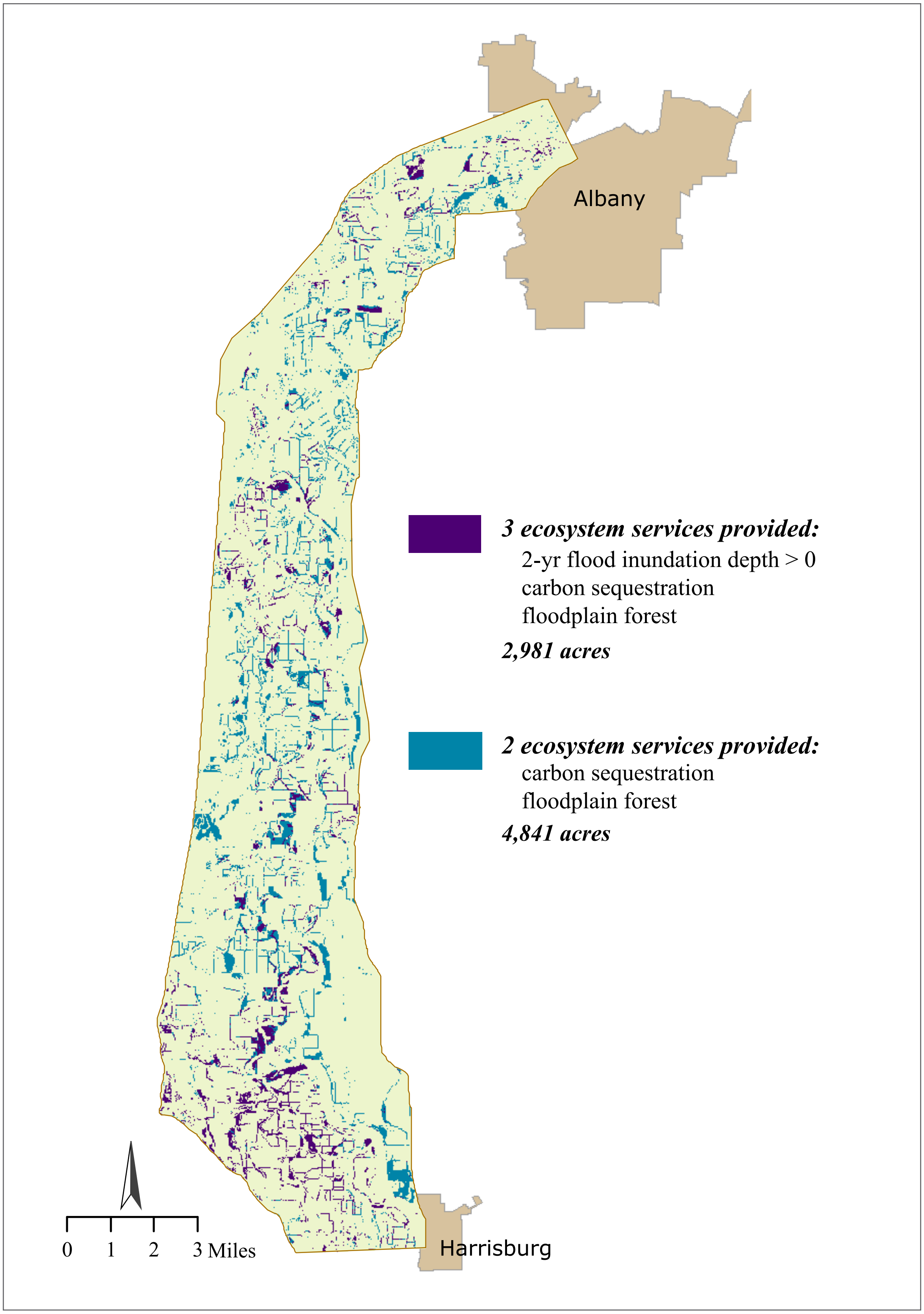


Figure 30. Locations in the study area landscape where more than one ecosystem service can be provided in 2050.

carbon for the 2,981 acres is 165,513 metric tons and for the 4,841 acres it is 261,585 metric tons. For carbon sequestration and floodplain forest, the identified locations indicate a change (an increase) from 2000 to 2050. The 2-year flood inundation data represent current conditions and so the identified locations do not show where conditions change from 2000 to 2050. However, these locations do show where non-structural flood storage is currently being provided without monetary compensation or any other acknowledgment of its value. The need for this service will continue and may become increasingly important with climate change.

Estimates of monetary income compensation

The locations shown in Figure 30 are places where conventional crop production in 2000 is converted to the production of more than one ecosystem service in 2050. The specific 2000 agricultural classes and corresponding acreage for these locations are shown in Table 17. To apply the monetary estimates from Table 16, the agricultural classes are aggregated into *Income Classes*: Irrigated (I), Non-Irrigated (NI) and Hay/ Pasture (HP). The low and high dollar per acre estimates shown in Table 17 come directly from Table 16, and a low and high sub-total for each crop is calculated by multiplying the number of acres by the dollar per acre estimate. The resulting estimates for the study area provide a range of annual income for ecosystem service production that would compensate farmers with an income similar to what they receive from present-day conventional crop production. For the 2,981 acres that could provide three ecosystem services, the range is $888,800 to $958,900; for the 4,841 acres that could provide two ecosystem services, the range is $1,275,500 to $1,436,000.

Field scale perspective

In preceding chapters and the previous paragraphs, mapped representations of ecosystem services are at the scale of the study area landscape. This scale of understanding and evaluation are necessary to inform a discussion about the potential societal benefits of incorporating ecosystem services into the landscape. However, if ecosystem services are to be provided by private landowners, decisions about whether

3 ecosystem services

Agricultural class	Acres	Income class*	Low estimate ($/ acre)	High estimate ($/ acre)	Low sub-total	High sub-total
Irrigated annual rotation	1,090	I	391	394	$426,137	$429,406
Grass seed rotation	678	NI	200	264	$135,659	$179,070
Grains	290	NI	200	264	$57,901	$76,430
Hay	264	HP	171	174	$45,176	$45,969
Irrigated field crop	195	I	391	394	$76,076	$76,659
Mint	148	I	391	394	$57,761	$58,204
Pasture	124	HP	171	174	$21,217	$21,589
Christmas trees	42	I	391	394	$16,237	$16,362
Orchard	37	I	391	394	$14,429	$14,540
Bare/fallow	35	NI	200	264	$7,012	$9,256
Sugar beet seed	31	I	391	394	$11,976	$12,068
Double cropping	26	I	391	394	$10,112	$10,190
Caneberries & vineyards	21	I	391	394	$8,254	$8,317
Hybrid poplar	2	I	391	394	$850	$857
	2,981				***$888,798***	***$958,917***

2 ecosystem services

Agricultural class	Acres	Income class*	Low estimate ($/ acre)	High estimate ($/ acre)	Low sub-total	High sub-total
Grass seed rotation	1,896	NI	200	264	$379,200	$500,544
Irrigated annual rotation	1,054	I	391	394	$411,929	$415,090
Hay	427	HP	171	174	$72,993	$74,274
Irrigated field crop	302	I	391	394	$117,949	$118,854
Pasture	301	HP	171	174	$51,402	$52,304
Grains	294	NI	200	264	$58,762	$77,565
Mint	116	I	391	394	$45,505	$45,854
Christmas trees	103	NI	200	264	$20,517	$27,082
Bare/fallow	102	NI	200	264	$20,424	$26,960
Caneberries & vineyards	90	I	391	394	$35,367	$35,638
Orchard	83	I	391	394	$32,553	$32,802
Sugar beet seed	40	I	391	394	$15,685	$15,805
Double cropping	21	I	391	394	$8,046	$8,108
Hybrid poplar	13	I	391	394	$5,229	$5,269
	4,841				***$1,275,561***	***$1,436,150***

* I = Irrigated, NI = Non-irrigated, HP = Hay/ pasture

$/acre estimates are presented in Chapter VIII, Table 16

Table 17. Estimates of annual compensation for ecosystem service production within the study area. The amounts are intended to provide farmers with an income similar to conventional crop production.

or not to produce them will be based, largely, on site scale considerations. The finer grain view in Figure 31 reveals the coarseness of the GIS data relative to site scale conditions and illustrates important aspects of ecosystem services that are not apparent at a landscape scale.

The ecosystem service data shown in Figure 31 are the same data shown in Figure 30. At this finer grain, the critical role of property ownership is visible. Figure 31a shows multiple taxlot parcels in Benton and Linn Counties and their relationship to the ecosystem service data. The spatial patterns of the ecosystem services which result from their biophysical qualities are incongruent with the human created patterns of property ownership boundaries. An example of this is the contiguous swath of blue on the east side of the river in Figure 31a. This swath represents an increase in both floodplain forest and carbon sequestration, and the contiguous patch is advantageous from the perspective of ecosystem function and process. However, the patch spans four taxlot boundaries which is cumbersome from a sociocultural perspective. It is possible that the same family owns more than one of the taxlots but it is also possible that on-the-ground implementation of this pattern would require the willingness and cooperation of four separate landowners.

Figure 31b and c show a single taxlot of approximately 100 acres which, in this example, corresponds to an agricultural field. Figure 31b illustrates the coarseness of the GIS data relative to a farmer's considerations at the scale of an agricultural field. The specific pattern of ecosystem services imposed on the agricultural field would likely cause problems for a farm operation. The narrow band of ecosystem service data with a north/south orientation on the west side of the field creates a pattern that would fragment the agricultural field, make it difficult to work and perhaps leave too little area for worthwhile conventional crop production. In Figure 31c, the GIS data have been used as a general guideline to identify a single unit of forty-three acres within the field that could be converted to ecosystem service production. This pattern leaves a contiguous agricultural field of more than fifty acres but the farmer would need to decide if this configuration would work with the farm's operation. In this example, the 2000 agricultural class is an irrigated crop and from Table 16, the estimated annual income would be \$391 - \$394 an acre. Using these figures, the annual income for ecosystem service production on the forty-three acres would be \$16,813 - \$16,942. In some instances, a farmer might

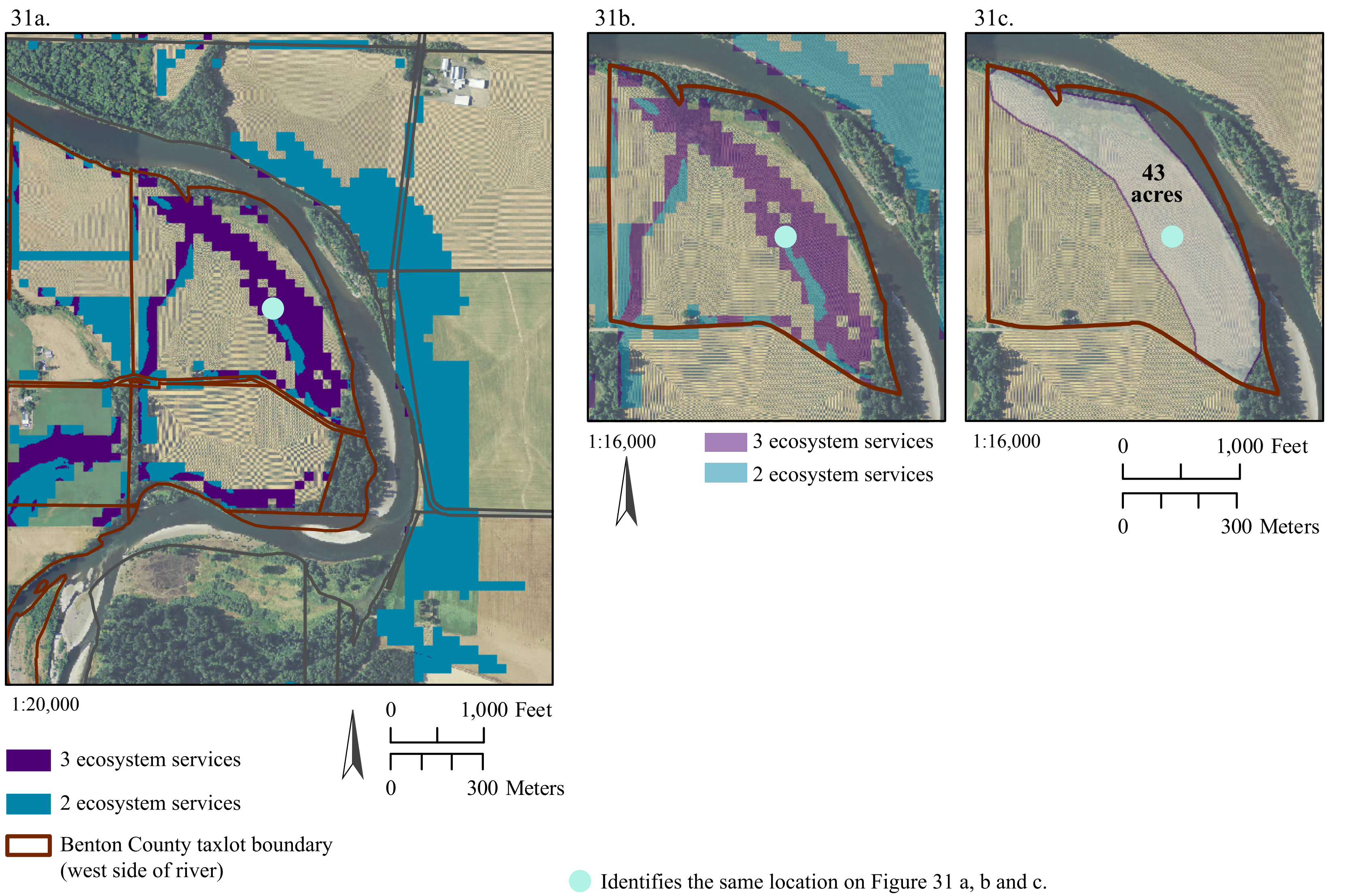


Figure 31. Field scale perspective. a, b) County taxlot boundaries and agricultural field configuration relative to ecosystem service data. c) Adjustment of ecosystem service data with consideration of field qualities and farm operations.

prefer to convert an entire field to ecosystem services rather than partition the field. The GIS data can provide general guidance about the location of ecosystem services but implementation will require coordination with farmers and consideration of farm operations and agricultural field qualities.

CHAPTER X

DISCUSSION

Illustrating a Landscape Approach to Ecosystem Services

The first three constituents of my proposed landscape approach to ecosystem services are illustrated in the qualities of the study area and in my research design. In Figure 32, these constituents are part of a broader framework of *landscape scale*, *landscape inquiry* and *landscape change and research*. The choice of study are illustrates *landscape scale:* The study area's spatial extent is sufficient to provide ecosystem services at a landscape scale. It is also a scale at which people are connected to the landscape through their personal experience and this connection is particularly strong for the farmers who participated in my interviews. The dissertation research illustrates *landscape inquiry:* The selection of ecosystem services for the biophysical component of my research was guided by the particular biophysical qualities of the study area's landscape. The interviews with farmers in the sociocultural component represent one aspect of people's relationship to the landscape's biophysical resources. The crop profiles and estimates of farmer's annual income from conventional crop production where ecosystem services could be produced offer a starting place for discussions about intentional landscape change. *Landscape change and research*: These constituents of on-the-ground change and associated research into social/ ecological systems are beyond the scope of my dissertation but these are included as part of the following discussion.

The potential for ecosystem services from the study area's agricultural landscape

Potential:"latent qualities or abilities that may be developed and lead to future success or usefulness" (Oxford Dictionary)

The results of my research show that there is potential for the provision of ecosystem services from the study area's agricultural landscape. My analysis provides estimates for the quantities of three ecosystem services that could be provided from the study area's biophysical environment. My interviews with farmers and conversations

Framework for a landscape approach to ecosystem services

	Key Constituents	Dissertation example
Landscape Scale	Delimit a spatial extent large enough to provide quantities of ecosystem services with societal benefit and also one at which people are connected to the landscape through personal experience	65,000 acres in a floodplain agricultural landscape with multigenerational family farms, a river environment providing recreation for the broader community, identifiable scenic quality
Landscape Inquiry	Analyze the landscape to identify ecosystem services that are available from the biophysical resources and are significant to people within that landscape	Carbon sequestration Flood storage Floodplain forest
	Consult with those making a living from the landscape to understand the perspectives and relationships of potential producers of ecosystem services. Subsequently consult with potential users and/ or funders of the ecosystem services	Interviews with farmers to understand the perspectives of one group who could potentially produce ecosystem services
	Determine feasible options for incorporating ecosystem services into landscape function (intentional landscape change)	Consider paying farmers to produce ecosystem services where they now produce conventional agricultural crops. The crop profiles provide estimates of farmers' current annual income where ecosystem services could be produced in the study area. This is offered as a starting place for discussions.
Landscape Change and Research	Implement an ecosystem services concept with on-the-ground change as part of the landscape's coevolving social/ ecological system.	Future research
	Monitor and document on-the-ground change and adaptation as part of a research framework into coevolving social/ecological systems and the long term potential for ecosystem service approaches to sustain and protect biophysical resources while maintaining sociocultural productivity	Future research

Figure 32. Framework for a landscape approach to ecosystem services - key constituents and dissertation examples.

with professionals who work with farmers suggest an interest in, and openness to, the idea of expanding crop options to include the production of ecosystem services. The potential for ecosystem service provision exists in both the biophysical and sociocultural parts of the landscape but there are multiple challenges in realizing that potential. The challenges range from broad cultural perspectives to operational details of organization and site scale management. The potential will not be realized in the near-term if it relies on sufficient data and economic models to determine the monetary value of the ecosystem services *before* implementing on-the-ground change. There is also no guarantee that a monetary value, once established, will be sufficient motivation for ecosystem service production. A near-term realization of the potential will require intentional change that is motivated by more than the prospect of monetary gain.

My dissertation is a first probe into the potential of the study area to provide ecosystem services; it presents preliminary estimates of what the landscape could provide and a starting place for discussions with the farming community. The next steps would involve an assessment by the broader community to determine if this type of shift in the landscape is desirable and, if so, whether or not it is feasible. At present, the motivations for incorporating ecosystem services into the agricultural landscape will need to come from a longer term vision of agriculture in the Willamette Valley. This longer term vision needs to come from both farmers and non-farmers with the common goal of maintaining and evolving agriculture as an integral part of the Willamette Valley. Since its establishment in the mid-nineteenth century, the Willamette Valley's agricultural landscape has evolved with changes in markets, technologies and culture. In light of the current awareness about the critical role of natural resources in human well-being, there is an opportunity for an evolutionary shift in the agricultural landscape with ecosystem services as the operational mechanism.

Challenges

Conceptual

An approach to ecosystem services such as the one I propose will require a shift in cultural perspectives about what it means to have a productive agricultural landscape. At present, the value of the southern Willamette Valley's agricultural landscape is measured and expressed by its extractive uses. In this cultural norm, a productive agricultural landscape equates to maximizing harvest (number of acres, pounds of seed, bushels of grain) and selling the harvest for the highest price possible. Agricultural land that is enrolled in conservation programs such as the Conservation Reserve Enhancement Program (CREP) is commonly referred to as land that has been ‘taken out of production’. The farmers I interviewed paused at the idea of being paid to produce crops that are not harvested, weighed and sold in a market. They were not opposed to the idea but this is a conceptual hurdle for farmers and non-farmers alike. There will need to be broad societal acknowledgment that there is value in an agricultural landscape that intentionally includes the production and stewardship of natural resources. If this is jointly acknowledged by farmers and non-farmers, then there will be a starting place to move from vague concepts of value to discourse about valuation that could initiate on-the-ground change. The farmers I interviewed indicated that they would be interested in learning more about how this type of joint effort could move forward. The farmers also indicated that they had no interest in either gratis production of public goods or receiving payments that are perceived by non-farmers as ‘helping out the farmer’.

Wealth production, values and uncertainty

One of the primary obstacles to incorporating ecosystem services into landscape function is the loss of near-term, and potentially long-term, economic wealth production. One pathway to address this obstacle is to make ecosystem services economically productive and competitive with other uses. This approach underlies much of the current ecosystem services research. Another way to address this obstacle is to seek ways to make ecosystem services an economically feasible landscape option and this is consistent with my landscape approach. This path is an intentional reordering of individual and societal values; it first considers biophysical resource value and then economic wealth production. This path requires a longer term view and a willingness to accept and work with uncertainty. There is good reason to believe that a commitment to this type of path can offer a future landscape with greater security in natural resources and a more robust set of societal options. This is a possible outcome, not a certainty; there are no guarantees. Evidence does support an almost certain future with increasing limitations in natural resource availability and an increase in the number of people using those resources. Even so, there is a reluctance to initiate potentially mitigating landscape change because it may not be economically justified in the short-term and the outcome is uncertain. If ecosystem services can be made economically feasible, there might be more willingness to explore a path that is uncertain but potentially advantageous.

