Sustainable Natural Resource Management:
Identifying land cover change and associated environmental impacts of wetland conversion in the Upper Klamath Basin, Oregon

Master of Natural Resources' Case Study

By Amy S. Bradley

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Abstract

This case study examines the Upper Klamath Basin of Oregon, which is experiencing a water crisis due to over-allocation. The purpose of this case study is to identify land cover / land use change looking specifically at wetland conversion and to discussion the effects of wetland loss on ecosystem services. This case study uses Geographic Information System techniques to process and analyses historic Oregon vegetation data from 1938 and 1992 and National Land Cover Data from 2001 and 2011. This study also discusses policies that led to the over-allocation of resources and recommendations on wetland restoration and sustainable natural resource management practices.

Introduction

Sustainable natural resource management entails utilizing and conserving natural resources in a way that is economically viable and socially acceptable while maintaining environmental services and population values. Natural resources including water, soil, air, and wildlife are essential to human survival. Although this view of natural resources seems anthropogenic, the underlying aspects of sustainable natural resource management and the view of this paper is holistic and geared toward a new management paradigm.

Wetlands, for instance, are a natural resource in need of sustainable management because of the fundamental functions provided through ecosystem services, wildlife habitat, and human sustenance, which merits priority for restoration and preservation (Peacock et al., 2012). Wetlands are an integral part of the overall health of the local environment and when mismanaged can become a complex problem, as evident by the water crisis in the Klamath Basin of Southern Oregon and Northern California, where the degradation of ecosystem services stems from the implementation of unsustainable environmental policies. In all, sustainable natural resource management policies and practices affect the rate and quantity of wetland conversion to cultivated agricultural lands, which affects ecosystem services. Thus constituting the need to understand the economic, environmental, and social impacts of wetland conservation and restoration.

Sustainability

According to the United States Federal Government, sustainable means to “create and maintain conditions, under which humans and nature can exist in productive harmony to support present and future generations" (EPA, 2015, p.1). Nevertheless, there are varying views on how to define sustainability with little consensus amongst professionals because the definition varying depending on the values of the beholder (Floyd et al., 2001; Jaeger, 2005).

Wetlands

Prior to the mid-20th century, the term "wetland" was not in common use instead terms such as bog, marsh, and swamp described these areas (Mitsch and Gosselink, 2007). With the writing of wetland preservation regulations came the need to define wetland. In general, a wetland must have hydric (saturated) soils, hydrophytes (wetland vegetation), and wetland hydrology (water level, flow, and frequency) (NRCS, n.d.; Mitsch and Gosselink, 2007).

Nonetheless, formal and legal definitions exist because scientists, managers, and regulators need precision and consistency. In order to inventory, evaluate, and manage wetlands officials needed a classification system. This system separates wetlands into two broad categories: coastal (tidal) and inland (non-tidal). Subdivisions of these broader categories include: tidal salt marshes, tidal freshwater wetlands, mangrove wetlands (all of which belong to the coastal wetland category), and freshwater marshes, peatlands, freshwater swamps, and riparian systems (the latter of which are grouped as Inland wetlands) (Mitsch and Gosselink, 2007; Cowardin, 1979).

Wetlands are important because they provide a value to society in the form of population value, ecosystem services, and regional/global values (Mitsch and Gosselink, 2007; UNPEI, 2006). More specifically, the value of population refers to the plant and animal species that rely on wetland habitat; ecosystem services hydrologic functions of the wetland; and the values that effect global environmental health and biodiversity (Table 1) (Mitsch and Gosselink, 2007; UNPEI, 2006; NSW, 2010).

Table 1. Wetland Values

Population Values	Ecosystem Services	Global and Regional Values
- Animals harvested for pelts - Waterfowl & other birds - Fish & shellfish - Timber & plant harvest - Peat harvesting - Endangered & threatened species	- Flood mitigation - Storm abatement & coastal protection - Aquifer recharge - Water quality - Aesthetics	- Maintain water & air quality - Global cycles of nitrogen, sulfur, and carbon

Source: Mitsch and Gosselink (2007).

Environmental Policies Affecting Wetlands

The early years of wetland legislation focused on reclaiming wetlands for cultivated agricultural land in order to increase production and create economic growth. Federal legislation, such as the Swampland Act of 1850, provided States with grants to invest in reclamation of land by draining swamps (Carlson, 2010). Table 2 lists the legislative acts and programs that encourage wetland conversion, such as the Payment-in-Kind Program and certain U.S. tax deductions and credits both aimed at converting unused lands, often wetlands, into production, the latter of which was reformed in 1986 (See Table 3) (Votteler and Muir, 2002). Additionally, the Flood Control Act of 1944 gave authority to the Army Corps of Engineers to build irrigations systems and provide surplus water to domestic and industrial users as a part of flood control projects (USFWS, 2014).

Table 2. List of Acts or Programs That Encourage Wetland Conversion

Act or Program Name	Outcome
Federal-Highway Act of 1968	Construction affects wetlands
Federal Crop Insurance	Encourages farmers to convert flooded areas (often wetlands) into production
Flood Control Act of 1944	Authorized flood control projects often at the expense of wetlands
National Flood Insurance Program	Encourages development of flood plains
Payment-in-Kind Program	Encourages farmers to convert unfarmed areas into production
Small Reclamation Project Acts of 1956	Encourages reclamation project often at the expense of riparian habitat
Surface Mining Control and Reclamation Act	Regulates surface mining and reclaiming coal-mined lands, including wetlands
Surface Transportation Revenue Act of 1991	Projects directly and indirectly destroy wetlands
U.S. Tax Code	Encourages farmers to drain and clear wetlands with tax deductions and credits
Water Resources Development Act of 1976, 1986, 1988, 1990	Projects directly and indirectly destroy wetlands

Source: Votteler and Muir (2002).

Prior to 1945, laws enacted to protect wetlands focused on habitat, specifically for migratory birds, such as the Migratory Bird Conservation Act of 1929 and the Migratory Bird Hunting Stamp Act 1934. The Migratory Bird Conservation Act of 1929 established a treaty between the United States and Canada that named migratory birds, regulated take limits, and acquired land and water to develop into migratory bird reservations (USSCEPW, 2002). In contrast, the Migratory Bird Hunting Stamp Act, recently amended by Congress, requires the purchase of a “duck stamp” to hunt migratory waterfowl of which the proceeds fund wetland conservation projects (US Congress, 2014).