Organizational frameworks

The organization of societal frameworks for ecosystem services will play a crucial role in their implementation. This is a broad topic and not part of my dissertation research but it presents a major challenge moving forward. Therefore, I offer a brief discussion in the following paragraphs.

Currently in the United States, there are no practical societal frameworks for the concept of ecosystem services other than goods such as food and timber which already have a monetary value determined by economic markets. Government institutions and policies as well as economic markets have evolved, for the most part, by either excluding consideration of natural resources or assuming their supplies are inexhaustible. These long-standing norms and their resulting institutional and market frameworks are obstacles in devising social systems that are appropriate for the qualities of non-market ecosystem services.

In economics, a *public good* is one that is: 1) nonexcludable, meaning that the supplier of the good cannot prevent non-payers from using the good and, 2) nonrival in consumption, meaning that multiple users can simultaneously use or consume the good (this assumes that the quality of the good remains constant for all users). Although not always explicitly stated, non-market ecosystem services have been largely managed as public goods. Economic approaches to the exchange of goods and services exclude public goods because they cannot be "efficiently produced and consumed in a competitive market" (Krugman and Wells 2005). As long as natural resources (ecosystem services) are plentiful and not degraded by use, their management as public goods is adequate. Evidence now shows that many natural resources do not meet the criterion of being nonrival in consumption; their use by one person or group can limit or impair their use by others. An example of this is upstream water use affecting downstream users. In a limited number of cases, for example water quality, government regulations impose restrictions to mitigate harmful effects. One of the problems presented by ecosystem services is that they are still nonexcludable (for the most part, individuals use them but do not pay) but they are rival in consumption (they are finite and degradable). This creates a tension between near-term individual betterment and longer-term societal well-being. Individuals may continue to improve their own near-term circumstances by maintaining the status-quo and disregarding the drain on broader societal resources. This choice ignores a possible future in which available resources can no longer support either societal needs or these personal gains. The management of ecosystem services is ultimately a societal problem that will require the evolution of new forms of social cooperation and organization.

The term common pool resources has been used to characterize the qualities of ecosystem services (Ostrom et al. 1999, Lant et al. 2008, Kenward et al. 2011). Ostrom et al. list two criteria for common pool resources: 1) it is difficult to exclude non-paying users and 2) exploitation by one user reduces resource availability for others. The referenced discussions of common pool resources note Hardin's Tragedy of the Commons in which individual users of common pool resources exploit and ultimately deplete the resources on which they depend. Given the social systems in the United States, there are two assumed pathways to address the problem of common pool resource exploitation: 1) central control by government or, 2) division of resources and private ownership (Ostrom 1990, Dietz et al. 2003). Ostrom (1990) illustrates the ways in which these two approaches fail to protect common pool resources. She asserts that both approaches are too sweeping and both assume that the users of common pool resources are helpless to address the problem themselves and; therefore, solutions must be imposed from the outside. She states, "Instead of there being a single solution to a single problem, I argue that many solutions exist to cope with many different problems. Instead of presuming that optimal institutional solutions can be designed easily . . . I argue that 'getting the institutions right' is a difficult, time-consuming, conflict-invoking process". Because they are already socially embedded, the options of managing common pool resources through centralized government control or private ownership are tempting. These options might prove more expedient in the near-term but less than successful in achieving the long-term provision of ecosystem services. A more difficult path in the near-term is to first acknowledge the need for new forms of social stewardship and then to make a commitment to the process of experimentation, learning and adaptation that will be necessary to evolve social frameworks better suited to the provision of ecosystem services.

Ecosystem service districts

The concept of ecosystem service districts has been proposed as one approach to their organization (Heal et al. 2001, Salzman 2005, Goldman et al. 2007, Lant et al. 2008, Thompson 2008). Service districts are a familiar organizing framework in many communities and examples include irrigation districts, conservation districts and fire service districts. There is not a single template for how to organize a district but I view participation in an ecosystem service district as a choice. For example in my study area, farmers could choose to participate in an ecosystem service district or not. The notion of ecosystem service districts has yet to move beyond the conceptual stage. The idea offers a starting place that is familiar; but, ecosystem service districts will need to address their unique characteristics and cannot simply follow the pattern of other types of districts. The combination of familiarity (the district concept) and the need to chart a different path could prove useful in initiating ideas that have grounding in the present but are not bound by, and cannot rely on, existing organizational frameworks. Ecosystem service districts could provide an operational pathway that is well suited for accommodating ecosystem services into landscape function. From a sociocultural perspective it offers a framework for a process that initiates communication, deliberation and negotiation about common pool resources. From a biophysical perspective, it offers a way for landowners to aggregate their individual production of ecosystem services to quantities that meet the expectation of societal benefit.

A COMPLEX HIERARCHY

Moving ecosystem services from concept to landscape change presents a complex, interconnected hierarchy of relationships and questions with a daunting number of unknowns and challenges throughout. At a high level there are questions about the fundamental relationships between biophysical and sociocultural systems. At finer scales, the biophysical processes associated with the provision of ecosystem services are poorly understood, for example carbon sequestration and nutrient cycling. This lack of scientific understanding makes it difficult to begin to characterize and quantify ecosystem services in ways that work with current exchange systems. There is a common motivation across disciplinary boundaries in ecosystem services research to make the concept operational in ways that are useful to decision-makers. There is an urgency to get information and practical frameworks into decision-making processes with the belief that this is the most expedient path to natural resource protection. With a sense of urgency comes a tendency to rely on what already exists rather than stepping back to ask if what is exists is well suited to the problem. The integration of knowledge and research from the disciplines of ecology and economics is a dominant theme in the current ecosystem services research agenda. This theme builds on the existing knowledge and perspectives of each discipline, and new insights will come from their integration. Ecology and economics are crucial in ecosystem services research; but, as I argued in Chapter II, other approaches could contribute different perspectives and perhaps additional operational pathways.

Research in a landscape approach to ecosystem services

Hierarchy

The hierarchy of ecosystem service relationships suggests a research structure for a landscape approach to ecosystem services. The foundation of the hierarchy is the landscape; it is here that the interdependencies of social and ecological systems will ultimately determine the provision of ecosystem services. A landscape's biophysical and sociocultural systems provide the next level in the hierarchy of a research framework. This distinction in the hierarchy should not be seen as a division of biophysical problems on one side and sociocultural problems on the other. Rather, it is a way to organize thinking and approaches to problems that are unique to different disciplines but does not lose sight of the whole. There are hierarchical scales of biophysical and sociocultural relationships and processes within the landscape. An example on the sociocultural side is the set of relationships among: 1) farming and non-farming communities, 2) a group of farmers that might participate in an ecosystem service district and, 3) relationships between two neighboring farmers. An example on the biophysical side are the indicators of biodiversity that could be measured 1) across floodplain forest habitats within the study area, 2) those that could be measured within a single patch of floodplain forest and, 3) those that could be measured in a microhabitat on the forest floor. Biophysical and sociocultural relationships are also at play within the hierarchical structure. Relationships within the farming community, and between farmers and non-farmers, combined with the availability of natural resources from the study area's biophysical component will determine the provision of ecosystem services at a landscape scale. At an intermediate level, the relationships among farmers participating in an ecosystem service district combined with the biophysical resources available from their individual farms will influence quantities of ecosystem service production. At a finer scale, the relationship that a farmer has with their own farm's biophysical resources will play a role in their decisions about ecosystem service production.

There are opportunities to address current gaps in ecosystem services knowledge within a hierarchical research framework. With the landscape as the foundation, ecosystem services that vary over space and time, such as carbon sequestration, can be studied across multiple variables. If floodplain forest is provided as an ecosystem service at the landscape extent, within that habitat are opportunities to study associated ecosystem services such as nutrient cycling and soil fertility. It has been noted that sociocultural relationships will be key in implementing ecosystem services (Daily 1999, Carpenter et al. 2006, Turner and Daily 2008, Fisher et al. 2009) and ideas about important qualities and collective decision-making have been proposed (Wilson and Howarth 2002, Spash 2008, Stallman 2011). Pretty (2003) lists four features that are important in collective action for common pool resources: 1) relations of trust; 2) reciprocity and exchanges; 3) common rules, norms and sanctions; and 4) connectedness in networks and groups. He also identifies bonding, bridging and linking as important types of connectedness. Kenward et al. (2011) conducted a study to identify effective governance strategies for resource management and sustainability. They found that the provision of ecosystem services was positively associated with adaptive management and knowledge leadership, and negatively associated with regulatory tools. In their concluding remarks, Kenward et al. state, ". . . our study sets the scene for investigating causality through planned experiments. . . . We envision . . . a socio-economic equivalent to landscape scale experiments in ecology . . ." In my proposed hierarchical research framework, such an inquiry can be conceived and evaluated not just as a socio-economic experiment but also in the broader context of the landscape as an evolving social/ecological system.

Exploring, learning by doing and adaptation

An important quality of my proposed approach is a place for research that includes exploration, learning by doing, adaptation, and experimentation that is broadly rather than narrowly defined. The concept of exploration is rooted in physical place but it applies elsewhere; to explore is to search out, to travel into or through an unfamiliar place. I have argued that incorporating ecosystem services into landscape function presents new and complex challenges and it is appropriate to acknowledge these as unfamiliar territory that could benefit from seeking out, as yet, unknown responses and opportunities.

Learning by doing uses the best available data and knowledge to initiate on-the-ground change with the acknowledgment that currently available information is likely to be imperfect and insufficient. Learning by doing includes the generation of new knowledge that can be used to adjust and adapt. The combination of adaptation and learning by doing are what Hallegatte et al. (2012) present as a cycle of learning, acting and revising. They also refer to this as action and learning in parallel and discuss it as part of a robust decision-making process. Action and learning in parallel can begin to address one of the major hurdles in moving ecosystem service approaches forward. There is a tendency to delay on-the-ground change with the hope that future data and knowledge will provide better guidance. However, generating new data and knowledge requires research and experimentation, and these are in need of the *in situ* 'laboratories' that could be provided by on-the-ground change.

Formal definitions of *experiment* often begin with reference to scientific methods, controlled conditions and demonstrations of truth. These narrow definitions offer a limited perspective of experimentation. Possibilities are opened by moving to broader definitions such as this one from the New Shorter Oxford English Dictionary: an experiment is a procedure or course of action tentatively adopted without being sure that it will achieve its purpose. This definition is appropriate for an ecosystem services approach in its acknowledgment of uncertainty in both process and outcome. If this definition is extended to include adaptation, it becomes part of an experimental action and learning process. In the experimental process, a course of action is tentative because it is a starting place and intended to change (adapt) based on new knowledge that is generated through action and learning.

A framework that includes established methods and ways of working along with those that are exploratory and more broadly experimental could offer a research foundation for ecosystem services that is strengthened by complementarity. Established methods can begin to fill identified knowledge gaps and research that is more exploratory has the potential to find pathways and opportunities that are presently unforeseen. If this framework is applied in a real-world context of learning, action and adaptation then landscape change becomes part of the research process.

Intentional change in landscape coevolution

Landscapes are physical expressions of the coevolutionary relationship between people and their biophysical environments. People combine available environmental resources with knowledge, skill, technology and values to create places within their environments to provide for their needs and, if possible, their wants. Scientific evidence over the past few decades documents the increasing consequences of the relationships that people have established with their environments. This has resulted in broader awareness about two important aspects of these consequences: 1) the biophysical resources are finite and have been diminished and degraded by use and, 2) people depend on these resources for basic life needs as well as enriching human experiences.

Because it is evolutionary, the relationship between people and their biophysical environment will change. Evidence suggests that, if people's current patterns and expectations persist, the change will come about by resources being so depleted that people's needs can no longer be met. People have an option to initiate a change with the intention of evolving landscape relationships in a different direction. There is an opportunity to develop an ecosystem services approach that plays a role in this redirection by offering an operational pathway in the process. In the implementation of an ecosystem services concept at a community level, people will need to grapple with questions about relationships with their biophysical resources, their fellow community members and future generations. Working through these questions along with active engagement in learning, doing and adaptation could be part of the coevolutionary process that intentionally changes the relationship between people and their environment.

Why a landscape approach to ecosystem services?

The relationships that people have with their biophysical environment and with each other are at the core of my proposed approach to ecosystem services. The qualities and evolution of these relationships matter for the long-term sustainable provision of natural resources to support and enhance people's lives. Relying solely on monetary valuation as the means to protect and sustain natural resources is somewhat tenuous. In the short-term it delays the implementation of on-the-ground change until monetary valuation can be established and assumes the monetary value of ecosystem services will be competitive with other uses. With monetary valuation approaches, the long-term provision of natural resources relies on their competitiveness in economic markets which operate to achieve relatively short-term objectives. This suggests that even if the production of ecosystem services is initiated, their long-term provision and protection is at risk from uses with greater monetary income potential. The intention of focusing on landscape relationships is to include aspects of people's values that are outside the bounds of monetary valuation but could play a role in landscape coevolution. The choices people make in their personal lives draw on a complex set of interacting values, one of which is monetary value. Monetary cost is frequently a constraint but where other values have higher priority, it is not the sole consideration. Examples of this include maintaining a particular quality of life and sending a child to college. Commitments based on a deeper set of personal values are more likely to endure than those based on monetary efficiency alone. Fostering and evolving a similar societal set of values regarding natural resources could offer greater security for the long-term provision of those resources than monetary valuation alone.

Some of the hurdles in a landscape approach are higher than those in approaches which focus on the monetary valuation of ecosystem services. It asks people to step away from this country's long established societal norms of short-term wealth production and personal gain to consider the long-term provision of collective landscape resources. Selecting a landscape scale that is relevant to people's personal experience makes it more likely that their values are connected to the landscape and run deeper than a monetary bottom line. In the near-term this connection can serve as motivation to consider monetary feasibility rather than wealth production to incorporate ecosystem services into landscape function. Perhaps more importantly, fostering the evolution of people's connection to the landscape and its resources contributes to the long-term security of natural resource provision. This is a long-term, coevolutionary approach in which people truly grasp the finite quality of nature's resources and set out to intentionally redirect the relationship that has evolved to this point.

APPENDIX A

WILLAMETTE RIVER BASIN AND WILLAMETTE VALLEY ECOREGION

The Pacific Northwest Ecosystem Research Consortium developed their three alternative future scenarios for the Willamette River Basin (WRB). The WRB includes the Willamette Valley Ecoregion (WMV), the Coast Range (west of the WMV) and the Cascade Range (east of the WMV).

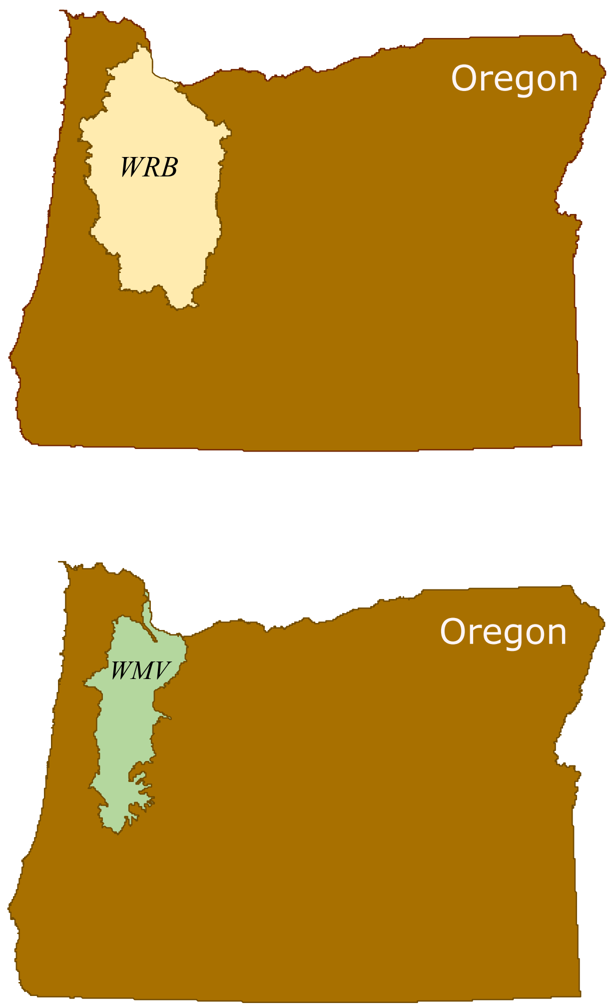


Figure 33. The Willamette River Basin and the Willamette Valley Ecoregion within Oregon.

APPENDIX B

PNW-ERC SCENARIO COMPARISON

TABLE 2. List of significant policies and quantities for each alternative-future scenario.

Parameter	1990	2050 Conservation	2050 Plan Trend	2050 Development
Population				
County totals	1 970 000	3 900 000	3 900 000	3 900 000
Urban (UGBs), %	1 691 600, 86%	3 649 000, 94%	3 616 300, 93%	3 377 100, 87%
Rural, %	278 400, 14%	251 000, 6%	283 700, 7%	523 400, 13%
Urban				
Density—gross residential dwelling units per ha (total WRB weighted average)	10.4	23.0 (average for new development 1990–2050)	19.5 (average for new development 1990–2050)	15.3 (average for new development 1990–2050)
Total area in UGBs	179 700 ha	201 500 ha	200 300 ha	231 900 ha
Area added to UGBs	···	21 800 ha	20 600 ha	52 200 ha
Rural residential				
Expansion area	Limited to rural residential zones and grandfathered parcels	50% clustered development adjacent to 1990 rural residential zones	Within existing 1990 rural residential areas only	Location determined by probability based on suitability for rural residences
Total rural structures	117 691	116 372	122 843	214 259
New structures added 1990–2050†	···	5204	12 382	108 070
Agriculture				
By LU/LC	569 000 ha	468 600 ha	553 200 ha	493 300 ha
By active farm uses	441 100 ha			
Riparian vegetation extent and timing	Range of vegetation types	All 1999 303(d) listed streams show riparian vegetation by 2020, plus all	303(d) listed streams increased 1990 riparian vegetation amount by 10% by	303(d) listed streams increased 1990 riparian vegetation amount by 10% by

Continued on the next page

Scenario comparison from the Pacific Northwest Ecosystem Research Consortium's (PNW-ERC) Willamette Alternative Futures, published in: Hulse, David, Allan Branscomb and Susan G. Payne. 2004. Envisioning Alternatives: Using Citizen Guidance To Map Future Land and Water Use. *Ecological Applications* 14(2):325-341.

TABLE 2. List of significant policies and quantities for each alternative-future scenario.

Parameter	1990	2050 Conservation	2050 Plan Trend	2050 Development
Forest				
Highlights of management intentions	Continuation of major trends observed from 1972 to 1994	Industrial forest land changes to private nonindustrial if population density is greater than 39 persons per km^2	Northwest Forest Plan for federal ownership, continuation of recent trends for others	Industrial land changes to private nonindustrial land if population density 27 persons per km^2
Clearcut patch size; federal, state, private, private nonindustrial	Nonindustrial 5.3 ha, others 12 ha	Industrial declines from 12 to 4 ha; others range from 2.3 to 5.3 ha	12 ha, 2.3 ha (private nonindustrial)	12 ha, 2.3 ha (private nonindustrial)
Proposed riparian vegetation				
Urban	As depicted in Fig. 1b LU/LC ca. 1990	Metro 60 m all streams. Other urban areas: 6–7th order, 30 m (Willamette River); 3–5th order, 15 m; 1–2nd order, 8 m	No riparian zones were designated to exclude development. No riparian vegetation was added within UGBs	No riparian zones were designated to exclude development. No riparian vegetation was added within UGBs
Agricultural	As depicted in Fig. 1b LU/LC ca. 1990	All streams have riparian vegetation (minimum: private, 30 m; public, 91 m) plus additional areas in tier 1 conservation zones	303(d) listed streams increase 1990 riparian vegetation amount by 10% in 30 m riparian zones	303(d) listed streams increase 1990 riparian vegetation amount by 10% in 30 m riparian zones
Forestry	As depicted in Fig. 1b LU/LC ca. 1990	Federal: 91 m (each side) all streams; state: 61 m all streams; private: 30 m minimum all streams, plus additional tier 1 legacy trees	Federal: 91 m (each side) on large fish-bearing streams, 46 m on small streams; all other lands: 21 m	Federal: 46 m large streams only (each side). None on other lands
Water use	Per state water rights database, in a moderately dry year.	Per capita municipal use 8.2% lower than Plan Trend; vacated irrigation rights transferred to instream use	Per capita municipal use projects extensions of recent trends	Per capita municipal use 12.5% greater than Plan Trend

† Some 1990 rural structures are absorbed into expanding UGBs and are no longer rural in 2050.