What followed was an era of wetland protection in which legislations was passed to tax fishing and hunting equipment such as the Dingell-Johnson Act 1950, which taxes fishing equipment (USFWS, n.d.) and the Pittman-Robertson Act in 1937 that placed a tax on hunting equipment. In addition, legislation to protect wilderness passed, such as the Wilderness Act and the Wild and Scenic Rivers Act that declared wild and scenic rivers are to be free of dams (BLM, 2014).

According to Carlson (2010), the “Progressive Era conservation movement”, beginning after 1960, sought to “elevate science above politics, collectivism above individualism, and empower the central state at the expense of local governments” (p.453). Table 3 lists the policies, programs, and regulations that discourage or prevent wetland conversion, such as the National Environmental Policy Act of 1969 (NEPA), which began the requirement of environmental impact statements for all Federal projects that may affect the environment. Additionally, the formation of the Environmental Protection Agency in 1970 established policy to protect and preserve the national wetlands (American Biology Teacher, 1973).

Table 3. Policies, Programs, and Regulations Discouraging or Preventing Wetland Conversion

Coastal Zone Management Act	Provides Federal funding for wetlands programs in most coastal States
Endangered Species Act of 1973	Provides for the designation and protection of wildlife species in danger of extinction
Executive Order 11990, Protection of Wetlands	Requires minimized impacts of Federal activities on wetlands

Federal Water Pollution Control (Clean Water Act)	Regulates activities that involve the disposal of dredged and fill materials in US waters, including wetlands
Federal Water Project Recreation Act	Authorized Federal funds for the development and distribution of fish and wildlife information; development of policies and procedures relating to fish and wildlife
Food, Agriculture, Conservation, and Trade Act of 1990	Wetland Reserve Program purchases easements on farmed wetlands and subsidizes restoration of croplands to wetlands
Food Security Act of 1985 (Swampbuster)	Suspends agricultural subsidies for farmers who convert wetlands to agriculture
Migratory Bird Conservation Act	Approved acquisition of migratory bird habitat
National Environmental Policy Act of 1969	Requires environmental impact statements of all major Federal actions affecting the environment
National Wildlife Refuge Acts	Establishes refuges, many of which contain wetland acreage
National Wildlife Refuge System Administration Act of 1966	Provides the guidelines for managing National Wildlife Refuges
Ramsar Convention (Treaty)	A list of internationally important wetlands and encourages wetland conservation
Tax Deductions for Conservation Easements	Tax deduction for donating land to conservation organizations for the purpose of conservation
U.S. Tax Code Reform Act of 1986	Eliminates incentives for clearing land; deductible for wetland protection expenditures; capital gains on converted wetlands treated as income
Wild and Scenic Rivers Act	Protects designated river segments from dams
Wilderness Act of 1964	Requires a review of Federal lands for inclusion in the National Wilderness Preservation System

Source: Votteler and Muir (2002).

The most recent protection of wetlands comes in the form of Federal programs, such as the Wetland Conservation Provision established by the 1985 Farm Bill, which forbids participants in USDA programs from converting any remaining wetlands for agricultural production unless equal wetland benefits are created through wetland mitigation (NRCS, n.d.). Additionally, in 1989, President George Bush launched the "no-net loss of wetland" policy that requires the creation of a wetland equal to that of the destroyed wetland (Votteler and Muri, 2002; NRCS, n.d.). Another notable Federal program, the Wetlands Reserve Program now called the Agricultural Conservation Easement Program, established by the 1990 Farm Bill, reduces agricultural impacts on wetlands by working with ranchers and farmers to increase the benefits of wetlands on their property while maintaining agricultural production (NRCS, n.d.).

Wetland Conversion to Farmlands

By 1920, across the United States, 53 million acres of drained land became farmland (Carlson, 2010) increasing to over 64 million acres by 1954 with 286,108 acres in Oregon (USGS, 2013). By the mid-1980s, over half of the nation's original wetlands were lost to human development prompting the enactment of several programs, as listed in Table 3 (NRCS, n.d.). Evidence of the program success emerged in 2004 when President George Bush announced the first net-gain in wetland acreage, meaning more wetlands were created than were destroyed (NRCS, n.d.). Nevertheless, there is still a need for wetland conservation and restoration because of the important role they play in the economic and environmental health of a region.

Designating land-use is a government responsibility, so the decision to conserve a wetland lies within the control of government policy-makers; however, non-profit organizations also purchase lands for conservation. Incentive-based tools such as the Conservation Banking offered by the U.S. Fish and Wildlife Service could contribute to the conservation of wetlands (Montana Department of Fish & Wildlife, 2006). Other programs include - the North American Wetlands Conservation Act Program and the Wetlands Reserve Programs, all of which offer some sort of financial and technical assistance to qualified landowners.

Ecosystem Services

Wetlands provide a range of ecosystem services making their conversion to farmlands less of a desirable outcome and measured need for restoration needs to be a priority. Ecosystem services provided by wetlands include water purification, groundwater recharge, soil formation, nutrient cycling, wildlife habitat, carbon sequestration, flood protection, and landscape aesthetics and recreation (Floyd et al. 2001; ABT, 1973; Mitsch and Gosselink, 2007).

Social Values

There are several interest groups involved in the UKB including biologists, the First Tribes, environmentalists and irrigators (Stern et al., 2014). Everyone wants to improve water quality and quantities available. The conflict arising around water use: to retain the water in the rivers or to withdraw it for irrigating fields (Stern et al., 2014).

Involved in the conflict concerning the conservation of wetlands are wildlife, residence of the watershed, recreational users, and potential private owners. Regarding rights and entitlements, local wildlife depends on the wetland giving them superior privilege. Moreover, the residences of the local watershed need a steady supply of quality water gained through the environmental services provided by the wetlands (WSDOE, n.d.).

Social perspectives on environmental issues, such as conserving wetlands instead of converting them into farmlands, can cause confusion and frustration in society when policies are not agreed upon or properly understood. Moreover, members of society sometimes feel the regulatory institutions in charge of making policies are not considering their concerns. Often times there is no obvious solution to a problem or one that cannot be solved by science alone because the problem involves a variety of different value systems. Problems such as these can be described as a “wicked” problem (Shindler and Cramer, 1999).

Wicked Problem

According to Shindler and Cramer (1999), wicked problems are problems for which there is no solution. Wetland conservation and restoration can become a wicked problem if not managed sustainably, such as the problems in the Klamath Basin located in Southern Oregon and Northern California. The Klamath Basin is residence to the First Tribes, farmers, ranchers, urbanities, and commercial anglers as well as several endangered species and native species of wildlife.

In 1905, the Klamath Project began reclaiming wetlands for agricultural use under the Water Reclamation Act (Jenkins, 2011). Lotteries for land grants in California, between 1917 and 1947, resulted in thousands of veterans receiving awards for parcels of land on which to farm. By 1960, 75 percent of the Klamath Basin's wetlands were developed for agricultural production (Lakelubber, 2016).

The year 2001 was the first year since the beginning of the Klamath River Project in which farmers were without irrigation, which resulted in a loss of approximately 200 million dollars’ worth of agricultural inventory (UCS, n.d.). The Bureau of Reclamation Office, by order of a judge, retained water in Klamath Lake and flowed un-diverted water downriver to ensure protection for endangered fish (Commissioner Connor, 2013).

As of 2011, 200,000 acres of Klamath Basin wetlands were converted into farmland with only 25,000 acres (less than twenty-five percent of original wetlands) remaining intact. The basin contained seven dams, forty-five pump stations, 185 miles of canal, and 516 irrigation dikes (Jenkins, 2011). The results were a decline in Waterfowl populations by two-thirds because the run-off from farmland fertilization affected the quality of the water in the remaining wetlands (Jenkins, 2011) and aquatic life populations declined (i.e. suckerfish and salmon).

Water shortages in the Klamath Basin are a wicked problem due to the complexity of differing social values held by the various stakeholders involved in the situation, including irrigators, Klamath Tribes, and the Department of the Interior requiring some sort of trade-off, which manifested itself in the Klamath Basin Restoration Agreement (KBRA) and the Klamath

Hydroelectric Settlement Agreement (KHSA). The KHSA includes programs to ensure water flow to the National Wildlife Refuge located in the basins, programs to "rebuild fish population [and have more] predicable irrigation water allocation [for] farmers" as well as assistance to farms affected by the dam removal (Jenkins, 2011). Social values, as described by Stankey and Clark (1992), held by the stakeholders involved in the Klamath Basin crisis include commodity, amenity, environmental quality, ecological, public use, and spiritual. Specifically, the Klamath Basin provides its stakeholders with multiple ecosystem services such as rangeland, fresh water, fishing, farmland, mining, timber, water quality, and habitat for endangered species, subsistence, recreation, tourism, and a place to hold Tribal ceremonies. Public perception and differing values and perspectives create a need for resource managers to use integrated planning.

The perception of the public varies depending on the stakeholder with which they aligned themselves. The perception of ranchers and farmers is their right to public property is in violation (Peterson, 2014). Whereas, environmental groups and Klamath Tribes perception is there is a need to restore the Lost River sucker and shortnose suckerfish populations and water quality (Barboza, 2013). Additionally, public perception is that government agencies are responsible for implementing and upholding public policy. According to Klamath County Commissioner John Elliott, the public's perceptions regarding the Klamath Basin Restoration Agreement (KBRA) is false in that the public thinks by refusing the KBRA the dams will stay, water will be available, and environmental and Tribal trust issues will merely disappear (Beaver, 2010).

The Klamath Basin water crisis took a dualistic form with one side maintaining values associated with the Dominant Resource Management Paradigm (DRMP) and the other the New Resource Management Paradigm (NRMP) (Shindler and Cramer, 1999). For the most part, the irrigators maintained the DRMP perception of "commodity output over environmental protection [and that] amenities are coincidental to commodity production" (Shindler and Cramer, 1999 p.30). Whereas the Klamath Tribes and environmental groups believe "amenity outputs have primary importance [and hold] environmental protection over commodity output", which is the philosophy of the NRMP (Shindler and Cramer, 1999, p.30). In particular, the Klamath Tribes' standpoint is for the removal of the four dams and an irrigation plan that recovers the fisheries (Saxon, 2014).

Integration and sustainability are similar in that both attempt to reconcile natural resource management issues. Integration, according to Clarke et al. (1999), is not a particular outcome, yet the process by which to reach the outcome. This is similar to sustainability in that both are a process focused, rather than outcome-based. Additionally, Clarke et al. (1999) note that integration brings together disciplines and subjects from various contextual backgrounds and is reliant on the comprehension of individuals from multiple sources. Integration may be a necessary step of sustainable management because it brings to the table all social aspects of resource management. An example is found in the document entitled, "A Human Geographic Issue Management System for Natural Resource Managers in the Willamette Valley, Oregon", which is designed to integrate biology and social ecology when tackling watershed issues with those who use the resources of the watershed (Preister et al., 2002).

For the natural resource policy makers, the Klamath Basin crisis required integration because of the multitude of values embraced by the various stakeholders. Integrated management plans recognize the need to incorporate the benefits of multiple ecosystem services. In this case, the KBRA demonstrates integration can work because it appreciates and respects the diverse values and perspectives of the various stakeholders, relies on a wide knowledge base including citizens, science, and the experiences of managerial agencies and is ultimately a means to the end (Clarke et al., 1999).

As noted, the current plan for the Klamath Basin water crisis is the Klamath Basin Restoration Agreement and the Klamath Hydroelectric Settlement Agreement, which is a cooperative agreement between fifty organizations (KlamathRestoration.Gov, n.d.) in April 2014 and was introduced in Congress as the Klamath Basin Water Recovery and Economic Restoration Act of 2015 by Senator Ron Wyden (Govtrack.us, 2015). Regardless, the KHSA is sustainable, achievable, and acceptable on the premise it receives adequate funding and if the stakeholders follow the agreement. The success in agreeing on an Integrated Management Plan (IMP), such as the KBRA and the KHSA, was the participation of the stakeholders and the public and now the key to implementing an IMP is the acceptance and participation of the stakeholders.