APPENDIX C

DISSERTATION SCENARIO DEVELOPMENT

2050 Scenario development

Background

As discussed in Chapter 3, the Pacific Northwest Research Consortium's (PNW-ERC) representation of a current landscape was developed for circa 1990 conditions. Each of their three future landscape representations (Plan Trend 2050, Conservation 2050 and Development 2050) were modeled from the 1990 current condition using operational guidelines based on assumptions particular to each scenario. The landscape representations were modeled in 10 year time steps; i.e. there are modeled landscape representations of Conservation 2000, 2010, 2020, 2030 and 2040 that incrementally develop the Conservation 2050 landscape. I also discuss in Chapter 3 my reasons for choosing a current condition representation (circa 2000) that was developed subsequent to the PNW-ERC's project. Although the same data sources (for example Landsat TM), processing steps and land use/ land cover classes were used for the 1990 and 2000 representations, the results are sometimes inconsistent. This is due in large part to cover classes where confidence in accurate classification from satellite imagery is low, for example distinguishing pasture from natural shrub or grassland.

The PNW-ERC's Conservation 2050 representation develops coherently in 10 year increments from the 1990 representation. The PNW-ERC's modeled 2000 representation is based on scenario assumptions applied to the 1990 representation. There are inconsistencies between the PNW-ERC's *modeled* 2000 representation and the circa 2000 update that I use to represent current conditions. These inconsistencies can be attributed to the previously noted challenges in land cover classification and also the difference in a modeled future landscape based on a set of assumptions versus one based on newly collected data. The inconsistencies in the 2000 representations (modeled vs. update) present problems in pairing the circa 2000 update with the 2050 modeled landscape. One of the most obvious inconsistencies is that there are 6,592 acres of mixed forest in my study area in the circa 2000 updated landscape and there are 6,067 acres of the same forest classes in the PNW-ERC's Conservation 2050. This apparent decrease in forest is logically inconsistent in a floodplain forest landscape on a conservation trajectory. The inconsistencies are also evident at a finer spatial grain. Keeping with the forest example, although the number of forest acres are essentially the same in the 2000 representation and the PNW-ERC's Conservation 2050 representation (6,592 in 2000 and 6,067 in 2050), only 2,806 of those acres are in the same location.

To the degree possible, landscape inconsistencies were addressed as I modified the PNW-ERC's Conservation 2050 scenario to include ecosystem services. For example, in addressing the forest inconsistencies, if a grid cell was one of the mixed forest classes in the 2000 representation, it remained in that same class in my modification of the PNW-ERC's Conservation 2050 representation. The result is a 2050 representation of mixed forest that includes all mixed forest present in the 2000 representation and any additional forest present in the PNW-ERC's Conservation 2050 representation. For comparison, the mixed forest classes in the PWW-ERC's 2050 landscape are 9.4% of the study area's acreage and they are 13.2% in my modified 2050 landscape. The modification of mixed forest achieves two objectives: it increases the amount of floodplain forest (one of my three ecosystem services) and increases the total amount of forest between 2000 and 2050 in a way that is consistent with a floodplain forest landscape on a trajectory intended to increase ecosystem services and habitat conservation. Tables 17 and 18 compare the landscape representations of LULC 2000, my dissertation 2050 and the PNW-ERC's Conservation 2050.

Modifying PNW-ERC's Conservation 2050 scenario

For the purpose of my dissertation, I have modified the PNW-ERC's Conservation 2050 scenario to include the production of ecosystem services in the agricultural landscape. My representations of agriculture and natural vegetation differ from those of PNW-ERC; my representations of water and built classes are identical to those of PNW-ERC.

Guidelines for modification based on farmer interviews

Based on my interviews with them, farmers are most interested in crop alternatives where land is currently in grass seed production. This ground generally presents more limitations for agricultural crop production than ground that is planted in row or field crops. Recent trends in grass seed markets also have farmers questioning the

Table 18. Land use/ land cover 2000, 2050 dissertation scenario and PNW-ERC Conservation scenario.

Value	*Land use/ land cover*	*2000 (acres)*	*2050 Dissertation scenario (acres)*	*Conservation 2050 PNW-ERC (acres)*
1	Residential 0 - 4 DU/ac	1,039	991	991
2	Residential 4 - 9 DU/ac	152	229	229
3	Residential 9 - 16 DU/ac	20	46	46
4	Residential > 16 DU/ac	3	10	10
6	Commercial	160	152	152
7	Commercial/Industrial	240	15	15
8	Industrial	42	165	165
10	Residential and commercial	0	1	1
11	Urban non-vegetated unknown	251	150	150
16	Rural structures	289	290	290
18	Railroad	100	100	100
20	Secondary roads	350	350	350
21	Light duty roads	1,124	1,099	1,099
24	Rural non-vegetated unknown	274	1,068	1,068
29	Main channel non-vegetated	77	399	399
32	Stream orders 5 - 7	0	3,401	3,401
33	Water	4,486	1,918	1,918
49	Urban tree overstory	53	168	184
52	Forest semi-closed mixed	395	321	0
53	Forest closed hardwood	5,500	6,780	4,498
54	Forest closed mixed	698	1,810	1,565
55	Upland semi-closed conifer	0	5	5
56	Conifer 0-20 yrs	109	0	0
58	Forest closed conifer 41-60 yrs	1	3	4
59	Forest closed conifer 61-80 yrs	3	18	52
60	Forest closed conifer 81-20	2	26	44
61	Forest closed conifer >200y	0	1	2
66	Hybrid poplar	66	214	219

Table continued on next page

Table 18 continued. Land use/ land cover 2000, 2050 dissertation scenario and PNW-ERC Conservation scenario.

Value	*Land use/ land cover*	*2000 (acres)*	*2050 Dissertation scenario (acres)*	*Conservation 2050 PNW-ERC (acres)*
67	Grass seed rotation	17,812	10,618	23,058
68	Irrigated annual rotation	10,763	7,552	2,085
71	Grains	3,011	1,473	0
72	Nursery	472	404	17
73	Caneberries & Vineyards	558	202	62
74	Double cropping	181	54	26
76	Mint	1,617	890	94
78	Sugar beet seed	477	259	17
79	Row crop	0	342	390
80	Grass	0	592	1,483
81	Burned grass	0	1	2
82	Field crop	0	790	912
83	Hay	2,973	4,101	2,896
84	Late field crop	0	258	293
85	Pasture	1,493	4,353	4,122
86	Natural grassland	1,541	3,940	3,873
87	Natural shrub	2,880	4,791	5,206
88	Bare/fallow	921	714	271
89	Flooded/marsh	13	609	950
90	Irrigated field crop (perennial)	3,188	1,605	294
91	Turfgrass/park	606	129	149
92	Orchard	352	529	591
93	Christmas trees	587	449	493
95	Woodlot	5	271	273
98	Oak	154	169	219
101	Wet shrub	0	211	303

	LULC 2000 (acres)	*2050 Dissertation scenario (acres)*	*PNW-ERC Conservation 2050 scenario (acres)*
Built environment			
Built	4,121	5,064	5,064
Urban vegetation	659	297	333
Built subtotal (acres)	***4,780***	***5,361***	***5,397***
Forest and natural vegetation			
Mixed forest	6,592	8,915	6,067
Conifer forest (aged classes)	115	49	103
Natural shrub	2,880	4,791	5,206
Natural grassland	1,541	3,940	3,873
Marsh/ wet shrub	13	820	1,253
Oak	154	169	219
Forest/ natural subtotal (acres)	***11,295***	***18,684***	***16,721***
Agriculture			
Grass seed rotation	17,812	11,212	24,542
Hay/ pasture	4,465	8,454	7,018
Berry, vineyard, orchard, perennial	4,098	2,335	947
Row crops, grains	17,442	12,736	4,106
Woody crops	658	934	986
Agriculture subtotal (acres)	***44,475***	***35,671***	***37,598***
Water	***4,486***	***5,320***	***5,320***

Table 19. Aggregated land use/ land cover comparison.

dependability of future income from grass seed crops. In modifying PNW-ERC's Conservation 2050 scenario, I have focused on particular agricultural crops (primarily grass seed) as places where conventional agricultural crops could be transitioned for the production of ecosystem services (floodplain forest, carbon sequestration).

Specific modifications of PNW-ERC's Conservation 2050 landscape representation

Forest

If a grid cell is mixed forest (values 52 - 54) in land use/ land cover 2000 (LULC 2000), it remains in that same forest class in 2050. Mixed forest in 2050 includes mixed forest from LULC 2000 and any additional mixed forest present in the PNW-ERC's Conservation 2050.

Natural shrub

Grid cells that are natural shrub (value 87) in LULC 2000 and specific agricultural crops or natural grassland in PNW-ERC's Conservation 2050, remain natural shrub in 2050. These classes are: grass seed rotation (67, 80, 81), hay (83), pasture (85) and natural grassland (86).

Natural grassland

Grid cells that are natural grassland (86) in LULC 2000 and grass seed rotation or agricultural crops with a carbon biomass value of zero (refer to Nelson et al. 2009 appendix, Table 2) in PNW-ERC's Conservation 2050, remain natural grassland in 2050.

Grass seed rotation

Grass seed rotation is considered and processed after the above modifications of forest, natural shrub and natural grassland. Grid cells are excluded from processing in this step if they were grass seed rotation in PNW-ERC's Conservation 2050 and have already been reclassed to forest, natural shrub or natural grassland for the 2050 landscape. After this exclusion, grid cells that are grass seed rotation in PNW-ERC's Conservation 2050 and a different agricultural class in LULC 2000 remain in their LULC 2000 class in 2050.

Water and built classes

I have incorporated PNW-ERC's Conservation 2050 representation of water and built classes in my version of a 2050 landscape. The final step in processing the 2050 landscape representation corrects any unintended modifications of water and built classes by imposing PNW-ERC's representation of these classes.

APPENDIX D

DATA PROCESSING FOR THE INTERPOLATED BATHYMETRIC SURFACE

D1. Preliminary data processing

The USGS 2002 data were obtained as text files with a northing, an easting and an elevation in meters for each data point. The northing and easting were used to create a spatially referenced point file (GIS) with the elevation value as an attribute field. The Gregory 2011 data were received as .csv and .xls files with latitude, longitude and depth in meters for each data point. The latitude and longitude were used to create a spatially referenced point file (GIS) with the depth value as an attribute field. Both data sets were processed to have the same spatial reference system as the Lidar data and the elevation values were converted to feet. The spatial reference system for the Lidar data is Oregon Lambert (a Lambert conic conformal system unique to the state of Oregon); the units for this system are international feet.

Oregon Lambert
Projection: Lambert Conic Conformal
Datum: NAD83
Units: International Feet, 3.28084 (.3048 Meters)
Spheroid: GRS1980
1st Standard Parallel: 43 00 0.000
2nd Standard Parallel: 45 30 0.000
Central Meridian: -120 30 0.000
Latitude of Projection's Origin: 41 45 0.000
False Easting: 400000.00000 Meters
False Northing: 0.00000 Meters

D2. Updating the USGS 2002 data

It has been a decade since the USGS data were collected and, in a few locations, the river has changed enough that modifications were needed. The 2009 NAIP images showed locations where the river had migrated significantly from its 2002 course. In these locations I deleted the USGS centerline points over the distance of the migration and added points (over that distance) with interpolated bathymetry values using points just upstream and downstream of the migration.

D3. Converting Gregory's 2011 depth values to elevation

The data collected by Gregory in 2011 report depth to the channel bottom rather than elevation. Creating the Lidar/ bathymetry surface requires elevation values. The 2002 USGS data were collected with considerable attention to elevation values and reference points (USGS 2003) and therefore are considered a more accurate representation of elevation values. However, the USGS 2002 data only cover the mainstem, not side channels or alcoves. The purpose of the following process is to approximate side channel elevation relative to the 2002 USGS mainstem elevation so that side channel bathymetry can be included in the study area's Lidar/ bathymetry surface.

Each side channel or alcove is associated with three types of points (Figure 1):
1) the group of side channel or alcove points (from Gregory 2011)
2) an associated group of ten points from the mainstem (from Gregory 2011)
3) one mainstem centerline elevation reference point (from USGS 2002)

The group of side channel or alcove points were manually selected in ArcMap with the data displayed over the 2009 NAIP imagery. The ten mainstem points (from Gregory 2011) and mainstem (centerline) reference point (from 2002 USGS) for each side channel or alcove were selected in consultation with Stan Gregory. The objective was to have the points be representative of the mainstem bathymetry near the side channel or alcove. In general, each group of ten 2011 mainstem points has five points upstream and five points downstream from the USGS 2002 mainstem reference point.

The average depth value is calculated for the ten Gregory 2011 mainstem points (mainstem average depth). For each point in the associated side channel, the difference between the mainstem average depth and the side channel depth is calculated (calculated depth difference = side channel depth - mainstem average depth). If the side channel point is deeper than the mainstem average, the calculated value is positive; if the side channel point is more shallow than the mainstem average, the value is negative. To assign an elevation value to each side channel point, the calculated depth difference is subtracted from the associated 2002 USGS mainstem elevation value. If the mainstem is deeper than a side channel point, the calculated depth difference is negative. The result of subtracting this negative value from the USGS mainstem elevation value is to *add* it to the mainstem elevation value, i.e. - the elevation in the mainstem is lower (mainstem is deeper) than the elevation in the side channel (it is shallower).

For example:
the mainstem average depth (of the 10 mainstem points) = 10’
a side channel depth for one of the points = 4’
calculated depth difference = 4’ – 10’ = - 6’
the mainstem reference elevation (from USGS 2002) = 180’
calculated elevation for the side channel point with 4’ depth = 180’ – (- 6’) = 186’.

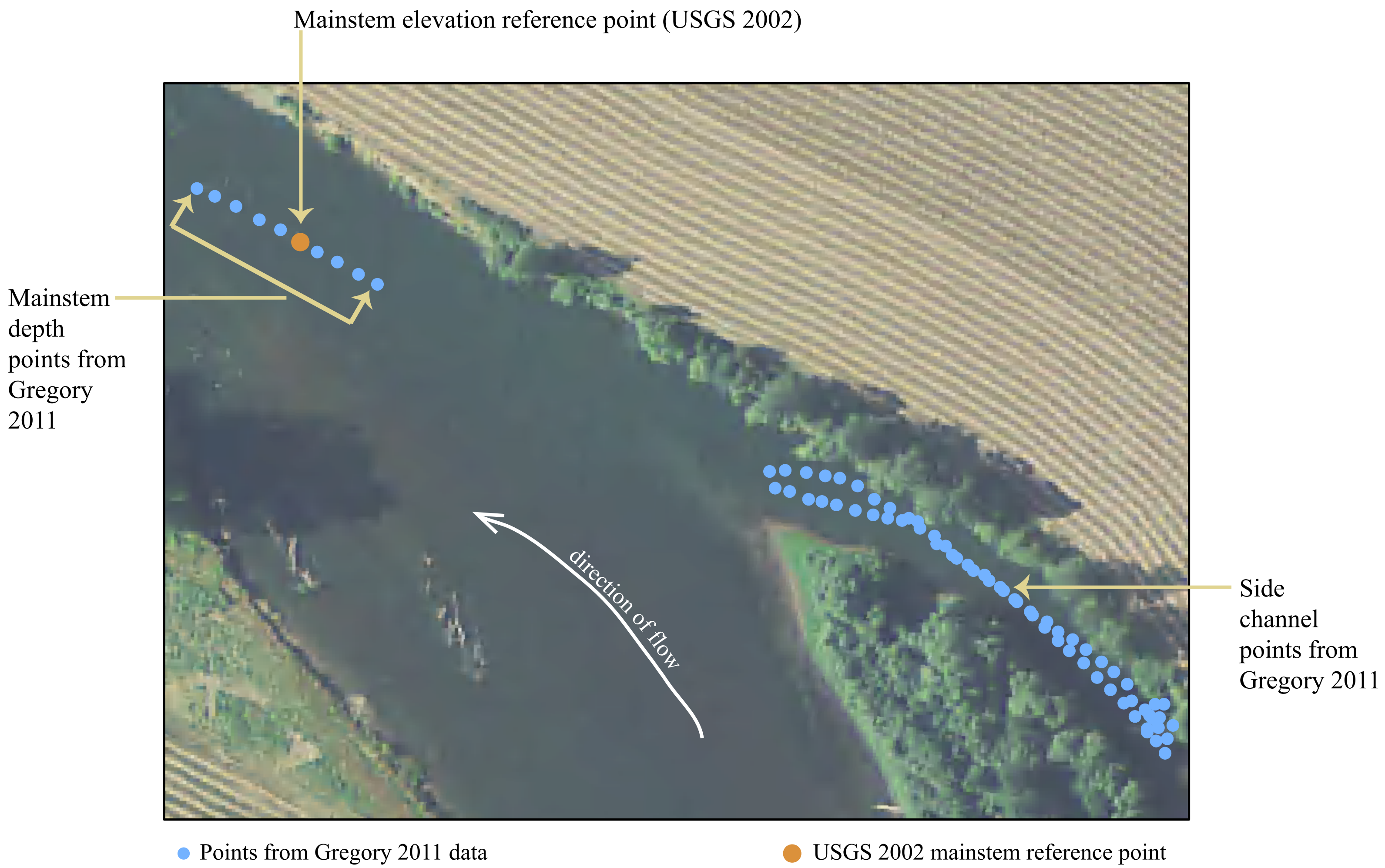


Figure 34. Data processing for side channel elevation. Elevation values were assigned to each side channel point using a series of calculations to determine side channel elevation values relative to the USGS 2002 mainstem reference point.

APPENDIX E

DATA PROCESSING FOR THE LIDAR/ BATHYMETRY SURFACE

Data processing used ArcGIS version 9.3
In the following narrative the terms grid (grid cell) and raster (raster cell) are used interchangeably.

The Lidar/ bathymetry surface maintains the same spatial reference system (Oregon Lambert. details below) and resolution (3' cell size) as the Lidar source data.

Oregon Lambert

Projection: Lambert Conic Conformal
Datum: NAD83
Units: International Feet, 3.28084 (.3048 Meters)
Spheroid: GRS1980
1st Standard Parallel: 43 00 0.000
2nd Standard Parallel: 45 30 0.000
Central Meridian: -120 30 0.000
Latitude of Projection's Origin: 41 45 0.000
False Easting: 400000.00000 Meters
False Northing: 0.00000 Meters

E1. Lidar mosaic

The Lidar source data were delivered as quadrangle sections. The quadrangle sections covering the study area were clipped to the study area boundary then mosaiced into a single raster file (grid) in Arc (Toolbox > Data management > Raster > Raster dataset > Mosaic to New Raster). In the processing options, Pixel type is *32 bit float* and mosaic method is *mean*.

E2. Channel Boundary

The polygonal boundary where the bathymetric surface joins the Lidar surface was manually digitized in ArcMap. The 2009 NAIP imagery, the Lidar elevation surface and hillshade created from the Lidar elevation data were used as guides to determine where the water surface in the mainstem or side channel meets the land surface (i.e. the bank). Inside of the polygonal boundary, an interpolated bathymetric surface is created from the USGS 2002 points and the Gregory 2011 points. This bathymetric surface is then integrated with the Lidar surface outside of the boundary.

E3. Bathymetric surface

Four sets of points were appended into a single vector file (shapefile) which served as the input for the interpolated bathymetric surface (Figures 10b, c and 11b):

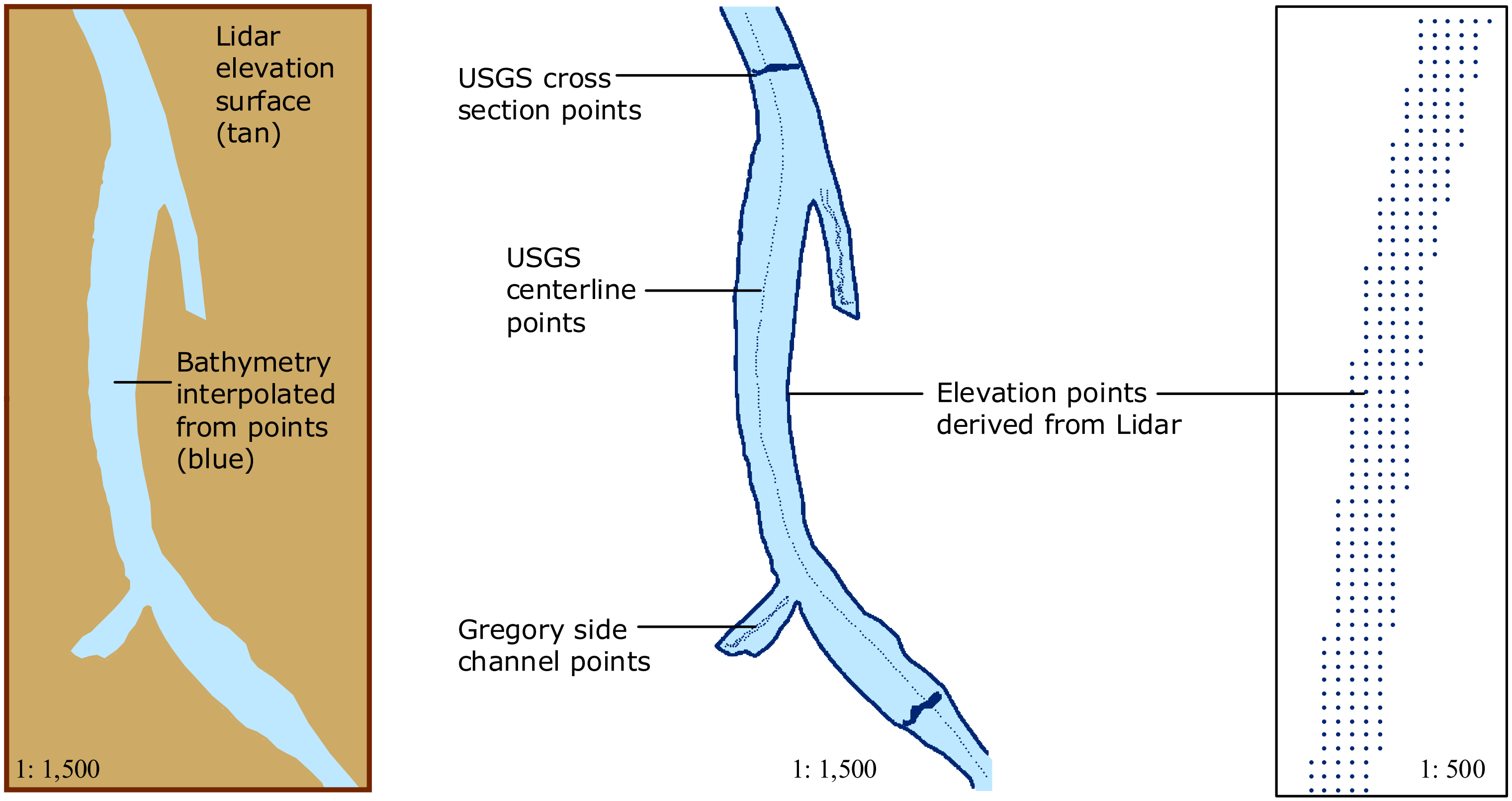
1) USGS 2002 centerline points
2) USGS 2002 cross section points
3) Gregory 2011 side channel points
4) Lidar points at the boundary where the interpolated bathymetric surface meets the Lidar surface. These points correspond to a 15’ band outside of the polygonal channel boundary (from E2 above). A 15’ buffer was created outside of the polygonal channel boundary; this buffer was used to select grid cells from the Lidar. The grid cells in this 15’ band were converted to a set of vector points, each point with an elevation attribute from the Lidar data. This set of 15’ boundary points serves two purposes: 1) the elevation values are used in the interpolation operation for the bathymetric surface and, 2) the points are used as ‘anchors’ to integrate the interpolated bathymetric surface into the Lidar surface.

E4. Interpolation

The vector file which includes the four sets of points described in E3 is the input file for a natural neighbor interpolation process in ArcGIS (Arc Toolbox > Spatial analyst > interpolation > natural neighbor). The interpolation method was chosen by processing a subset of the points with each of Arc’s interpolation options. In comparing the output from each interpolation option, the natural neighbor remained truest to the input point elevation values and produced smoother transitions across the interpolated area. Compared to the other outputs, these qualities are more consistent with the purpose of this project.

E5. Joining the bathymetric surface to the Lidar surface

Integrating the bathymetric surface with the Lidar surface requires a version of the Lidar surface with NoData where the final surface will have values from the bathymetric interpolated surface. A raster version of the channel boundary (from E2) was used for this purpose.



A Lidar/ bathymetry surface was created by integrating an interpolated bathymetric surface with the Lidar elevation surface.

Points for the bathymetric interpolation are from 4 sources:
1) USGS 2002 centerline points
2) USGS 2002 cross section points
3 Gregory 2011 side channel points
4) Elevation points derived from Lidar data
(at the channel boundary)

The boundary of the bathymetric surface overlaps with and has elevation values from the Lidar surface. The bathymetric surface is integrated with the Lidar surface at this boundary using the mosaic process in ArcGIS.

Figure 35. Subset of the study area showing details of processing for the Lidar/bathymetry surface.

The final integrated bathymetric/ Lidar surface was created in ArcGIS (Toolbox > Data management > Raster > Raster dataset > Mosaic to New Raster) with two inputs:

1) the Lidar surface with NoData for grid cells where elevation values come from the interpolated bathymetric surface.

2) the interpolated bathymetric surface from E4

The two input data sets overlap in the territory of the 15' band created in E3. In this territory, the two data sets have the same grid cell values (elevation) that correspond to values from the Lidar source data.

In the mosaic processing options, Pixel type is *32 bit float* and mosaic method is *mean*.

APPENDIX F

DATA PROCESSING FOR THE MODELED SIDE CHANNEL EXCAVATIONS

ArcGIS 9.3 (ArcMap, ArcToolbox and ArcInfo) were used for data processing

Data processing for the modeled excavation used ArcGIS 9.3 software (ArcMap, ArcToolbox and ArcInfo) from Environmental Systems Research Institute (ESRI).

For Sites B and C the process began with a clip of the analysis extent from the Lidar/ bathymetry surface. For the analysis extent of each of these sites, a series of raster subtraction operations produced the excavated surface. The process incrementally lowered the elevation within the analysis extent to values below the water surface elevation. The objective was to model a modest excavation which decreased elevation below the water surface at least 0.5’ to 1.0’. Rather than lower the entire analysis extent to the same elevation, the surface was lowered in a way that might occur in the field; the modeled excavation removed more from the highest starting elevations and less from starting elevations that were closer to, but higher than, the water surface elevation.

Site B

For the analysis extent at Site B:
Lidar/ bathymetry elevation range, starting surface: 193.595’ - 216.698’
Water surface elevation range : 206.013’ - 206.802’

Data processed in ArcInfo, Grid using 6’ cell
Starting grid: ls_11a
Grid: id11_adj1 = con(LS_11A > 214, LS_11A - 10, LS_11A)
Grid: id11_adj2 = con(id11_adj1 > 212, id11_adj1 - 7.5, id11_adj1)
Grid: id11_adj3 = con(id11_adj2 > 210, id11_adj2 - 6.5, id11_adj2)
Grid: id11_adj4 = con(id11_adj3 > 205, id11_adj3 - 2.5, id11_adj3)
Grid: id11_op2 = con(id11_adj4 >= 207, id11_adj4 - 1, id11_adj4)
Grid: id11_op3 = con(id11_op2 > 205, 205, id11_op2)
id11_op3 range of values: 193.6’ - 205.0’

Site C

For the analysis extent at Site C:
Lidar/ bathymetry elevation range, starting surface: 293.045’ - 302.379’
Water surface elevation range : 299.441’ - 299.899’

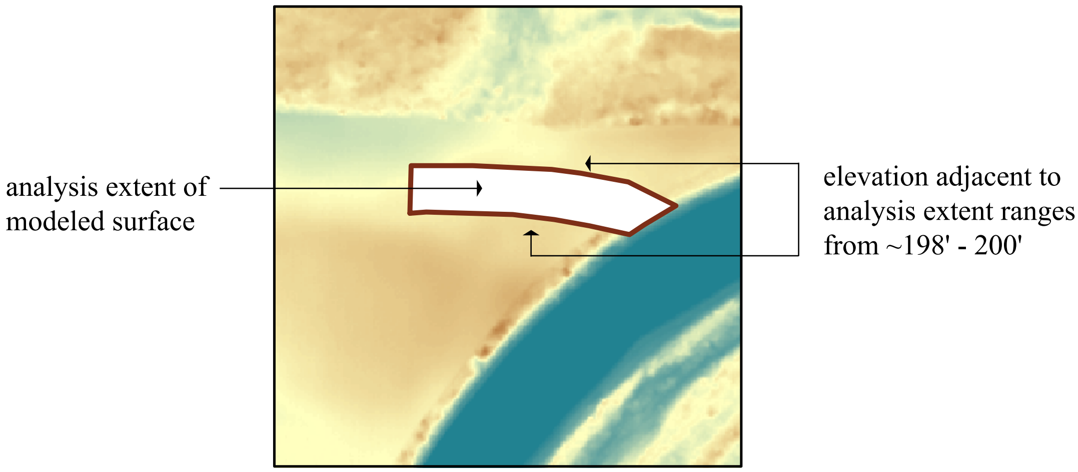
Data processed in ArcInfo, Grid using 6’ cell
Starting grid: id1_ls (293.045’ - 302.379’)
Processing:
Grid: id1_adj1 = con(id1_ls > 301, id1_ls - 4, id1_ls)
Grid: id1_op2 = con(id1_adj1 > 299, id1_adj1 - 2.5, id1_adj1)
Grid: id1_op2b = con(id1_op2 > 298.5, id1_op2 - 0.5, id1_op2)

id1_op2 range of values: 293.045 - 298.5

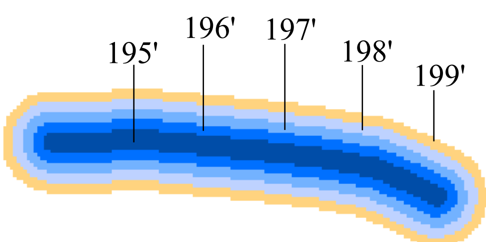
Site A

The channel reconnection at Site A required different processing due to the surrounding topography, much of which is near or just below the 2-year water surface elevation. At this site it is necessary to create a channel that is below the water surface elevation *and* the surrounding topography to direct water from the mainstem to the identified 2050 channel. At this site, a series of buffers were created to model a channel that would connect the mainstem to the 2050 channel (Appendix C, Figure 1). The lowest point of the modeled channel is at the channel center with elevation values increasing to tie into the surrounding topography. The buffers were created as vectors and assigned elevation values. A surface grid with 6’ cell size was created from the vector file and clipped to a size slightly larger than the analysis extent. Arc Toobox ‘mosaic to new raster’ was used to incorporate the new channel surface into the Lidar/ bathymetry surface using the ‘mean’ option for the mosaic method.

Lidar bathymetry surface showing analysis extent for Site A.



Buffer with elevation values that is mosaiced into Lidar/ bathymetry surface shown in Figure 13.



Grid cells with the value of 195' are the lowpoint (center) of the modeled side channel. Elevation increases in 1' increments to 199'. The cells with value 199' (and some of the 198' cells) overlap with the cells adjacent to the analysis extent in the Lidar/ bathymetry surface. The values for the overlapping cells are averaged in the mosaic process.

Cross section of modeled side channel with elevation values corresponding to the buffer values

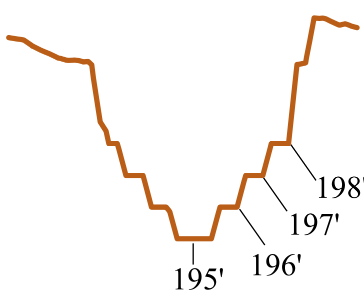
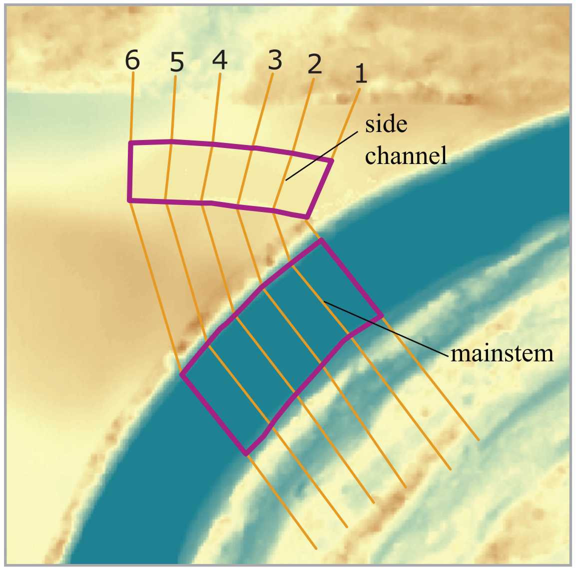


Figure 36. Excavated surface modeled with buffers at Site A.

APPENDIX G

CROSS SECTIONS FOR SITES A, B AND C

Site A - Cross sections



Surface elevation

222 ft

AMSL

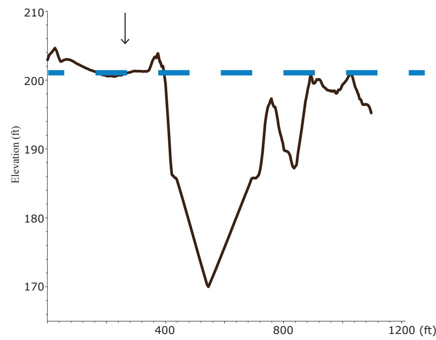
159 ft

Analysis extent

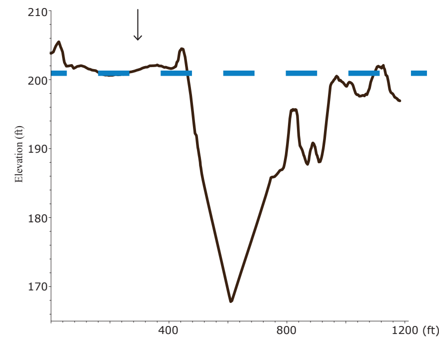
1: 6,000

Bathymetry is shown for the before and after side channel modeled excavation at each cross section (numbered 1 - 6) for Site A. The cross sections show the side channel and mainstem Willamette. The mainstem bathymetry stays the same in the before and after representations.

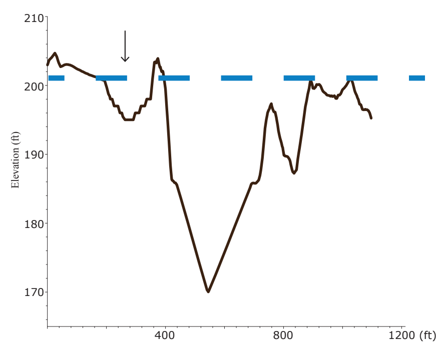
XS 1 before



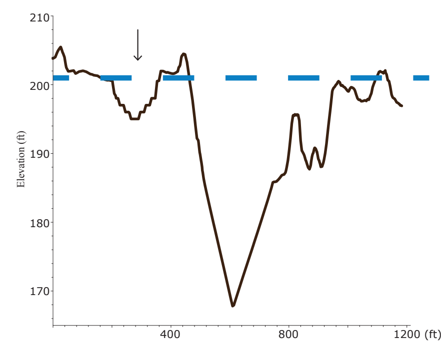
XS 2 before



XS 1 after



XS 2 after

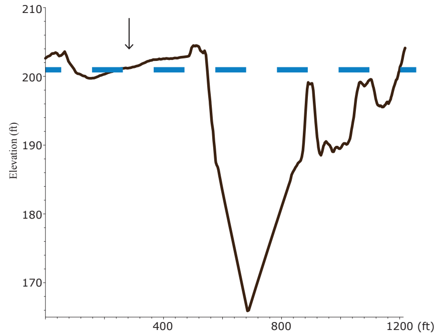


Water surface at 2-year flood

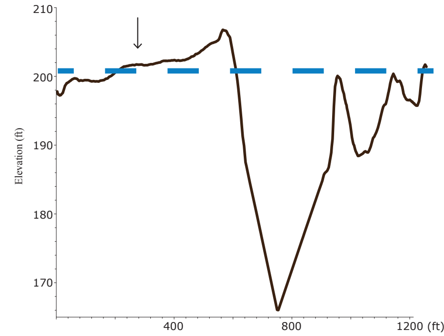
The arrow indicates the same side channel location in each before and after cross section pair.

Site A - Cross sections continued

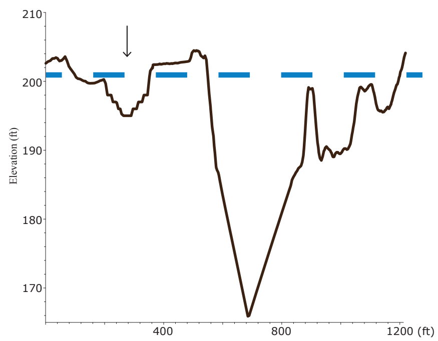
XS 3 before



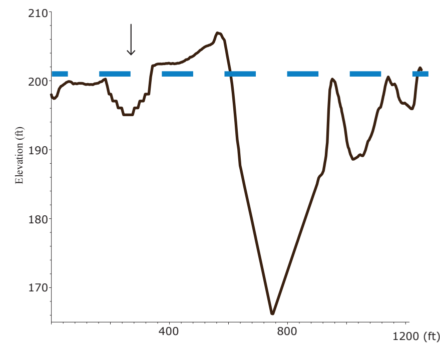
XS 4 before



XS 3 after



XS 4 after

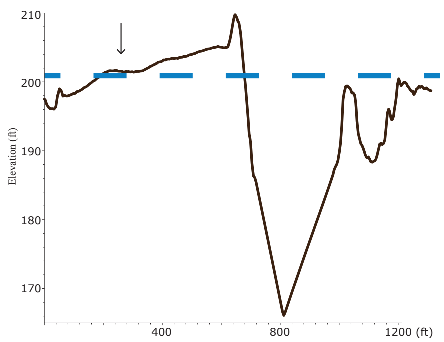


Water surface at 2-year flood

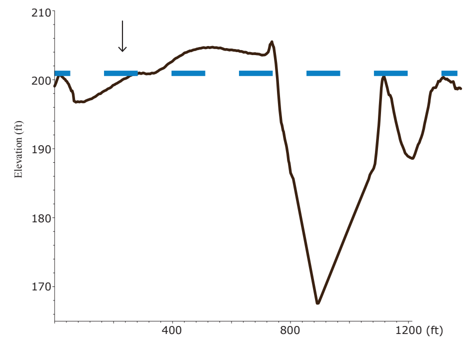
The arrow indicates the same side channel location in each before and after cross section pair.