Wicked problems have no consensus of values or science yet requires a socially acceptable solution, which Shindler et al. (2004) describes as on that is physically possible, economically feasible, and easily adopted by the cultural all of which the current plan encompasses. The resolution of the Klamath Basin Crisis and the success of the KBRA and KHSA will set a precedent for future water conflicts, as it has been a wicked problem needing a workable solution for decades.

The root of the problem with water shortages in the Klamath Basin stems from the era of environmental policy aimed at expanding agricultural lands. Today, federal policy and local land use rules regarding wetland restoration in the Klamath Basin reflects the shift in paradigms from the old paradigm to the new. However this change is not easy and can take decades to change as evident by the situation in the Klamath Basin. Additionally, the case study of the Klamath Basin illustrates how ecosystem services are affected by land cover change from the conversion of wetlands to agricultural lands.

The Klamath Tribes

For the purpose of this paper, the discussion of land use by the Native American tribes in the UBK (namely, Klamath, Modoc, and Yahooskin (a band of the Paiute) will begin with the 1864 treaty, which bound the Tribes to the Klamath Reservation (Kelly and Gosnell, 2014). Additionally, the 1864 treaty put the management of the natural resources in the hands of the Federal government. Within a few decades, the Allotment Act of 1887 was enacted, which had the effects of turning 25 percent of the reservation into individual, privately-owned 160-acre plots that were allotted to tribal members many of which were then sold to non-tribal members (Kelly and Gosnell, 2014). By the early 1900s, the BOR's Klamath Irrigation Project reduced the available water, which a century later resulting in one of the Nation's worst water crisis. In addition, during the early 1900s, the timber industry moved into the region turning the reservation essentially into a fiber farm in which the Tribes members had no control over management decision. The Tribes received income disbursements for timber sales until 1954 when the Klamath Tribes were dissolved, the reservation was sold (former Tribes members received a stipend), and federal management and entitlements ended (Kelly and Gosnell, 2014).

Since 1986, when the Klamath Tribes' (the Klamath, Modoc, and Yahooskin Tribes) sovereign nation status was restored and the management of the reservation lands transferred from the Forest Service to the Tribes both sides began working together in a mutual collaboration to manage the Tribes natural resources (USFS, 2012). In 2011, the Master

Stewardship Agreement was created between the U.S. Forest Service, Lomakatsi Restoration Project, Klamath Tribes, and the Nature Conservancy, which states the Tribes commitment to manage the forests and as a result developed the area's only local-based restoration crew (USFS, 2012). Additionally, in 2012, the Klamath Tribes, the Chemult and Chiloquin District Ranger Stations and Interdisciplinary Teams developed the "Red Knight and Blue Jay Landscape Restoration Projects: A Partnership in Stewardship on former Klamath Reservation Lands" with the goal to restore the landscape into a ponderosa and mixed-conifer forest, which will improve wildlife habitat (USFS, 2012).

In addition to the USFS, the Klamath Tribes also work with the U.S. Department of the Interior on matters of managing their natural resources. For instance, the "Development of Tribal Ecosystem Workforce Initiatives for the Implementation of Landscape Scale Restoration in southern Oregon and northern California" focuses on restoring a diverse forest ecosystem, enhance and protect natural resources, and improve water quality (Fierro and Bey, 2014). Some of the restoration projects involving the Klamath Tribes include Lomakatsi Restoration, Tribal Stewardship Agreement, Fremont-Winema Restoration Projects, and the Klamath Basin Tribal Youth Employment and Education Initiative (Fierro and Bey, 2014).

Current Land Ownership

There is approximately an equal share of publicly and privately owned land in the Upper Klamath Basin (UKB), roughly 2.3 million and 2.9 million, respectively. Table 4 lists the variety of agencies, including Federal, state, and Non-Government Organizations (NGOs) that manage the public lands, and designation types in the UKB.

Table 4. Publicly Owned Land (1993) UKB

Federal		State		NGO & Private	
Description	Acres	Description	Acres	Description	Acres
Area of Critical Environmental Concern (BLM)	8694	Board of Forestry	26777	Delta / Marsh (NGOs)	27775
Bureau of Land Management (BLM)	228900	Federal Railroad Administration (Common School Lands)	6861	FWS (Private)	7067
Forest Service (USFS)	26771	Department of State Lands	1013	Natural Resources Conservation Services (Private)	23195
Military Reservation (DOD)	1542	State Park & Recreation	1723	Ducks Unlimited (Private)	393
National Forest	1546659	Department of State Lands	893		
National Park (NPS)	95122	Wetland Mitigation Bank	42		
National Trail	106				
National Wildlife Refuge	75603				
Recreation Area	4868				
Research Natural Area	2650				
Scenic River	13584				
Wilderness	109557				
Wildlife Area	3286				

Data Source: Public Land Cover shapefile, DAS, State of Oregon

Of the Federally managed lands, 73 percent are National Forest, 11 percent are BLM land, and National Parks and wilderness areas each equal five percent, National Wildlife Refuges designation is four percent, and the remaining designations each equal one or less than one percent (See Figure 1). Of the State managed lands, 66 percent is Board of Forestry lands, 17 percent is designated as Common School Lands owned by the Federal Railroad Administration, wildlife areas have eight percent, and the Department of State Lands manages five percent of the total lands managed by the State (See Figure 2).