Site A - Cross sections continued

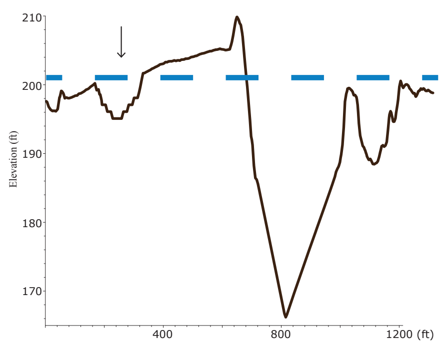
XS 5 before



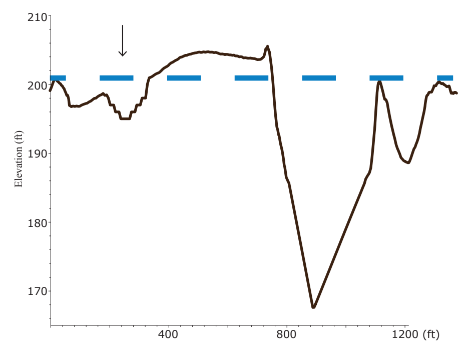
XS 6 before



XS 5 after



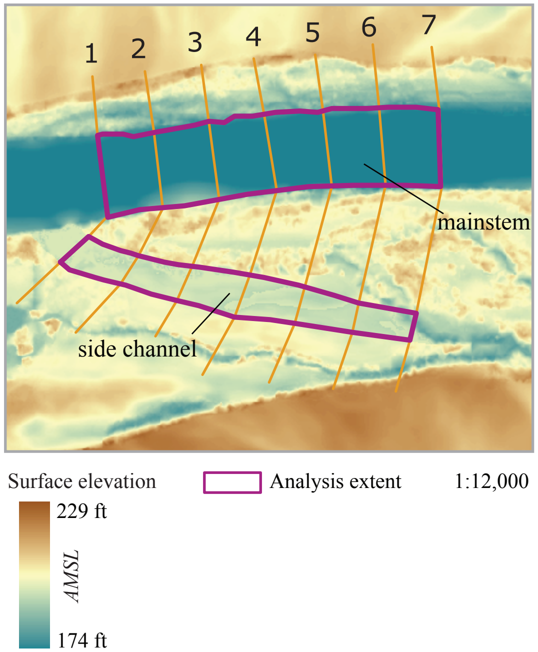
XS 6 after

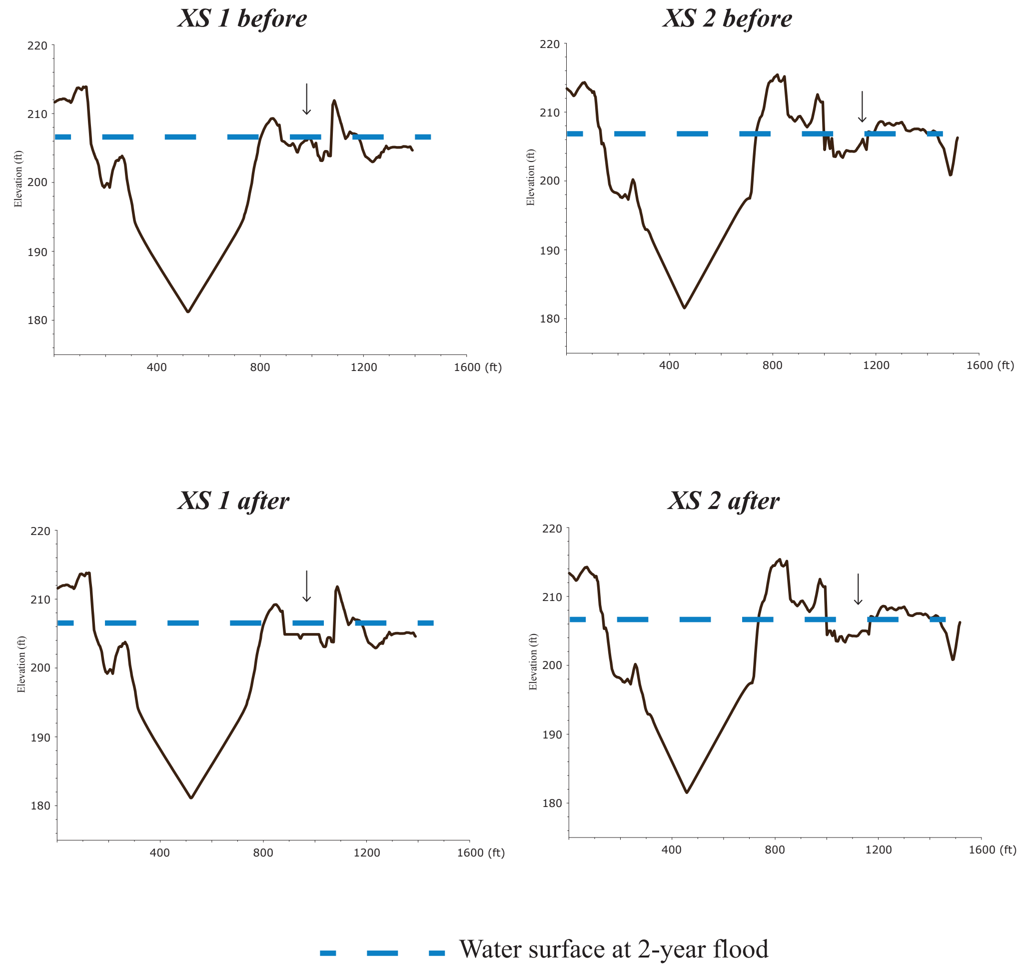


Water surface at 2-year flood

The arrow indicates the same side channel location in each before and after cross section pair.

Site B - Cross sections



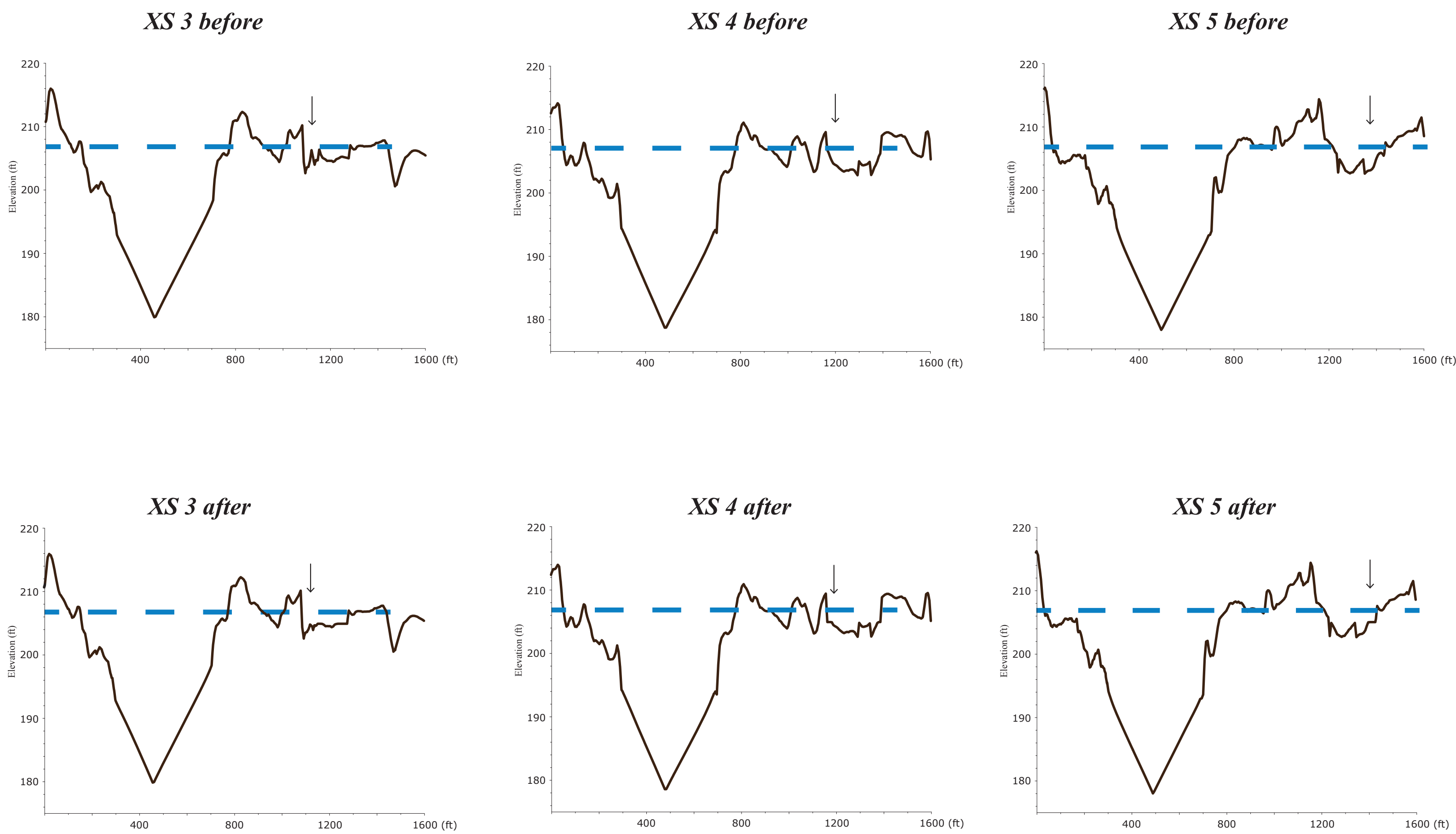


Bathymetry is shown for the before and after side channel modeled excavation at each cross section (numbered 1 - 7) for Site B. The cross sections show the side channel and mainstem Willamette. The mainstem bathymetry stays the same in the before and after representations.

The arrow indicates the same side channel location in each before and after cross section pair. The excavation at most cross sections for Site B is minimal.

The arrow indicates the same side channel location in each before and after cross section pair.

Site B - Cross sections continued

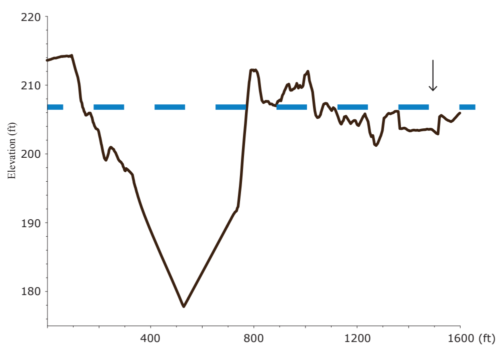


Water surface at 2-year flood

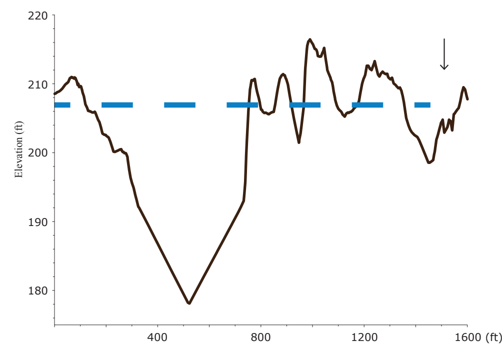
The arrow indicates the same side channel location in each before and after cross section pair.

Site B - Cross sections continued

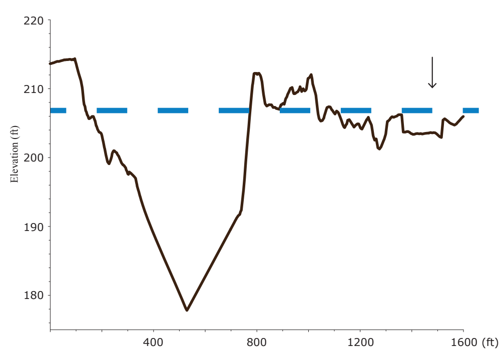
XS 6 before



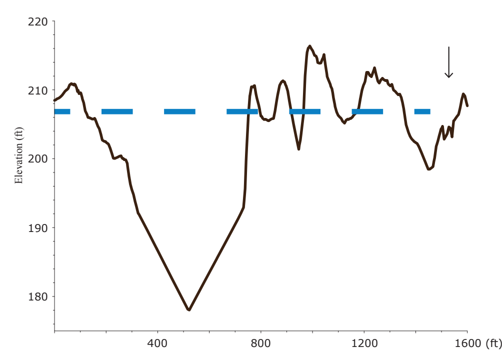
XS 7 before



XS 6 after



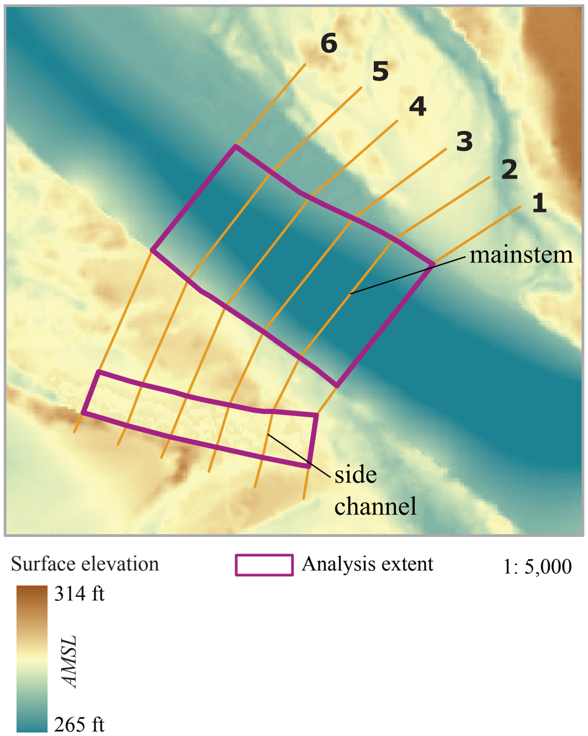
XS 7 after

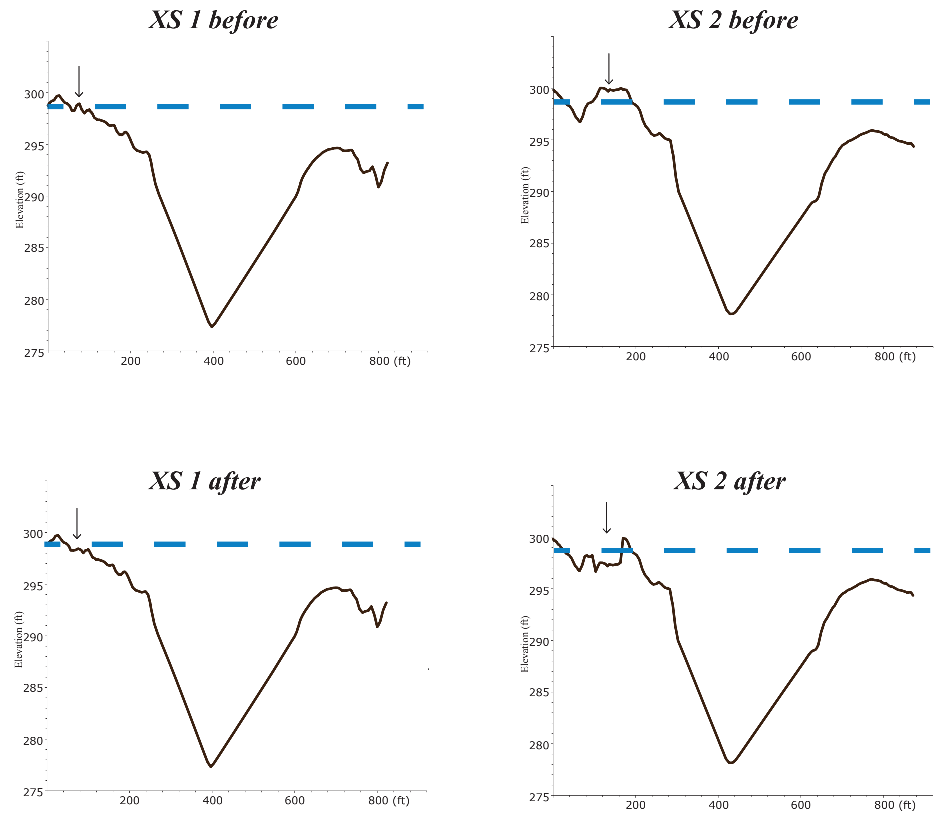


Water surface at 2-year flood

The arrow indicates the same side channel location in each before and after cross section pair.

Site C - Cross sections



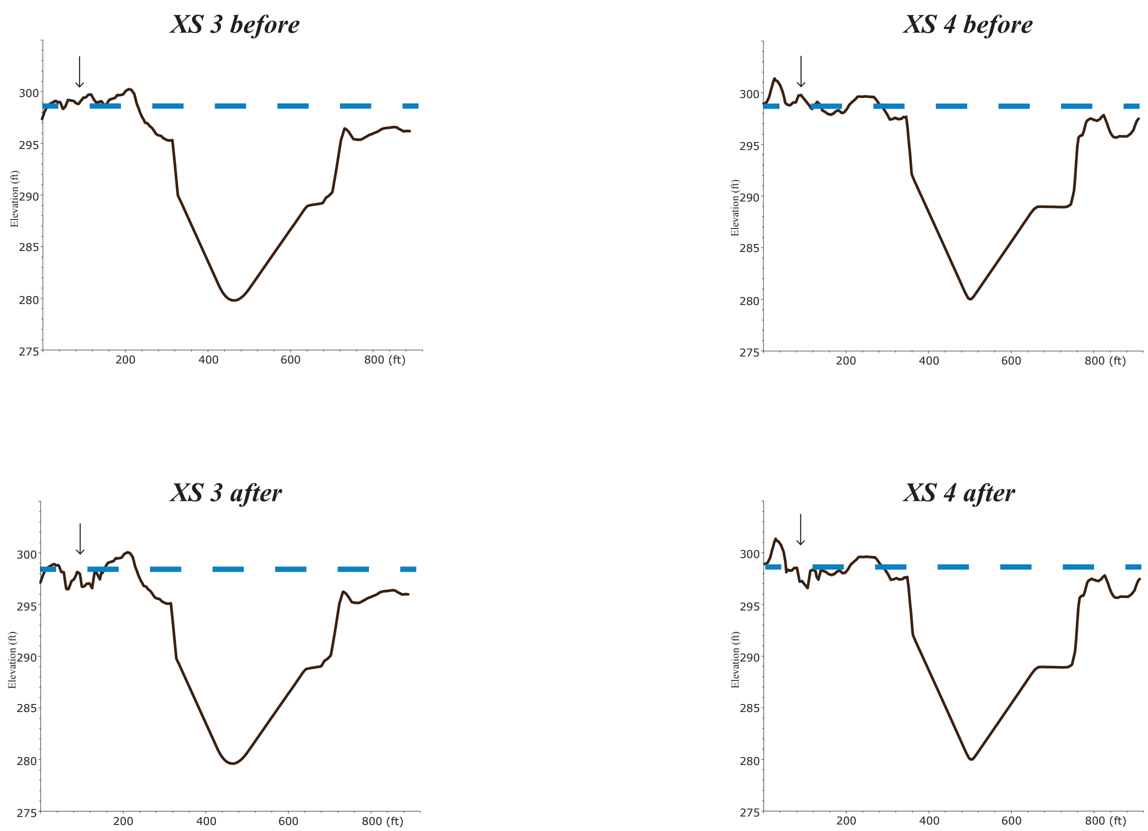


Bathymetry is shown for the before and after side channel modeled excavation at each cross section (numbered 1 - 6) for Site C. The cross sections show the side channel and mainstem Willamette. The mainstem bathymetry stays the same in the before and after representations.

Water surface at 2-year flood

The arrow indicates the same side channel location in each before and after cross section pair.
In some cases, for example XS 2, the modeled excavation is clearly visible.
In others, for example XS 1, the exacavation is minimal and less obvious.

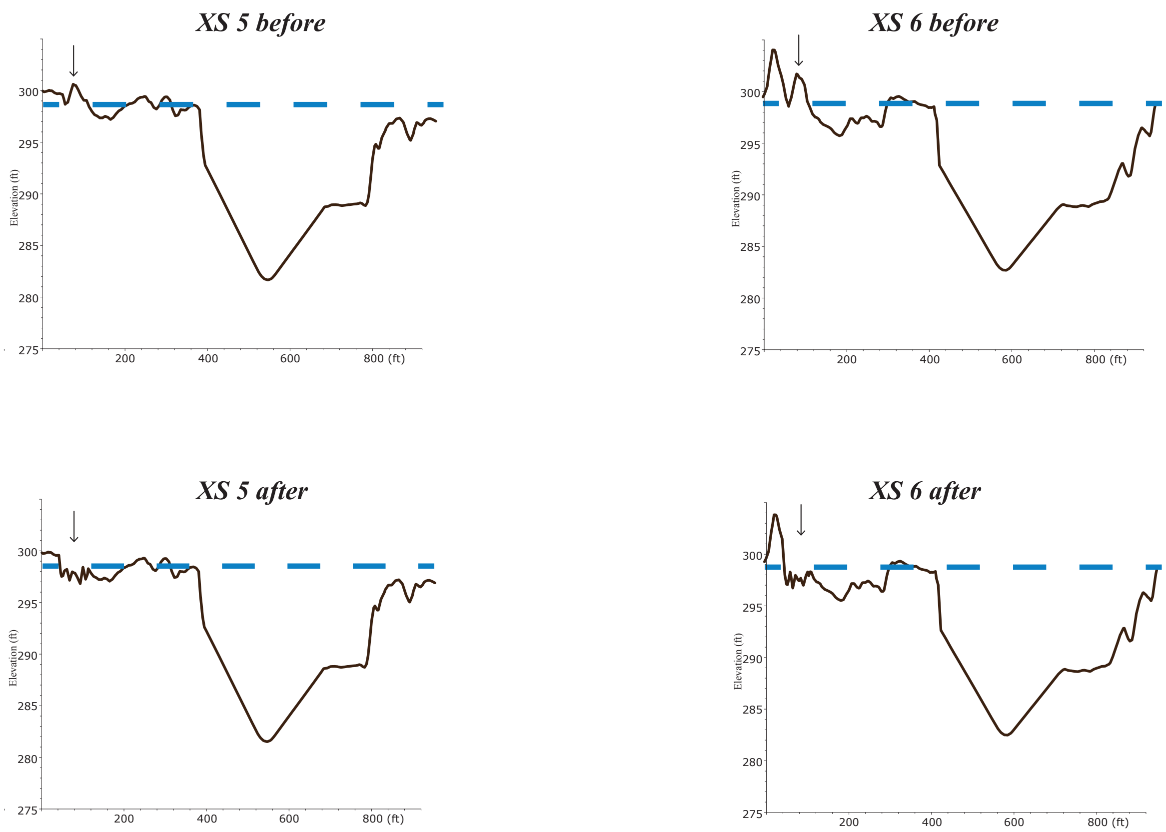
Site C - Cross sections continued



Water surface at 2-year flood

The arrow indicates the same side channel location in each before and after cross section pair.

Site C - Cross sections continued



Water surface at 2-year flood

The arrow indicates the same side channel location in each before and after cross section pair.

APPENDIX H

MODIFICATIONS TO NATURAL VEGETATION CARBON ESTIMATES

Mixed forest maximum carbon estimate

Following the advice of Stanley V. Gregory (Oregon State University, Department of Fisheries and Wildlife Science), I have modified Nelson et al.'s (2009) estimates of carbon for the mixed forest and natural shrub classes. There are three mixed forest classes represented in my study area's 2000 landscape: forest semi-closed mixed (class 52), forest closed hardwood (class 53) and forest closed mixed (class 54). My study area is a subset of the data developed by the Pacific Northwest Ecosystem Research Consortium for the Willamette Valley Ecoregion (PNW-ERC 2005); the mixed forest classes were originally designed to distinguish mixed forest types across the ecoregion. Dr. Gregory points out that, although three mixed forest classes are represented in the data for my study area, these distinctions are not necessarily seen in this part of the landscape. To reflect the on-the-ground reality, I have derived a single carbon value for all three mixed forest classes rather than apply the separate values used by Nelson et al. The value for mixed forest classes is based on the area percentage of each of the three mixed forest classes in my 2000 study area as shown in Table 1. I use a maximum carbon value (at 125 years) of 555 mT/ha for all mixed forest classes to estimate biomass carbon in the 2000 and 2050 landscapes.

		lulc 2k acres	*% of mixed forest*	*max. C biomass at 125 yrs. from Nelson, Table 2 (mT/ha)*	*C biomass contribution to mixed forest (mT/ha)*
52	Forest semi-closed mixed	395	6%	317	19
53	Forest closed hardwood	5,500	83%	578	482
54	Forest closed mixed	698	11%	508	54
	total mixed forest (acres)	***6,592***		***adjusted max C for all mixed forest***	***555***

Table 20. Mixed forest carbon estimate.

Mixed forest - estimating age for biomass carbon

The land use/ land cover data do not distinguish age within mixed forest classes and I found no research to guide decisions about determining and distributing age classes for my study area's mixed forest. I consulted with local experts ((Stanley V. Gregory at Oregon State University and, Bart Johnson and David Hulse at University of Oregon) to find an appropriate approach given the lack of data and need to estimate age for the calculation. Their recommendation is based on their collective knowledge of the landscape and informed by a Lidar derived distribution of vegetation height within the landscape's mixed forest classes. For the mixed forest carbon calculation, I assume an average age of 75 years in the 2000 and 2050 landscapes. The expert group agreed that this value is a reasonable representation of the current (circa 2000) landscape for the purpose of estimating carbon biomass. There are no data or methodologies currently available to support a different value for the 2050 landscape and, therefore, the mixed forest biomass carbon is also calculated with an average age of 75 years in the 2050 landscape. While it is true that individual trees will age over the 50 year time span, my estimate is based on the assumption (for modeling purposes) that some trees will die, new trees will grow but the average forest age remains constant.

Natural shrub carbon estimate

Dr. Gregory also advised that, in my study area, the natural shrub land cover class (87) is functionally a young forest rather than a distinct land cover type. For this reason, my estimate of carbon associated with the natural shrub class is based on the 555 mT/ha derived for mixed forest rather than the value from Nelson et al. Table 2. I have calculated a value for natural shrub with the assumption that it is a young mixed forest with an average age of 25 years. Using the age adjustment value from Nelson et al.'s Table 4, the calculated carbon value for natural shrub is 111 mT/ha (555mT/ha * 0.2). The carbon associated with natural shrub is based on the value of 111 mT/ha in the 2000 and 2050 landscapes.

Land use/ land cover	***Max C value from Nelson Table 2[1] (mT/ha)***	***Age estimate***	***Adjustment of max value from Nelson Table 4[1]***	***C value adjusted (mT/ha)***	***C value rounded to integer for analysis (mT/ha)***
Residential 0 - 4 DU/ac	23.20		1.00	23.20	23
Residential 4 - 9 DU/ac	20.88		1.00	20.88	21
Residential 9 - 16 DU/ac	17.40		1.00	17.40	17
Residential > 16 DU/ac	11.60		1.00	11.60	12
Commercial	0.00		1.00	0.00	0
Commercial/Industrial	0.00		1.00	0.00	0
Industrial	0.00		1.00	0.00	0
Residential and commercial	0.00		1.00	0.00	0
Urban non-vegetated unknown	0.00		1.00	0.00	0
Rural structures	23.20		1.00	23.20	23
Railroad	0.00		1.00	0.00	0
Secondary roads	0.00		1.00	0.00	0
Light duty roads	0.00		1.00	0.00	0
Rural non-vegetated unknown	23.20		1.00	23.20	23
Main channel non-vegetated	0.00		1.00	0.00	0
Stream orders 5 - 7	0.00		1.00	0.00	0
Water	0.00		1.00	0.00	0
Topographic shadow	0.00		1.00	0.00	0
Urban tree overstory	23.20		1.00	23.20	23
Forest semi-closed mixed	555.00	75 yrs	0.60	333.00	333
Forest closed hardwood	555.00	75 yrs	0.60	333.00	333
Forest closed mixed	555.00	75 yrs	0.60	333.00	333
Upland semi-closed conifer	555.00	75 yrs	0.60	333.00	333
Conifer 0-20 yrs	74.93		1.00	74.93	75
Forest closed conifer 21-40 yrs	166.78		1.00	166.78	167
Forest closed conifer 41-60 yrs	262.52		1.00	262.52	263
Forest closed conifer 61-80 yrs	344.69		1.00	344.69	345
Forest closed conifer 81-20	555.05		1.00	555.05	555
Forest closed conifer >200y	629.89		1.00	629.89	630
Hybrid poplar	75.05	15 yrs	1.00	75.05	75
Grass seed rotation	2.54	5yrs	0.70	1.78	2
Irrigated annual rotation	0.00		1.00	0.00	0
Grains	0.00		1.00	0.00	0
Nursery	0.00		1.00	0.00	0
Caneberries & Vineyards	45.99	25 yrs	0.80	36.79	37
Double cropping	0.00		1.00	0.00	0
Hops	0.00		1.00	0.00	0
Mint	0.00		1.00	0.00	0
Sugar beet seed	0.00		1.00	0.00	0
Row crop	0.00		1.00	0.00	0
Grass	2.54	5 yrs	0.70	1.78	2
Burned grass	2.54	5 yrs	0.70	1.78	2
Field crop	0.00		1.00	0.00	0
Hay	5.08	15 yrs	0.70	3.56	4
Late field crop	0.00		1.00	0.00	0
Pasture	5.08	15 yrs	0.70	3.56	4
Natural grassland	10.15	15 yrs	0.75	7.61	8
Natural shrub	111.00		1.00	111.00	111
Bare/fallow	5.08	5 yrs	0.70	3.56	4
Flooded/marsh	0.00		1.00	0.00	0
Irrigated field crop (perennial)	45.99	5 yrs	0.70	32.19	32
Turfgrass/park	0.00		1.00	0.00	0
Orchard	45.99	25 yrs	0.80	36.79	37
Christmas trees	20.15		1.00	20.15	20
Woodlot	510.70	45 yrs	0.75	383.03	383
Oak	115.53	75 yrs	0.60	69.32	69
Wet shrub	239.40	25 yrs	0.20	47.88	48

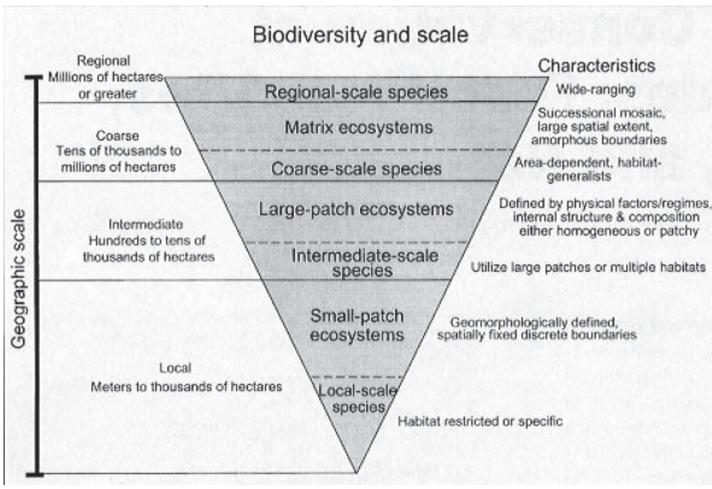
[1] Tables 2 and 4 are from the Appendix in Nelson et al. 2009

Table 21. Land use/ land cover vegetation age estimates, carbon adjustments and carbon values.

APPENDIX I

HIERARCHICAL APPROACHES TO BIODIVERSITY

Hierarchical biodiversity framework from Poiani et al. 2000 (their Figure 1.)



Hierarchical biodiversity framework from Noss 1990 (his Figure 1.)

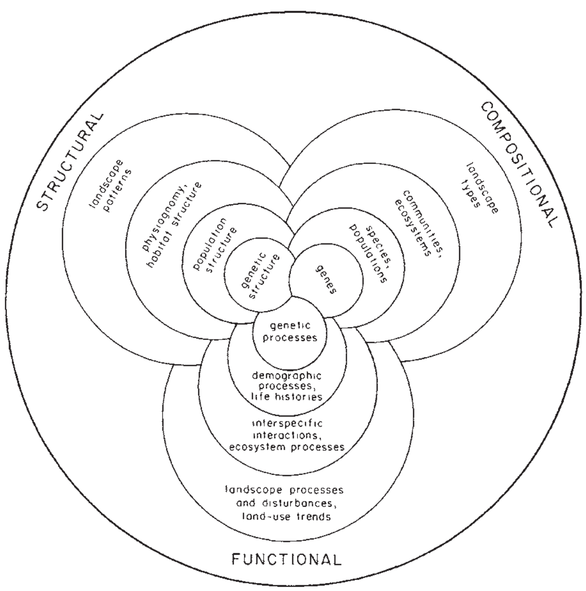


Figure 1. Compositional, structural, and functional biodiversity, shown as interconnected spheres, each encompassing multiple levels of organization. This conceptual framework may facilitate selection of indicators that represent the many aspects of biodiversity that warrant attention in environmental monitoring and assessment programs.

APPENDIX J

INTERVIEW QUESTIONS

Farm and personal history

The purpose of this category is to get to know people and discover information that could be relevant to other categories. For example, if the farmer's children have chosen other professions, how does this affect plans for the future?

Example questions:

- How long have you been farming here?
- How many generations of farmers?
- If children - do they plan to continue farming the land?

Cropping

The purpose of this category is to learn about the farm's agricultural system. Answers to these questions are incorporated into the crop profiles.

Example questions:

- How much land is in production?
- What crops do you grow?
- Details for specific crops (main crop, irrigated)
- History of specific crops.

Agricultural Trajectory

The purpose of this category is to understand the farmer's perspective on Willamette Valley agriculture in general and, on their own operation's past, present and future.

Example questions:

- How has Willamette Valley agriculture changed since you started farming?
- How has the global economy of the past few years affected your operation?
- Are you optimistic for the future of Willamette Valley farming?

Ecosystem services

The purpose of this category is to understand the farmer's perspective on producing ecosystem services as part of their agricultural system. I expect this set of questions to be the most variable from interview to interview. I do not expect everyone to know what ecosystem services are; and, I expect some who do to be less than enthusiastic. I plan to approach this in terms of production of non-conventional crops.

Example questions:

- Are they open to the idea of producing ecosystem services?
- Are some current crops more likely than others to be transitioned to ecosystem services?
- Are some locations within the farm more likely than others to be transitioned to ecosystem services?
- How would the farmer approach valuation?
- Are some mechanisms for exchange more attractive than others? (for example ecosystem service markets vs. government programs).

APPENDIX K

FARMER PROFILES FROM INTERVIEWS

<u>Jim</u>

Farmer

Jim is in his mid-50s and describes their operation as “just a good ol family farm”. His grandfather and great uncle came to the Willamette Valley from Michigan. His grandmother lived near their current farm, “lived right down there (points southeast). There is a single big tall fir tree where my grandmother and her sister lived and they were born and raised. My grandfather and grandmother met and were married; my great uncle and great aunt married.” His grandfather died young and his grandmother raised six boys through the depression. When Jim’s father got out of the service he farmed in partnership with two of his brothers. Like many other farmers at that time, his father also worked off the farm in a local cannery and driving gravel trucks.

> Then ‘bout the time the freeway went through in the late ‘50s, early 60s we had some property where the freeway went through. They paid for property they took and we used that money, turned right around and started buying land with that money. We were in the sheep business and it was pretty good at the time – did very well in that. So just kind of grew and expanded. (Jim)

In the early 1970s, Jim’s father split from his brothers and started building their “current complex”.

Jim has three sisters, three children and three grandchildren. His father, one sister, two sons and a nephew are all involved with running the farm. “So we’re all in partnership. Right now we’ve been in a big passing on stuff and doing the whole succession thing.” I commented that it was great that his children want to continue the family farm. Jim’s response was, “They love it. They wouldn’t do anything else, I don’t think. And I have three grandsons coming up the pike. They’re about yea tall right now so they’ve got a ways to go. They can decide what they want to do.”

Farm

Jim uses a book of mapped fields over aerial photos to show me some of the 8,000 acres they farm. "It is kind of a mishmash of owned and rented." Jim's knowledge of the land is impressive. He knows who owns what and comments about the qualities of individual fields as we look through the book of maps.

Their operation has both business diversity and crop diversity. They have two family farms, one warehouse and a small trucking operation. The warehouse allows them to process and ship their own seed. Having their own trucks makes it more efficient to get their products to market, "It is just kind of a convenience thing, we can get it done on our time frame." They also do custom hauling for seed companies.

"Diversity has kind of been the key to our existence. We have neighbors that are strictly grass and strictly annual ryegrass. I don't know how they do it. We've been fortunate. And we're fortunate we've got enough diversity in our soils that we can do that too." Their crops include annual and intermediate ryegrass seed, fescue, wheat, peppermint and corn. This year they have decreased the fescue and increased the wheat. They have done well with corn for the past few years. "Yes, being diversified – when one thing is hot, usually something else is cold. The vegetables have been outstanding the past couple years. The corn has saved our bacon. The peppermint has been good to us." Jim talks about past experience with some of the crops that they could grow:

> … it's different techniques, different marketing and the whole bit. Clover for example – we don't have a way to clean it here. So we have to haul it. But we tried growing clover a couple of years ago and it was a disaster. Last year we tried growing cabbage for seed. We had done it before, years and years ago. It was an absolute wipe out, disaster. What the bugs didn't get, the deer got. What the deer didn't get, the bugs got. We just chalked that one up. To do those kind of crops you need someone who is a double A personality, real meticulous. We don't have anybody on the payroll like that. Every farmer kind of has his niche of what he grows and can grow good. Those aren't ones we do real well on, we're not set up to do them.

The farm has six year round (permanent) employees in addition to the family members. During harvest, Jim estimates they have fifty employees. To compensate for the economic slow down, the permanent employees have cut back their hours. With this arrangement, no one has been laid off and employees keep their benefits.

Farming in the Willamette Valley

"That is a problem with the whole farming industry – when things are hot, everybody wants to grow whatever is hot, so we overproduce – and this is a typical cycle – we see this every three to seven years. It goes up and we plant fence row to fence row of whatever is hot and it just does this (hand gesture down). Right now we're deep, I mean we've dug a ditch in the valley – we've got a canyon. We've got to crawl our way back out of that canyon." Jim says one of the ways to start crawling out of the canyon is to just stop producing, "You go up and down the valley and there is no fescue left; it is just gone." They are storing seed in warehouses and processing it as needed:

> Used to be the warehouse was running 24 hours a day, 7 days a week. You went in and you cleaned everything that you brought in. We bring in 12-15 million pounds of seed every summer. We would usually finish up around March cleaning everything. So we'd have everything bagged, ready to go. The way things are now, we don't even clean it. Just leave it in the bin, bulk. Because when you clean it, put it in the bags – you've got all the problems - you've got to move it, you're moving it around, mice are getting into it.

Although Jim says, "We've seen this before and we'll see it again. We're creatures of habit." He also notes, "It is going to be interesting to watch because we are definitely in some type of a transition – I'm just not sure what direction it's going to go." He questions the future market for grass seed, "What does the future hold for the grass industry in the Willamette Valley? We can produce an awful lot of grass in this valley pretty quick. We can produce just about what the world needs in one harvest season. What's the future?/ how much grass is going to be needed?" He expects changes in the industry as well:

> And you're not exactly sure when you come out the other side what it's going to look like either. Because it used to be, back in the old days, there was 20 - 30 seed companies in the valley. So when you come out of it, you'd have these 20 - 30 seed companies all planting these varieties. Well you don't have 20 - 30 seed companies in the valley anymore. You've got, I don't know how many, maybe 5-10 major. So when we come out the other side, what's going to be out there?

Jim doesn't appear to be bothered by all this future uncertainty, "So it will be interesting, it'll be fun, I enjoy it."

Ecosystem services

Jim's bottom line on ecosystem services seemed to be the same for any crop they consider growing, "Well it depends on the crop and it depends on – does it fit into our program? We'll play around with a lot of stuff on a small scale but it's got to fit into our program." He also pointed out that, "If there is a crop out there that I've never grown before or I know kind of how it works but it takes a lot of extra work – if I can make $600 an acre growing that but I can make $600 an acre growing straight-up annual ryegrass – why not stick with the annual ryegrass?" Jim was open to the idea of ecosystem services and noted potential benefits for both farmers and farmland:

> I think it would work, I really do. That would be nice, it would take some pressure off of having to put this property into a crop every year. That's what is hard – because back whenever, guys didn't worry about having to crop on that piece of dirt every year. They'd fallow it or do whatever and now – I don't know if we got ourselves into this box or if it's just the way it is but it seems like you've got to pull a crop off that piece of dirt every year. (Jim)

JACK

Farmer

Jack is a young 3rd generation farmer with two small children. He started at Oregon State University as a business major but, "it was totally college of business – nothing to do with agriculture. Then I decided I still liked agriculture so I went back into agronomy. So I got a double major in that."

Farm

Jack and his father are co-owners of their farming operation and his sister works with them. "There is *so* much paperwork and records, she [sister] is keeping us organized there." His Dad owns some of the 700 acres that they farm and they rent the rest. "The management/ operations is separate. So the farming company that he [Jack's Dad] and I own, rents land from him. We also rent from other owners of land." Their main crop is grass seed and they are limited by having irrigation rights on only 14 acres.

Jack's grandfather on his father's side started farming on some of the same land they still have. "Well you could do it differently then – a little more subsistence style. Meaning he would make just enough. It didn't seem like he really thought much about the future as far as building anything up that could sustain in a way. He still got us into it." Jack and his Dad have tried to diversify the operation as much as possible:

> My dad has been *very* open to new ideas. Which is really the only way we can make it through now. It is pretty hard to have just the crop make you money enough to sustain. There is so much volatility in the market, it'll just take you out if you don't have something to even out the bumps a little bit. So we try to do some service – we process, clean, package and store seed for other farmers. …. This year the service income that we get from doing the cleaning for other people is a big thing because the market is so messed up that it is hard to do it on one thing.

Right now they produce mostly tall fescue seed. "We think it is one of the good grasses for the future because it is going to fit more with the need to cut down on water use etc. Fescue will stay greener with way less water." They also raise forage seed for grass fed beef pastures and some annual ryegrass seed. They have not followed the trend to move to wheat production this year. "A lot of our ground is so wet that it will not grow wheat. The last time we raised wheat, it cost us about as much as a trip to Hawaii. So we said next time I want to raise wheat, why not just go to Hawaii and call it even."

Farming in the Willamette Valley

Jack is keen on grass seed and the benefits of turf. "Grass seed is a crop that takes in carbon and gives out oxygen all the time. 600 square feet of turfgrass gives out enough oxygen for a family of 4 for a lifetime. Grass is important. So, I think it is a very green sustainable product anyway and I know we have minimized our inputs." What he sees in the future, and is planning for, is a shift toward grasses that are more drought tolerant. "But tall fescue as a kind of grass is one of the very best for water use – and it works for us."

When I asked if he thought the recent slump in local agriculture was just part of the expected cycle, Jack replied, "This one here is a little bit more disconcerting than some of them. I don't know when we're going to come back. So I think some of those things will come back but; we're not going to go back to the levels that it was for a long, long time. If we do have a recovery anytime soon, it is going to be slow and long."