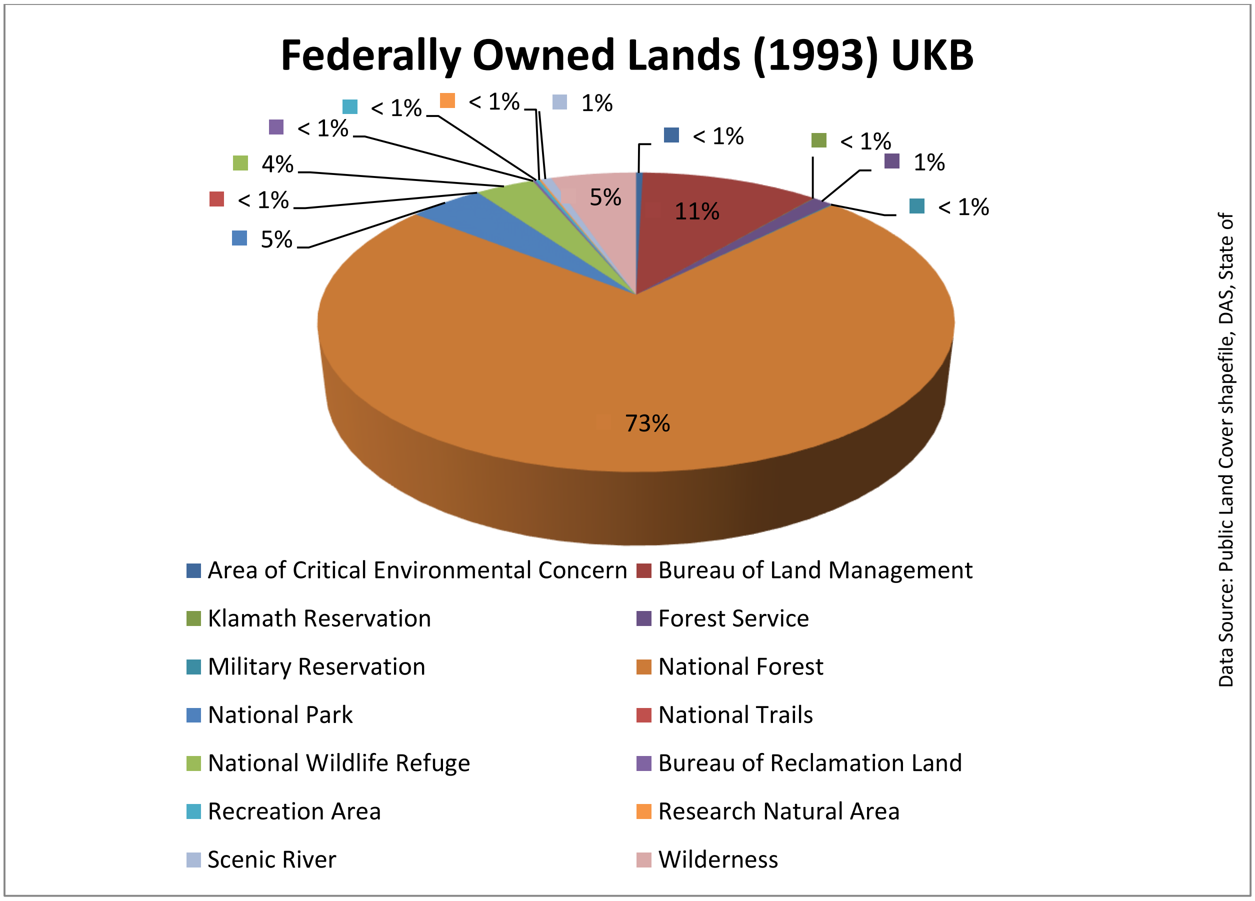

Figure 1: Federally Owned Lands in the UKB during 1993

Some of the publicly managed lands are privately owned, such as the wildlife refuges managed by the Fish and Wildlife Service and the Wetlands reserve managed by the Natural Resources Conservation Services (See Figure 3). NGOs manage less than one percent of the land in the UKB, all of which are deltas and marshes. Image 2 illustrates the land use for the state owned lands in Oregon's UKB in 1993.

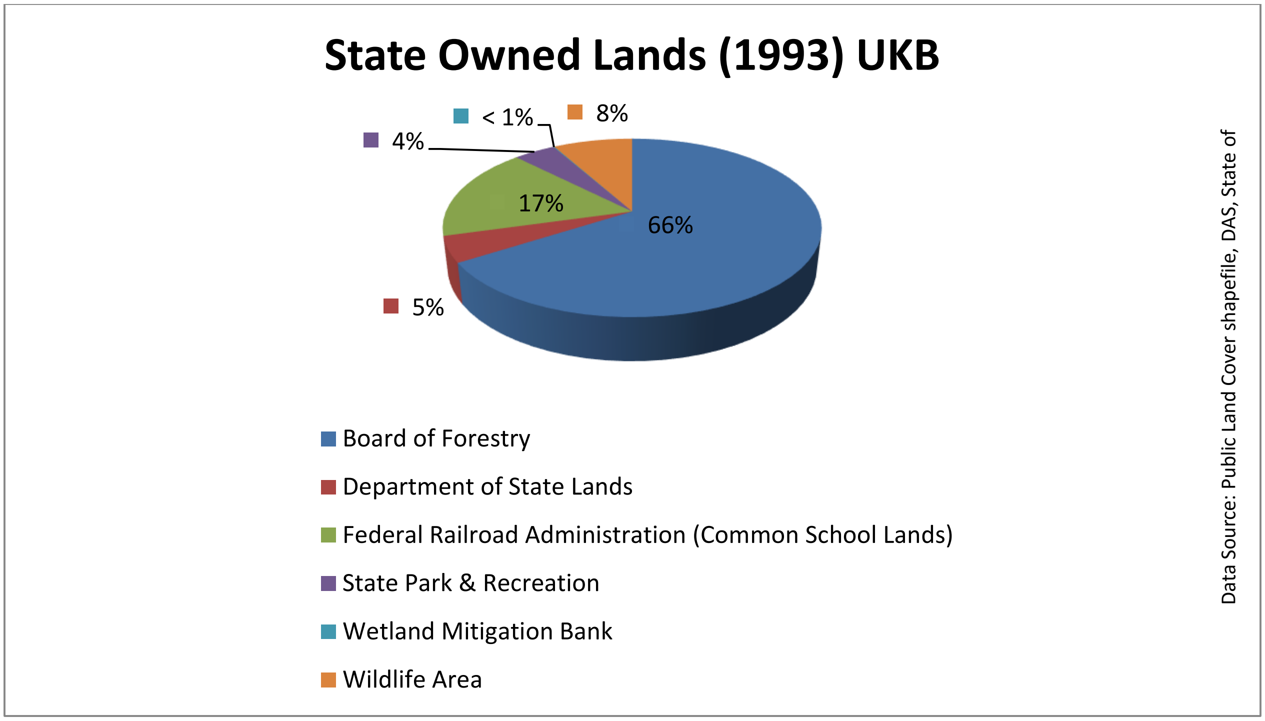

Figure 2: State of Oregon Owned Lands in the UKB during 1993

Current Land Management

Approximately, 73 percent of the UKB is managed by the Forest Service (FS), which is significantly more land than any other agency managing public lands and as such, the FS serves as lead manager for the BLM land in the UKB regarding Total Maximum Daily Limit (TMDL) (Forest Service, 2011). In general, the Forest Service's mission is the stewardship of wildlands and forests, which in the case of the UKB manifested into the "Klamath National Forest Ecological Restoration" plan, which intends to, restore the area to historic vegetation conditions and ecosystem process and reintroduce fire back into the ecosystem; details of which are summarized in Table 5.

Table 5. "Klamath National Forest Ecological Restoration" Projects, Forest Service, 2011

Project Name	Issue	Plan
Happy Camp Fire Protection	Protect the community from fires on FS lands	To link FS roads with newly constructed fuel breaks
North Fork Salmon River Road Restoration	Excessive sediment in water has increased temperatures resulting in poor water quality and loss of beneficial uses	Restore road system to prevent sediment from entering waterways, help meet TDML
Black Rock Aspen Restoration Project	Lack of controlled fire has led to dense conifer forests resulting in hazardous fire conditions, which can damage large-tree wildlife habitat	- increase aspen cover - return meadows to historic condition - reduce amount of non-historic trees (i.e. Jeffery and ponderosa pines) - create fuel management zones

Source: FS, 2011, p. 54 - 57

The National Parks System (NPS) manages the Crater Lake National Park, which occupies about 95,122 acres, approximately five percent of the UKB. The Division of Resource and Visitor Protection Law Enforcement manages federal law and state law enforcement, emergency medical services, search and rescue, firefighting, and visitor safety (NPS, 2016). The "General Management Plan/Environmental Impact Statement" (GMP), most recently completed in 2005, for Crater Lake National Park sets the course for resource preservation and visitor use for the next 15 years (NPS, 2005). The GMP contains four alternative management strategies, however, the NPS prefers Alternative 2, which focuses on increasing recreational diversity and education and research opportunities (NPS, 2005). For instance, Alternative 2 offers more non-motorized activities by seasonal road closures around the rim and re-tasking a paved trail into a non-paved, non-motorized access only trail (NPS, 2005). In addition, Alternative 2 focuses on developing collaborations with Universities, scientists, and education groups through which the NPS would gain scientific information that they would in turn disseminate to the public through in-depth, specialist tours (NPS, 2005). Lastly, Alternative 2 would utilize existing building in the nearby community to accommodate future staff and/or activity needs instead of constructing new buildings on park property (NPS, 2005).

Impacts of the Crater Lake National Park's GMP Alternative 2 would include enhanced resource information, which will improve management and if the need arises to use the nearby community's buildings, there would be a small increase to the local economy (NPS, 2005). The other alternatives in the GMP include a no-action plan, a plan that focuses on the "enjoyment of the natural environment" (p.5), and one that focuses on preserving and restoring the area's natural processes (NPS, 2005).

The Bureau of Land Management (BLM) manages approximately 11 percent of the lands in the Upper Klamath Basin (See Figure1) using the Resource Management Plan (RMP) written in 1995. The RMP calls for healthy forest ecosystems that will provide habitat and supply timber, recreation, and grazing for livestock, which will boost the local economy and lend to regional and national economic growth and all lands managed by the BLM have an Aquatic Conservation Strategy (BLM, 1995). Of the RMP's seven alternative plans, the BLM chose the "Proposed Resource Management Plan [that proposes to] emphasize ecosystem management; [retain] late-successional forest, restoration and maintenance of watershed conditions" and protection of listed species (BLM, 1995 p. R-3).

Importance of the watershed for protected /at risk species

This site has important significance, as it is the only location of two fish species the Lost River sucker (*Deltistes luxatus*) and the shortnose sucker (*Chasmistes brevirostris*). Both species were declared endangered in Klamath Lake and its tributaries as of 1988 by way of the Endangered Species Act of 1973 (Adams and Cho, 1998; Cooperman and Markle, 2011;

USFWS, 2012). Additionally, both species of suckerfish have a cultural significance to the Klamath Tribes who, by treaty, are guaranteed access to enough of the resource to meet the tribe's needs (Adam and Cho, 1998). The site is also important habitat for 80 percent of the Pacific Flyway's migrating waterfowl (USFWS, 2014).

Objectives

This case study focuses on land that was converted because of anthropogenic activities during the 20th and early-21st centuries in the Klamath Bain located in Oregon. The purpose of the analysis was to examine changes for coverage using National Land Cover Data and GIS techniques. A long-term study of this nature can further explain and record the impact of anthropogenic activities on the values of wetland ecosystems.

The objectives of this study were: to develop a quantitative conceptual understanding of the land cover/use changes which occurred during the last century; to locate the areas that were historically wetlands; to describe the ecological values of wetlands, and finally, to develop a set of wetland restoration recommendations.

Materials and methods

Site description

The study was conducted in the Upper Klamath Basin (UKB) of Oregon, which spans 5.2 million acres of Jackson, Lake, and Klamath Counties; however, the UKB extends into Modoc and Siskiyou Counties of California (NRCS, n.d). There are six sub-basins in the UKB watershed above the Iron Gate dam including the Lost River, Sprague River, Upper Klamath

Lake, and Williamson River sub-basins in Oregon and the Butte Creek and Upper Klamath (east) sub-basins, which lie mostly in California with a portion of its boundary is in Oregon.