Right now the benefits of being a farmer outweigh the inescapable uncertainty, "If you did it and looked at it on paper – it is insanity, pretty much. But you do it because that's what you do. We feel really blessed. It has allowed us to have a lifestyle… And to be out there and the land and the crops – if it is in your blood, you kind of like it." But he says, "I can't be all upbeat with you." One of his concerns is regulations. "My worry about the future is the regulations. We have no voting block." He feels that over time regulations on agriculture could slowly eat away at its viability. "You can get chased out because you absolutely went broke – and that is a viable option that happens a lot. And then you can do it because the regulations make it actually impossible. I think the actually impossible is going to take a while." He is also concerned with the way agriculture is perceived by non-farmers. "You are probably seeing that I feel some pressure living and farming here. I feel like we are not appreciated for what we are doing." In particular he finds that people don't understand the constraints of non-irrigated agriculture:

> People in the valley say you can raise anything here – which is true to an extent. This is the extent – you have to have water rights. It is a little bit frustrating for me because I hear a lot of – why don't they raise food crops, that is so much more efficient and people want local. Well, I know; but I can't, I'm not allowed to get the water. I would love to have water and raise these crops. (Jack)

Jack was hopeful about building a sustainable farming operation for his sons, "So I am third generation, I want it to be fourth." However, he was unsure if farming in the Willamette Valley will be a desirable option for the next generation

Ecosystem services

We spoke in general about alternative cropping and specifically about crops for carbon sequestration. He had doubts about the practicality of crops for carbon sequestration and concerns about the overall effect on agriculture. He had recently attended a meeting where carbon credits and cap and trade were discussed. "The Salem people were like it's going to cost a lot of money. Because farmers, the awful fact of the matter is that most of our inputs are dependent on the price of fuel basically. The Salem guys said the price of your inputs would go up so many times more and, it is so disorganized on the carbon end and the acreage we're talking about. To make the carbon cap and trade thing effective, they have to use huge swaths of land." He listened to my ideas about the possibility of alternative crops (ecosystem services) as an option for farmers:

> I feel like the carbon credits are not going to be worth enough money to justify it –doesn't seem like it. Unless the community decides that we want this kind of a habitat and it's worth this much to us that we'll actually pay them [farmers] fair market value to have it. Then I think people [farmers] would do it. (Jack)

He was receptive to my suggestion that ecosystem services are a form of local production and could be presented as such to nearby communities. "It could be a good thing because, if nothing else, it could build up appreciation somewhat." He noted that compensation has to be fair and the value of production needs to be recognized. "It would be just compensation and a level of – Am I going to be on the team? Am I going to be respected for this or am I going to be like a welfare kid?" He went on to talk about the potential for mutual benefits for farmers and non-farmers:

> If there was a real coming together – we [non-farmers] realize we like this stuff [ecosystem services], we realize you [farmers] don't have a lot of options. We realize you're trying to do what you can. Here are some alternatives. Can we do this community wise and make it better? (Jack)

If done in the right way, Jack thought the idea of ecosystem services was worth pursuing. "A lot of farmers would be open to that, I think. That idea of coming together."

FRANK

Farmer

Frank and his wife Sara both come from farming families with long local histories. They have a grown daughter and grandchildren. Both of Frank's mother's parents were homesteaders and his father came from Michigan around 1904. Frank traces the lineage of Sara's family, "Our daughter is 7th [generation] and grandkids will be 8th generation on some of that property – just up the road here." His younger brother and nephew farm "around us and amongst us."

Farm

When asked about the size of his farm, Frank said, "I tell people 3,000 [acres] plus. Enough to keep busy." When asked about ownership, "over half of it is within the family – between Sara and I and the kids. Then we lease another 700 - 800 acres from Sara's sisters that they inherited from her folks." Frank's son-in-law plays a major role in running the farm.

Everything they grow is a seed crop, primarily grass seed. This year about one-third of the farm is in wheat. White clover is about 10% of this year's crop, a decline from 25% a decade ago. "We had a new crop to us this year and it was the most profitable. It was a spring vetch. So we're going to try a couple hundred acres this next year." Other crops they have grown in the recent past include turnip, pea, radish and mustard seed. They have their own warehouse to handle and process their seed. They have water rights on ~400 – 500 acres of their land. The farm operation had 7 employees at the time of our interview.

Farming in the Willamette Valley

Frank's comments about farming in the Willamette Valley were about his own operation, things he has tried and what works for him. "I have always focused on volume – having a volume acreage rather than 5 ac, 40, 100. Because I learned a long time ago, if you have a field that is smaller than 1% of your total acres, you probably will ignore it if something else needs to be taken care of. So you can't go over here and plant a little bit because you won't give it due diligence." He speaks with pride about how his practices have built on what he was given by previous generations:

> Since the 1840s, there has been a generation of my family on this land – this same land. I want to make it better and I actually believe that most of the land I farm is better than when I got it from my dad and my father-in-law. Because I took what they knew and built on it.
>
> We've got some of these fields that we've not removed the straw on and minimum tilled as much as we can for 12 -14 years. I think they are starting to approach the structure and stuff that might even be better than before white man came, before they were tilled.

He notes that other farmers are doing the same, “We’re not the only ones. How many people can say they took something off of it and it might be better than when they started?”

Ecosystem services

We started the discussion about ecosystem services with carbon sequestration as an example. Frank’s comment was, “I’d like you to tell me what we would grow beyond the grass seed that would store carbon any better than we already are.” He wasn’t opposed to the concept of ecosystem services as long as it “would have some viability to it on a yearly basis or an outcome.” His overall attitude toward farming suggests a willingness to consider producing ecosystem services, “I’m not saying that what I do is right. But show me how to do something better. We will adapt if it’s best. I have.”

<u>Wade</u>

Farmer

Wade is in his mid 60s and runs the family farm with one of his sons. His family has been in the Willamette Valley since the 1840s with a history comparable to those described by Peter Boag (Boag 1992) :

> Smiths came out here in 1846. Initially they came out of Iowa, caught a wagon train in Independence Missouri. Initially they didn’t settle, they kind of squatted on a piece of ground that somebody left up in the Portland area in ‘46. I don’t know too much about what they did while they were there but my great great granddaddy was enamored with a Methodist circuit rider, riding minister who came down to this end of the valley and sent word back that there is ground down here, come on down. So he left where they were at there and came down here in 1851 and took a homestead, he and his wife, just south of Shedd there. With the two of them they were allowed a full section of ground which is more than people could farm at that time but they took it anyway.

“My granddad was born on the homestead and went off to Oregon Agricultural College – graduated in ‘03 in mechanical engineering and then went off to work in the woods on steam engines as a mechanical engineer.” Wade’s grandfather returned to the area, married and purchased 80 acres in 1911. “Then my Dad was born in ‘16 in the house that sat where this house sits now.” (We were sitting in Wade’s living room.). His

Dad went to Oregon State College with no intention of becoming a farmer because "it was just too much work." By the time Wade's Dad graduated in 1940, "he figured out that things were becoming mechanized and he thought probably life on the farm would be better. He could see a way forward to making farming work. He thought he had some ideas that would help out." By the time he returned to the farm, Wade's Dad had married his mother who was a home economist. Wade's father joined his grandfather "as a partner in the farm, assuming half the debts for half of the assets – he said the debts exceeded the assets at that time." Wade says that when he was a boy,

> We were still pretty much a general farm. We had a Grade A dairy. I grew up on a farm with hogs, chicken, a flock of sheep – you just kind of had a little bit of everything. At that time, well even during my youth when I was in 4H, FFA, there were still two slaughter houses in Albany so we had a local market for livestock. The milk was hauled to Albany for processing, bottling, canning things like that. (Wade)

Although he was unsure about staying on the farm, Wade started in Agricultural Economics at Oregon State College. His education was interrupted by three years in the Army. "Toward the end of my army tour Dad said … I didn't necessarily need to have an agricultural degree but college is a good thing [and] there is a place on the farm if I wanted to come back. So I came back to Oregon State and well – the philosophy department claims me. Everything I know about farming, such as it is, I learned from Dad and the Extension Service and hanging out with smart neighbors." As his father before him, Wade returned to the farm because he saw possibilities in technological advances. "I used to tell people that if Dad was still milking cows when I got ready to do something, I wouldn't have come back to the farm. I would have been an insurance salesman. But with specialization … Commercial fertilizers helped us increase yields, research done in production and whatnot. It got to be profitable to where grass seed production – you could make a living at it."

Wade has a brother and sister, neither are involved with the farm. He farms with his son who graduated from Oregon State with a degree in Agriculture and "has been a farming machine ever since he was a kid. He's pretty well taken over the farming end of stuff." Wade's wife does the farm's bookkeeping.

Farm

Wade didn't give an exact figure for the number of acres they have in production but he says, "we've always been a mix of owned ground and rented ground." The family still owns acreage from his Grandfather including the original 80 acres from 1911 and an additional purchase of 60 acres. "We are a family owned seed corporation. The farm itself owns about a third of the ground we farm and the family members own about a third of the operation. The other third we rent from other landholders." When I asked about the arrangement with other landholders, Wade replied,

> We don't have any written leases. The people we deal with – it is a trust relationship. Several of ours are older people who grew up on the ground, grew up with a crop share rent and they feel that is the fairest and they like to keep that going. But that means I have to produce a crop every year for them so they have income. Crop share traditionally here is a third/ two-thirds. A third goes to the landlord or lady as the case may be and their expenses are the chemicals and fertilizer and processing of their crop. Then the farmer provides equipment and labor and the other two-thirds of the chemicals and fertilizers.

Wade's story tells the evolution of farming in the southern part of the Willamette Valley over the last century. "My granddad – when they were farming, it was subsistence farming. Well they raised some grain as a cash crop and some livestock. The farm, being subsistence, had sheep, hogs, dairy cows. There was farming with horses but my granddad, being a mechanical engineer, was involved with some of the earlier steam equipment that was used." Wade's grandfather and grand uncles did custom thrashing with a steam powered thrashing machine. "They moved from that – my granddad started experimenting with some grass seed for seed production."

When Wade's Dad started farming, "the livestock were still on the farm and we were a Grade A dairy and they were trying to keep that going but the grass seed was becoming a little more a part of the commercial operation – as opposed to the oats, barley and wheat that they had raised." At that time they started building cleaners to process grass seed. "As soon as they built the cleaners, Dad started doing some custom cleaning for neighbors. But the low ground was still permanent pasture. The medium ground was into grasses (for seed) and oats. The better ground, on what passes for a ridge here, was in some grain production (wheat, barley)." At the time, "there were still two slaughter houses in Albany so we had a local market for livestock. The milk was hauled to Albany for processing, bottling, canning things like that." Wade reflects on the broader circumstances that triggered the next transition in their farming operation:

> But after the war, the grass seed – well there were several things. Commercial fertilizers which allowed the yields to get bigger. There was a growing market initially because of more housing starts. More people having more homes with yards, so there was a turf market. Although the same varieties we were selling into the forage markets were being used as turf at that time – before a whole lot of breeding being done for specialty things. So it was a time of change and Dad was pretty forward looking and stayed on top of things and was able to incrementally build the farm at that time. And this wasn't just us, this is what was happening in the area.

By the time Wade returned to the farm, the animals were gone and seed production was becoming profitable. "The seeds continued to take off. Commercial fertilizers helped us increase yields, research done in production and whatnot. It got to be profitable to where grass seed production – you could make a living at it. Sometimes a good living and sometimes not so much. But it was a living and it has kind of gone from there."

I asked if their primary crop was grass seed. "Five years ago, maybe ten years ago, I would have told you yes. There was a time when every acre was grass for seed. Now I tell people we are seed producers." He notes that the recent ban on field burning limits their ability to produce grass seed. "To get a clean, quality crop – used to be we had field burning and chemicals. Then we were left with just chemicals." They are in a bit of a transition and looking for new crops that can be used as part of a rotation. Wade notes that they are planting "as much meadowfoam as we can." They grow open market and contracted grass seed. They also grow wheat, oats, white clover and radish seed for sprouting.

Wade joined a group of farmers to start a seed company in 1976. Over the years, the other farmers dropped out and Wade's farming operation became the sole owner of the seed company around 2000. The farm does business with the seed company. "So we do provide seed for them [the seed company] on contract, they buy some of our open marketed seed." However, the seed company operates as a separate business with its own purpose. "When we became the sole owners, I realized if it is going to work – it is a seed company – their job is to sell seed, not necessarily just mine." The seed company handles forages, turfs, alfalfas, sorghums, imports from New Zealand and tropicals from South America.

Farming in the Willamette Valley

"When I was graduating from high school, in our ag classes, they were telling us that farming was becoming a business – and boy, it did." Wade has seen changes in his neighborhood and farm structure. He fondly remembers growing up here, "There were a lot of houses here when I was a kid, we had neighborhood kids to play with." But he says, "Now it's just gotten to be pretty slim pickins out here in the country. In a lot of ways that is kind of a sad thing – just the community and whatnot." He has seen corresponding changes in farm operations, "But the consolidation – when I was a senior in high school in '61, we were cleaning seed for about 25 farm families. By '91 we were cleaning for 6 farm families and we were cleaning for more acres but, consolidation had taken it down to ~6 farm families."

Wade says of the current rough times in Willamette Valley agriculture, "The difference about what we're in now is they [seed crop prices] all went down and how fast they all went down. *Everything* has been hit and that's what's caught a lot of us." He notes the upside a few years back, "Most of the species, the prices rose – irrational exuberance hit the seed market also." The subsequent downside was particularly harsh, "And then when it came down, it was relentless – just kept coming down, coming down. We think we've bottomed now and we're starting to see a little bit of a rise in annual ryegrass is about the only thing that has come back."

Like other farmers, Wade wants to increase crop diversity as much as possible. In particular they would like to find alternatives to grass seed because "there is getting to be a little less mobility in the grasses for us." Growing many of the current grass seed varieties complicates field management, "Certification demands that you are out of one species – if you are going to change varities, you have to be out of that species for so many years before you can plant it again because you have to make sure that it is genetically pure."

Ecosystem services

Wade was quite willing to engage in a conversation about ecosystem services. He said he had looked into carbon sequestration about 8 years ago. He wasn't opposed to the idea but when it came to fitting into an agricultural operation, "I haven't seen where what we do is going to fit into the sequestration."

During our conversation, Wade expressed an openness to new ideas and opportunities as long as they fit with their farm's operation. Soon after our interview, Wade sent me an email summing up his thoughts on the topic.

> I don't mind changing crops on our farm, or even uses of the lands of our farm, as long as that change has hope, going in, of an economic gain to our farm enterprise. That gain can be as crass (and necessary) as cash profit or may be a benefit to soil condition or a future rotation. And we will do small scale projects as experiments for science partners or for our own education or amusement. That is part of the reason that we may fallow some ground this year, that is, it may be better for the farm to rest some ground rather than producing a crop that has no hope of being anything but an expense. (Wade)

Luke

Farmer

Luke is a young farmer who has had his own operation since 2001. He has been around agriculture all of his life and currently farms with his Grandfather. Luke's Grandfather has been farming since the 1950s when he started with turkeys, cattle and sheep.

Farm

Luke and his Grandfather farm ~2,000 acres, 75% is rented and 25% is owned by his Grandfather. Grass seed has been their primary crop, "well this year, I don't know what will be the primary – but normally it [grass seed] has been." They have cattle on separate rangeland and sheep which are fed on the grass acreage. They have always raised some wheat and, like many others, that acreage increased this year. For the last few years they have been "dabbling with a little bit of native stuff" which is marketed for restoration projects. "It has been a challenge, we're learning all the time with that one." They have slowly expanded this part of the operation and Luke thinks it could pay off in the long run, "the native stuff as a whole on a per dollar basis is a whole lot better [than their other crops]. There's that learning curve but, there is that potential when we learn the stuff."

Farming in the Willamette Valley

Although Luke has only had his own operation since 2001, he is familiar with past cycles in Willamette Valley agriculture. "I think we have had some bumps in the road. I think it was pretty bad in the early 80s, I wasn't around but … Of the cycles I've seen, this one is one of the worst I've seen in a long time. I think there is some big uncertainty on where we're headed totally." He seems to be taking the uncertainty in stride but says, "I can't tell you I'm terribly optimistic, I'm trying to be. I don't know, I think there's going to be some big changes and I hope that there is something new that comes along that will … I don't know, help us I guess. I don't know what that is right now." Luke sees more than just a downturn in agriculture triggered by a dip in the overall economy, "Obviously if the economy turns around some, I think it's going to help. It's gonna make the picture better but I think there still needs to be some changes." For their farm, "Yeah, I'll admit – another year or two of this and I'll be in trouble, it's not real pretty."

Luke says because of the high cost of inputs and low market prices, "We've kind of had to learn to do the no-till and try to tweak things to volunteer and that type of thing. I think we did a relatively decent job of doing that but it just went so far, it's stretching too thin." He notes that long time farmers like his grandfather have more cushion for a string of bad years. "If you have been involved, own a lot more, have a lot more equity – it's probably not going to hurt them as hard; or, they have more resources I guess I can say. Where I have only been in business 8 or 9 years, I don't have the deep pockets."

Ecosystem services

Luke's comment on producing ecosystem services was, "From my standpoint, we wouldn't hesitate if we thought there was profitability in it." He said that five years ago "when things were boomin" farmers might have been less willing to talk about ecosystem services but times have changed. "As I said, right now I think farming as a whole is pretty open to anything as long as it is can be profitable. I think everybody would be willing for a little bit of risk."

<u>Kyle</u>

Farmer

Kyle is a youthful 4th generation farmer who farms with his uncle, cousin and grandfather. When I asked about his father, Kyle said he had died just a few years ago. He didn't mention other family members and I didn't pry. Kyle was forthcoming when answering questions but his manner was generally quiet and reserved.

Farm

The family has been farming in the same location since 1895. They currently farm ~1200 acres without irrigation, all but 40 acres are family owned. Their main crop is perennial ryegrass seed; they also have 6 head of cattle, 50 acres of pasture and "a little bit of wheat." This year's 360 acres of wheat is slightly more than usual. Their ryegrass seed is public (or open market), "The variety we have is what is called a public variety and so, we can set the price and we can sell it to anyone we want. We are not under contract to anyone." They have their own warehouse for cleaning, bagging and shipping seed. In summers they hire "about 3 kids. For the past couple of years it has been college age kids."

Farming in the Willamette Valley

I asked Kyle about the cost of their inputs (fuel, fertilizer, herbicides, pesticides) versus the market price for their seed. He confirmed that the cost of inputs has risen but, "I think our market price – our last year's average was about the same as it was in '82. The last couple of years we have been at a break even or slight loss. It hasn't been dramatic for us." He talked about historical cycles in their operation, "I can look back in our records, from back in the '60s to now. And it goes in cycles – 'bout every 3-5 years, you'll get a good year and then you'll have a couple of bad years – average year – bad year – good year – bad year. I am kind of hoping that is what we are in now even though there are other factors coming into play." He was still able to maintain optimism, "We are probably three years into a downturn in the cycle and so we are expecting it to come up in the next two years. If not, then you start worrying." He said that if things don't turn around "within a couple years its gonna get pretty serious."

A new worry for Kyle's farm is the recent ban on field burning. They have kept their input costs down with field burning as a management tool. He expects an increase in chemical use to control slugs and mice and isn't looking forward to the transition. "We've always burned our fields so we don't have any experience with the other things but talking to the other guys, it doesn't sound fun."

Ecosystem services

We talked about the idea of producing non-conventional crops (ecosystem services) with carbon sequestration as an example. Kyle was receptive to the idea and thought others would be as well given the state of the grass seed market. "It is always a possibility, yeah. Your timing is right on with that. It is something I have started to look into myself but I don't really know very much about what my other options are." I asked what he thought about the longer time commitment required for ecosystem services. "That's definitely going to be different for each farm because each farm has their own situation. For us, we probably could do it, I don't think it is something we would be opposed to."

Zach

Farmer

Zach is a young third generation farmer. "My grandpa started here in the 50s." He was quite open and forthcoming about their operation and gave me a tour of fields, equipment and warehouses.

Farm

Zach farms about 2,700 acres with his father. About half of the land is family owned, Zach and his Dad lease land from Zach's grandfather. The rest of the land is rented. They have a warehouse that is separate from the farm. The operation has quite a bit of equipment which is technically owned by Zach's Dad but serves as a common resource. "He [Dad] owns most of the equipment but I have bought some to try to offset some of his costs. We're able to work it pretty easy. I pay all my own expenses but I use a lot of his equipment."