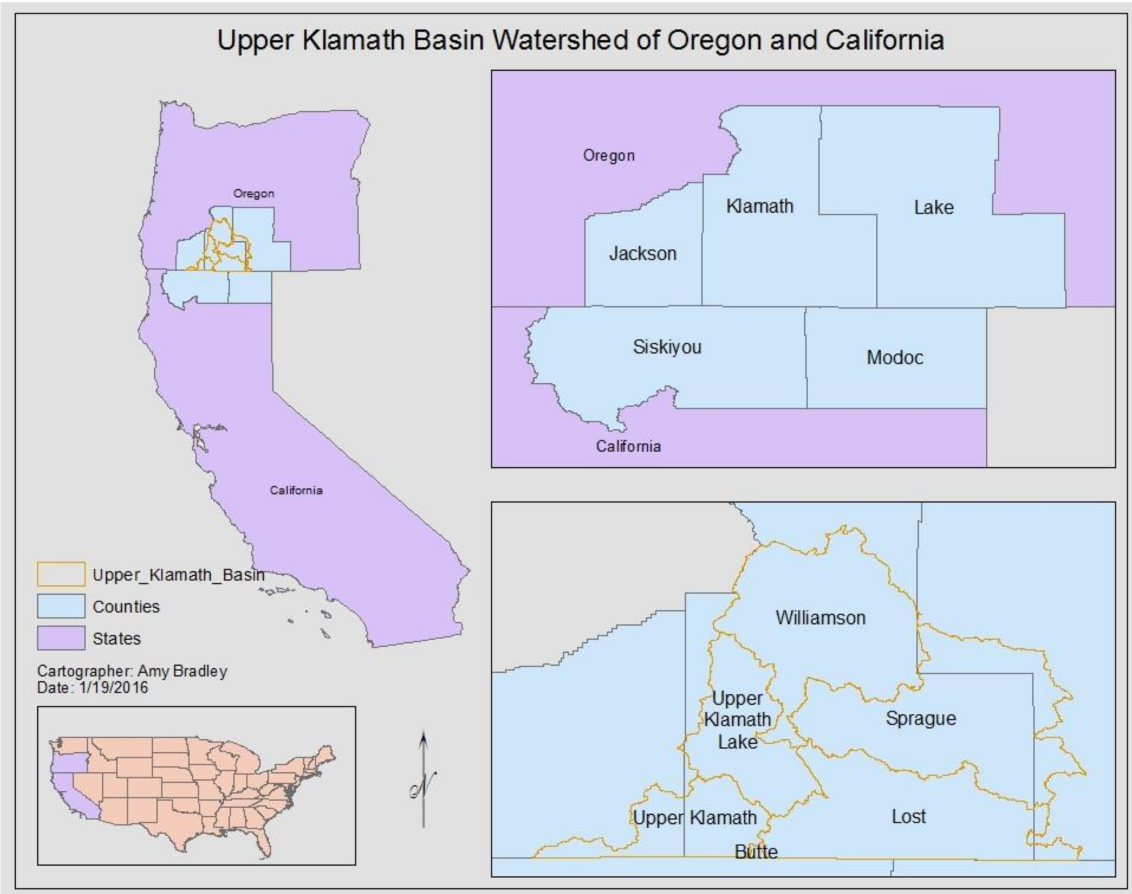

Image 1. Map of the Upper Klamath Basin Watershed of Oregon and California

The UKB is characteristic of the basin and range province on the east (USGS, 2013), which has steep mountain ranges that alternate with long, flat basins, respectively (NPS, 2015) and the Cascade-Sierra Mountains province, typically described as a rugged, mountainous landscape, to the west (USGS, 2013). The region incorporates significant water resources since it includes several major bodies of water including Crater Lake at Mount Mazama in the north, the Williamson and Wood Rivers, which flow from Mount Mazama, Klamath Lake and River, and the Lost and Sprague Rivers, which flow westward from the Basin and Range province in the east (USGS, 2013).

The water in the UKB watershed is recharged through yearly precipitation, which is influenced by the areas two climate zones including Climate Division Five "High Plateau" and Climate Division Seven "South Central Oregon" (Taylor, n.d.). A characteristic of the High Plateau is the large amount of snow due to its high elevation; however, the UKB receives less precipitation than the surrounding mountains due to its relative location to the Cascades and its distance from the coast (Taylor, n.d.). Unlike most of the Cascade Range in Oregon, the highest point of the Cascades in the UKB is only 9,000 feet in elevation, which reduces the effect of the rain shadow (Taylor, n.d.). Additionally, the land east of the Cascades in the UKB has a low elevation of 5,500 feet. This relatively small change in elevation results in moister air and more precipitation for the High Plateau (Taylor, n.d.).

Characteristics of the South Central Oregon climate zone include wide, high-desert prairies separated by mountain ranges and high mountain peaks (Taylor, n.d.). As Table 6 indicates, the in the western portion of this zone receives most of its precipitation during the winter months with a progressive decrease until, unlike the eastern portion, which receives most of its peak perception during the spring and summer months (Taylor, n.d.).

In general, the average precipitation for the UKB varies greatly based on location, as listed in Table 6. Most of this area receives low precipitation (<15" / year). For instance, the area near the City of Klamath Falls, in the SSW region, averages approximately 14 inches of precipitation per year. The exceptions are the areas in higher elevations, such as the Steens

Mountains in the eastern region, which receives ~40" / year and Crater Lake National Park in the NNW region, which receives averages over 66 inches of precipitation per year (Taylor, n.d.).

Table 6. Precipitation - (1971 - 2000) Seasonal and Annual Averages (inches)					
Location	Annual	Spring (Mar-May)	Summer (June - Aug.)	Autumn (Sept. - Nov.)	Winter (Dec. - Feb.)
Chemult	24.36	1.65	0.69	1.98	3.79
Chiloquin	20.19	1.6	0.55	1.55	3.03
Crater Lake Natl Park	66.69	5.54	1.35	5.74	9.59
Klamath Falls	13.95	1.19	0.52	1.13	1.82
Sprague River	16.08	1.38	0.57	1.27	2.14

Source: Taylor, (n.d.)

Database elaboration

Datasets for this study were obtained from the Oregon Geospatial Enterprise Office (GEO) and the Multi-Resolution Land Characteristics (MRLC) Consortium. The 1938 historic vegetation dataset from the GEO was created using ArcView 3.2 by integrating digital data from a variety of sources into an ArcView shapefile with an overall scale of 1:100,000 (Tobalske, 2002). Digital data contributors included the BLM, the Oregon National Heritage General Land Office, Oregon Gap analysis, and the Soil Survey Geographic all of which contributed to the 1992 Oregon Vegetation dataset with additional contribution from the Oregon Department of Fish and Wildlife Service, the Idaho cooperative Fish and Wildlife Research Unit and the Idaho Department of Water Resources (Tobalske, 2002). In order to identify the different vegetation cover boundaries of different vegetation types, 1:250,000 scale LANDSAT Multi-Spectral Scanner false-color infrared prints were visually photo-interpreted (Tobalske, 2002).