This year their crop acreage is about 1/4 wheat, 1/4 clover and 1/3 ryegrass seed. What comes out during the conversation is the importance of livestock and other crops that are produced on relatively few acres. "You can see that we are pretty diversified. We have a lot of different crops." They have about 300 acres of meadowfoam which works well as a rotation. "Turns out this is probably our only crop (meadowfoam) that is actually going to pay money this year – and it pays really well." The turnips they are growing this year are "kind of a neat crop to grow and they are real early. Usually we start harvest like the 25th of June on average. The turnips will be a couple days before that so that fits our program pretty well." They sell grass fed beef. "Last spring, I sold hardly any seed but I sold all of our calves. That paid my fertilizer bill. The cattle really help out a lot – just because it brings cash flow at a different time of the year." For the past few years they have grown forage pea seeds as a rotation but, "We're not going to grow any this year – they went in the toilet."

The farm is working to increase its no-till acres (1,000 this year) and take advantage of crop rotations. The primary motivation is to reduce input costs. "That is why we are trying to do as many rotations as we can – because it cuts down on all of our inputs. The other thing about the crop rotation is to get the planting easy so we can no-till. If you can follow peas or clover it is easy to no-till because there isn't very much crop residue. But to no-till behind wheat it is just too much of a battle." Throughout our conversation Zach was quite attentive to details about crop rotations (what can follow what), the cost of working fields and the timing of planting and harvest.

Farming in the Willamette Valley

I asked Zach if he saw himself farming in the Willamette Valley 20 years from now. "Yeah, I'm sure we'll find a way to do it but I'm going down the highway in a tractor goin slow and everybody's pissed.." Although he sees himself still farming in 20 years, he sees obstacles all along the way. Like another young farmer I spoke with, Zach expresses the feeling that agriculture is viewed as a nuisance by many in the non-farming community. He notes the impatience of drivers when they encounter farm equipment on the road and makes a more general statement, "I think most people would probably be glad to see us gone – I don't know." He doesn't have much faith in the Oregon

Department of Agriculture (ODA), "The ODA – I'm not really sure what they have done to help us – all they are is makin' rules and regulations against us."

Zach's farm has buffered itself from some of the uncertainty and volatility in agricultural markets with diversity in their cropping and operation. "There is a handful of guys that I could list that only have annual ryegrass. I would definitely be broke if all I had was annual ryegrass. …. I don't know where we would be if we hadn't grown wheat last year because we haven't been paid for any ryegrass so far." Even with diversification and good planning, farming is an uncertain business:

> We kind of got caught with the whole economy thing where oil and fertilizer prices were through the roof and by the time we got our crop harvested and in our bag, the economy had gone in the toilet. So we had the highest inputs ever and then our crop was worth nothing. We had done a lot of preselling, which you can only do so much of. So yeah, we got caught in that deal and that's just all straight out of our pocket.

Zach spent some time talking about the way contracts work in Willamette Valley agriculture. "Just about everything goes through a broker here in the valley. We're starting to get contacts with people outside of the valley. Some of the brokers are real shady." Like others I spoke with, Zach told stories of farmers getting the short end of the stick when it comes to contracts. "Some farmers know nothing about business. They can grow one hell of a crop but when it comes down to a seed company telling them, yeah, we're not giving you your money – they just kick their feet." Zach says, "We would never let that happen here – we get paid for everything." He is working on getting the word out to other farmers about developing and enforcing contracts.

I asked if Zach thought the down turn in the past couple of years was part of the normal agricultural cycle. "Oh yeah a little bit." He talked about their diversity providing some cushion and their ability to store seed from 2008 and 2009. "I'm not all that concerned about it yet. The price is pickin' up a little bit. There are enough stubborn people like me. All the cheap sellers have about sold out."

Ecosystem services

Zach had mixed feelings about the possibility producing ecosystem services. He was less than enthusiastic at the thought of producing something that wasn't a harvestable crop. “What are we doin this for? Because we enjoy farming and stuff. Would we want to tie it up for 15 years? What would we get out of that, drivin by for 15 years and watching stuff grow. I don’t know…” On the other hand, he could see potential benefit, “Seems like if it was going to pay just to watch it [grow], that would definitely benefit landowners.”

Zach was interested in carbon sequestration, “We’re hoping to get carbon credits just for growing the stuff we are growing. There is a lot of talk about that. We have a speaker coming to our January meeting who is supposed to talk a little more about that.” Zach’s bottom line on a willingness to produce ecosystem services was similar to most of the farmers I spoke with, “Yeah, I would think so. If it pays money.”

Gary

Farmer

Gary’s family sold their farm about 12 years ago and since then he has been employed by a program that works with farmers. His grandfather was born in Springfield and left construction to start his own farm near Coburg in the 1940s. Gary’s parents were both teachers but his father grew dissatisfied with the educational system and began farming with Gary’s grandfather. Gary started working on the farm when he was 12, “moving irrigation pipe for, I believe it was, 65¢ an hour.” He worked summers through high school and college and adjusted his college schedule to help with fall harvesting. “I did finally get a degree. And my folks urged me to get a degree outside of agriculture just as a fall back in case. So I have a degree in sociology. That and 50¢ might get me a cup of coffee.” Gary began farming full time with his father, brother and grandfather in 1981. He still has equipment and does a bit of custom harvesting each fall. Gary and his brother considered their ages when deciding whether or not to leave the farm. At the time, they both decided that it would be possible to make a career change. Gary seems relieved to have left the uncertainty of farming behind and satisfied with his decision to find a new career. “I have really enjoyed this position. Being able to keep my hands in the agricultural community and in agriculture. It has been a real rewarding career so far and I hope that I can continue.”

Farm

Gary's grandfather started in the 1940s with peppermint, wheat, corn and cattle. At the farm's "peak time", Gary worked with his brother, father and grandfather to operate 1700 acres on two separate farms. Peppermint continued as the main crop with wheat and corn grown for rotation. Gary's Mom did the books, his wife helped out and they had 5 year round employees. After an economic downturn for agriculture in 1988-1989, the family downsized their operation to one farm and ~900 – 1,000 acres. After Gary's father retired in 1994, he and his brother ran the operation together until their decision to sell in 1997. Their operation had become quite diverse by the time they decided to sell:

> We had diversified out – I had taken on a sheep business and we had an irrigation business in which we sold irrigation parts and systems. I took on raising livestock and we also had a harvest business in which we custom harvest sweet corn through a contract with Agripac. We were then raising corn, table beets, green beans, carrots, peppermint, wheat, some grass seed and just about anything else – some dill. We contracted and raised some Pinot Noir wine grape starts for newly established vineyards in the area. Just about anything we thought we could grow and would be economically profitable.

The collapse of Agripac was the proverbial straw that broke the camel's back for many local farmers, including Gary and his brother. "In 1997 we sat down around the kitchen table and had a long discussion. Economics in farming was not good at that point in time. That was one of the major factors in us getting out – is the fact that we were a major contributor/grower for Agripac."

Farming in the Willamette Valley

Gary describes the underpinnings of their operation from the early 1970s into the mid 1980s:

> As I indicated earlier, we had the 3 main crops; peppermint, wheat and corn. It was our feeling, and it was true to form, that if one of those crops had a good year, it would cover our costs. And if two of them had a good year, it was a decent year. If all three of them came through, it was a banner year. There were very few times that all three came through – very few. Often times we had two crops that did well in the same year. And then there were times when we only had one crop that made

> it work. You kind of have to live the lifestyle of what you bring in. What you reap is what you sow. That was our mental process from a marketing standpoint back then.

From Gary's perspective, things changed in the mid 1980s. "Then at about '85, things started to turn around and change and, to be very honest, I think as agriculture expanded – not even globally, but internationally – and that kind of started back in the late '80s – that changed that whole mentality as far as marketing was concerned." He saw the competition from cheaper production outside of the Willamette Valley. "Then we started to see competition in the mint business, bringing in cheaper, less quality oil from other regions. We saw the wheat market basically drop down from where it was at a $5 - $6 a bushel range to a $3- $4 bushel range. And so we had to start searching and come up with some other alternatives to help subsidize that. So, we did so." He says it is his personal opinion that the impacts of NAFTA (North American Free Trade Agreement) weren't well understood at the time and the consequences were "more dire than what we thought they were going to be. And that put a dagger in a lot of production agriculture."

"I characterize Oregon as a drop in the bucket as far as agriculture is concerned in the nation. We're not very big at all. We have to hit niches. We're capable of hitting niches because of the diversity of the soils and climate." He notes that this is important because Oregon can't compete with midwestern agriculture, "they are much larger and their ability to be large and get their supplies and inputs at a bulk rate, discount cost was the difference there." On the other hand Oregon has the ability to "run from crop to crop to crop and kind of stay on the top – what we call stay on the top of the wave. That is pretty much it in a nutshell of what I experienced in my farming career." Gary sees a trend to smaller farms and the need to hone in on specialized niches. "That's what I see in the future – that we are going to have a lot more small acreage producers but they are going to need a network that will get … they can go online and get in their email and here is Joe's Market who called and said I need 5 boxes of tomatoes tomorrow. OK – I go out and harvest 5 boxes of tomatoes, I take it to his market and I deliver."

Ecosystem services

Gary was keen on the future of small farms and niche production for Willamette Valley agriculture. Conceptually he thought the idea of ecosystem services for larger operations was worth pursuing and he felt farmers would be open to the idea. We talked a bit about the potential need for farmers to work together in a co-op type environment to organize the necessary volume of ecosystem services. He noted that the collapse of Agripac left many farmers apprehensive about this type of organization. In addition he noted that the general independent nature of farmers could be a hurdle. "The amount of independence that farmers have is sometimes their biggest enemy. Because number one – that shuts down their connection with the rest of society. They need to be more, I guess, adaptable to networking than what they are. But, they have seen both sides of the coin."

Ben

Farmer

Ben came from eastern Oregon to the southern part of the Willamette Valley when he was 21. He rented "the place over there, next door to me here. I've rented ever since." He appears to be in his 50s and has a grown daughter (perhaps two). He was the only farmer I talked to who did not talk about previous generations of farmers in his family. He was guarded at times during our conversation and seemed reluctant to talk about his family.

Farm

Ben grows fresh market produce and filberts. He rents most of his land and never said exactly how much land he has in production. He started the farm with hand-picked pole beans. He currently grows a wide variety of fruits and vegetables including peaches, apples, pears, blueberries, strawberries, marionberries, raspberries, sweet corn, tomatoes, peppers, pumpkins and "a bunch of the garden stuff like cucumbers." He sells mainly from a farm stand "just right out here. My daughter watches it. Then we do some self serve – do a lot of self serve. After hours, they can come out and get whatever they want." Ben buys additional produce like melons from local growers to increase the variety at the farm stand. About 18 acres of his land are certified Tilth organic. "So we do that too. We do both conventional and organic stuff."

Filbert prices have been very good for the past few years and Ben refers to them as his main crop. "I got real big into hazelnuts the last 5 years so I've got over 300 acres of hazelnuts that I do. People don't realize that it's the filberts that buys all the stuff around here, buys all the fancy equipment. I knock on wood. I hope it keeps up. The filberts have been really good so I've bought some properties the last couple of years and doing other stuff because it has been really, really good."

Farming in the Willamette Valley

From Ben's perspective, fresh market produce is a relatively stable niche in Willamette Valley agriculture. "So the only thing is you have your fresh market local stuff. I think that will always be here to a certain extent. The only thing I see in the valley is just go with the flow or you get a niche. Niches do stuff people like to do, like this, what we're doing here." He laments the loss of food crops to other types of production, "I used to love going out on the road and seeing cabbages and beans and corn and pumpkins. Now all you see is mint or wheat or grass seed. The good farmland is in grass seed." He comments on the grass seed market's susceptibility to global circumstances, "What's going to happen to the grass seed industry – if China ever starts raising grass seed, or down in Brazil or something like that – it will kill the market because they can't raise it as cheap here as they can there. And it will be no longer viable." He also sees China as a potential threat to his hazelnut market. "The only thing that would hurt us (with respect to hazelnuts) is if something happened in China. China buys 75% of our nuts. In the last 5 years, it went from 10% to 75%. If China decides to do something different, it could affect our little niche price that we get to a certain extent."

The cost of farmland, conversion of farmland and regulations are some of Ben's concerns for the future of agriculture in the Willamette Valley. Ben rents almost all of his land and says, "Well you can't afford to own it." He gives examples of wealthy professionals who buy farmland and maintain it as a get away home. "So how do you compete with somebody who can afford to spend 1.2 million on a place they can have hobby horses? I was trying to figure how to make it pay as a farm. That's the problem we have in this area. Farmers cannot compete with people who want a home site. To them what's a million dollars? Or two million dollars if they are really serious." He also has a real bone to pick with municipalities who purchase farmland for mitigation and urban services. "The biggest hits on farmland I've seen in the last 5 years in this area have been the municipalities. I can't compete with a water treatment plants. Nobody can. I can't compete with municipalities. When they need some more ground, the first thing they look at is – Oh, let's get some of this cheap farm ground. That's the number one thing I see hurting farmlands – more than housing." Even as a fresh market grower with a direct connection to his customers, Ben says, "People's attitudes are changing, they're getting worse and worse and they don't understand." Like other farmers I spoke with he sees increasing regulations as a real threat to the future of farming in the valley, "I think the legislature is gonna shut us down farming – all the rules and regulations coming in for stuff. Shut us down where we can't do anything."

Ecosystem services

Ben and I did not discuss the potential production of additional ecosystem services as part of his operation. As with the other fresh market grower I interviewed, Ben is already producing a marketable ecosystem service on prime agricultural soil. It is hard to conceive of a better match of natural resources and ecosystem service production. In addition, Ben expressed strong feelings throughout our conversation about agricultural resources being converted from food production to other uses that benefit urban communities and natural ecosystems. He feels that this sort of conversion is one of the major threats to farming. "BLM bought it through some kind of a thing for habitat for something – planted some trees on there through funds from all these government agencies." His views about conventional agricultural production versus other uses of agricultural land were clear, "Go up the freeway in California and they are pushing orchards out. Why? Some stupid little fish."

<u>Morgan</u>

Farmer

Morgan is a young farmer with small children. Some of the details of his story are intentionally vague because he was clear that he did not want to be identified. He is in business with his father and one brother growing fresh produce which they market directly from their own stand. He has another brother who farms at a different location. Morgan has a horticulture degree and says he always wanted to be a farmer. "Yeah, that was another reason I was able to buy land – because I knew early on what I wanted to do – very early. You figure out that it takes a lot of money to get into it and you have to build equity any way you can and as fast as you can to have a chance. So when I was in high school, I didn't spend any money. I started saving back then."

Both of Morgan's grandparents on his father's side grew up on farms in the midwest. They came to Oregon after his grandfather served in the military. While working as a millwright, Morgan's grandfather grew filberts on the side. At 55 he hung up his millwright hat and began farming filberts full-time. Morgan's Dad grew up working on farms and continued to farm as an adult. At first he had a separate profession but also partnered to farm with Morgan's grandfather. His Dad was selling fresh produce by the side of the road "under a large tree and they had a table that they put their stuff on. Then he built a small building and they sold stuff out of that. Then his fruit stand, which is what we call it, got bigger." Eventually Morgan's Dad gave up his other job and became a full-time farmer. "The first year he did that it was kind of scary because it is hard to give up a paycheck to farm."

Throughout the interview Morgan stressed the importance of family and faith:

> We go to church regularly now and that is important to us. There is a lot of faith involved in farming, I guess – for us, for me personally. It is definitely a big part of it. We like not being open during any of the Christian holidays; we can spend time with family. Sometimes you'd like to make money all year round but that is just one of the deals – you've got to take time for your family for at least a couple of months – go places and do things'.

Morgan expressed strong views about government, taxes and agriculture. More than once he voiced exasperation about tax policies as they relate to agriculture. "Another thing I think is real detrimental to agriculture is the estate tax. I think it singles out farmers proportionally in an unfair manner." He sees public lands as an untapped source of revenue, "I mean I like public lands because I like to go hunting on them and everything but there is a lot of BLM land in this state that people don't even set foot on. There is land-locked BLM land and if that was privately owned, they would be getting tax revenue on it and maybe wouldn't be under so much pressure for revenue."

Like some of the other young farmers I spoke with, Morgan believes non-farmers have misconceptions about agriculture and the way it works. "The point is – nobody understands agriculture. Nobody understands the entrepreneur, especially in agriculture."

He also expressed the independent nature of farming in the Willamette Valley. “I don’t even think we should have farm subsidies. What farmers need, is they just really need to be left alone.”

Farm

The family farm grows a diverse array of fruits and vegetables and operates a stand to market their produce. Filberts are their one commercial crop. This combination of fresh market and commercial filberts works well for them. “It is nice to have a commercial crop like filberts. Because when the price goes up, if you’ve got enough pounds, it is a real shot in the arm. But the fruit stand is nice because you get your money a little bit at a time and you have a lot more control.”

Morgan’s Dad “worked his way into 46 acres of high quality river bottom soil.” Additional land has been acquired over the years and the farm is now a little over 400 acres. His Dad’s original crops were sweet corn, cherries, apples and peaches. The cherries are gone now. The combination of wet springs and a couple of bad years caused them to take the cherries out of production. They now grow “a lot of different things, we grow over 70 crops. One thing about the fresh market produce business that we like is that we can spread the risk over different crops.” The list of crops includes strawberries, blueberries, raspberries, marionberries, tomatoes, swiss chard, melons, carrots, beets, sweet corn, cucumbers and onions.

The tight connection between farm production and marketing comes through as Morgan talks about the crops. They grow many varieties of blueberries to extend the season and hand pick them to maintain high quality. “I spread the season out on stuff like sweet corn too, using row covers and different tools to get it ripe earlier.” They sell bedding plants and hanging baskets during strawberry season. “If we’re selling strawberries, we might as well have more stuff for them to look at. It gives them more of a reason to come out.” The farm stand is clearly not an afterthought but an integral part of their operation. “And you can’t jerk people around like with hours. We stay open 9 – 6 from first day of the season to the last. And you’ve got to give them a clean place to shop. Ladies don’t want to go into a dump, they don’t feel comfortable there.” Morgan is aware that the realities of a working farm fall short of his urban customer’s neat and tidy expectations. “It’s hard too because there are so many details. You gotta keep your signs painted, keep things mowed, keep the garbage picked up by the side of the road. It's hard compared to normal agriculture."

Farming in the Willamette Valley

Morgan's views about farming in the Willamette Valley largely reflect his particular circumstance of being a fresh market grower near an urban center. One of his concerns is the ability to acquire new land to expand their operation and manage crop rotations. "Land is so important because when you want to expand your business, eventually you need more land. It seems like you'd always like a little bit more – to plant filberts on or something. We grow so many different crops – it's just better to have fresh ground to plant them on." He notes that land is hard to come by, in part, because of absentee owners. This pattern of absentee landowners and renters doesn't bode well for agriculture. "So pretty soon you have a bunch of people who own the agricultural base who aren't even involved in the industry. Sometimes they get ideas that aren't compatible." He sees both benefits and risks of operating so close to an urban center, "We feel under pressure from development. The urban growth boundary is kind of keeping them at bay. On the one hand it is nice to be close to a metro area where people can come out and visit our fruit stand but on the other hand we want that interface."

The fresh market side of their operation is somewhat insulated from global influences; they grow for and sell directly to people in a nearby urban center. This combined with their crop diversity provides relative stability for their operation into the future. The commercial filberts have been quite successful the past few years but Morgan has concerns about the future of the market. "Well, the thing that worries me about that is, we are selling over 65% of Oregon's crop to China." He noted the potential for a U.S. conflict with China in which case the price of filberts, "[Is] gonna just drop like a rock."

Ecosystem services

As a food producer, Morgan's operation already supplies an ecosystem service that is accommodated in our current market structure. Unlike the grass seed growers I spoke with, Morgan's farm is located on prime agricultural soils. We did not discuss the potential for their operation to convert to other ecosystem services. From a resource and ecosystem services perspective, it would be hard to top food production on prime agricultural soils.

APPENDIX L

LIST OF ACRONYMS

AIRES	Artificial Intelligence for Ecosystem Services
AMSL	Above Mean Sea Level
CREP	Conservation Reserve Enhancement Program
CWS	Clean Water Services
DEQ	Department of Environmental Quality
GIS	Geographic Information System
GLO	General Land Office
LULC	Land Use Land Cover
NAFTA	North American Free Trade Agreement
NAIP	National Agriculture Imagery Program
NPP	Net Primary Productivity
NRCS	Natural Resources Conservation Service
ODA	Oregon Department of Agriculture
OAIN	Oregon Agricultural Information Network
PNW-ERC	Pacific Northwest Ecosystem Research Consortium
RDG	River Design Group
SPOTAC	Stream Protection Opportunities Technical Advisory Committee
SSURGO	Soil Survey Geographic Database
USDA	United States Department of Agriculture
USGS	United States Geological Survey
WSE	Water Surface Elevation

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