The National Land Cover Database (NLCD) is produced through a collaborative effort by the Multi-Resolution Land Characteristics (MRLC) Consortium, which is a partnership between several federal agencies including the U.S. Geological Survey (USGS), the NRCS, BLM, the U.S. Environmental Protection Agency (EPA), Forest Service, NPS, USFWS, and the National Oceanic and Atmospheric Administration (NOAA) (Homer et al.,). The NLCD details 21 classes of land cover created from 1,780 Landsat 5 and Landsat 7 images taken during all seasons except winter (USGS, 2014). The process to develop the NLCD 2001 images included creating mapping zones based on preclassification of land cover based on similarity (USGS, 2014). The decision tree method was used on the 2011 Landsat satellite date in order to classify land cover categories (USGS, 2004). The spatial resolution for both NLCD 2001 and NLCD 2011 datasets is 1 arc-second, which is approximately 30m,the coordinate system is Albers Conical Equal Area, and the datum is the North American Datum of 1983. Additional processes to amend the 2001 and 2011 versions of land cover were completed in 2014 in order to correct differences between developed classes and the impervious surfaces dataset (Homer et al., 2004).

Landscape Analysis

There were three separate analyses for this case study: one to identify historic wetlands for comparison to land use in 2011; comparison of 1938 Oregon vegetation to 1992 Oregon vegetation; and comparison of the NLCD 2001, and 2011 data to determine change in land use. Assessment of the changes at the landscape levels are possible through the analysis of the quantity of individual Land Cover class code values. The Oregon vegetation and NLCD datasets were imported into ArcMap 10.0 and clipped to the area of the UKB using the Geoprocesing Clipping tool for the Oregon vegetation dataset and the data management toolset, raster processing, clip tool on the NLCD. Table 7 lists the 1938 and 1992 Oregon Vegetation datasets that were categorized, analyzed, and grouped in order to provide a better comparison. The 1938 Oregon vegetation dataset was visually analyzed to identify historic wetlands and an ArcMap 10.0 feature class was created from the selected wetlands, which was used to locate areas on the NLCD maps that were converted from wetlands to lands used for anthropogenic tasks. Mathematical computations were done to determine the difference between the individual vegetation categories, as listed in Table 7.

Table 7. List of the 1938 and 1992 Oregon Vegetation Categories.
The bold typeface represents the categories. The bulleted items explain the combination of vegetation found in each category when necessary.

1938 Oregon Vegetation	1992 Oregon Vegetation
Alpine tundra-barren	**Agricultural cropland and pastureland** • w/ big sagebrush-Idaho fescue • w/ Hardstem bulrush-cattail-burreed marsh • w/ Perennial bunchgrass seedings
Big sagebrush • Basin big sagebrush • Mountain big sagebrush • Wyoming big sagebrush	**Big sagebrush mix** • Big sagebrush-cheatgrass • Big sagebrush-cheatgrass/Western juniper-bluebunch wheatgrass • Big sagebrush-Idaho fescue • Big sagebrush-Idaho fescue/Low sagebrush-Idaho fescue
Bitterbrush	**Black greasewood mix** • Black greasewood-bottlebrush squirreltail
Coastal headland	**Brushfield**
Douglas fir • Pacific silver fir-mountain hemlock	**Douglas fir mix** • Douglas fir-true fir-ponderosa pine-western larch forest
Grand fir	**Douglas fir pure** • True fir-Douglas fir forest
Idaho fescue	**Low sagebrush / Idaho fescue** • Low sagebrush-Idaho fescue
Lodgepole pine	**Marsh / wetland** • Hardstem bulrush-cattail-burreed marsh
Mahogany	**Mixed Conifer Forest**

• Curl-leaf mountain mahogany	• Siskiyou-Sierra mixed conifer forest • Siskiyou mixed conifer forest-high elevation • Siskiyou mixed evergreen forest
Marsh / Wetlands	**Lodgepole pine mix** • Montane lodgepole pine forest and woodland pumice
Mixed conifer	**Hemlock mixed forest** • Mountain hemlock-red fir woodland • Mountain hemlock-true fir-lodgepole pine forest • Mountain hemlock forest • Mountain hemlock parkland
Oak mix • Oak-madrone • Oak-savanna	**Ponderosa pine forest mix** • Ponderosa pine-Douglas fir-true fir forest • Ponderosa pine-lodgepole pine forest • Ponderosa pine forest and woodland • Ponderosa pine forest and woodlands on pumice
Open Water	**Oak mix** • Oak-Pacific madrone forest and woodland • Oregon White Oak-Ponderosa Pine woodland • Oregon White Oak-Western Juniper woodland
Pine mix • Jeffrey pine • Whitebark pine	**Open water**
Ponderosa pine	**Recent timber harvest areas**
Riparian hardwoods	**Rimrock/canyon scrubland** • Rimrock and canyon shrubland-with sagebrush
Shasta fir-white fir	**Subalpine forest** • Subalpine fir-Engelmann spruce forest and parklands • Subalpine lodgepole pine forest and woodland
Subalpine forest • Subalpine fir	**Tufted hairgrass** • Tufted hairgrass-bluegrass montane meadows
Tufted hairgrass	**Urban / Industrial**
Western juniper woodland	**Urban mosaic w/ woodland** • Oak-Douglas fir-ponderosa pine-pasture-urban mosaic
Wet meadow	**Wetlands – alkaline grassland** • Alkaline grasslands and seasonal wetlands • Alkaline grasslands and seasonal wetlands/Big sagebrush-bottlebrush squirreltail
Wetlands-alkaline grasslands • Alkaline grasslands and seasonal wetlands	**Wetlands-sedge meadow** • Sedge montane meadows and wetlands
Willows	**Western juniper mix** • Western juniper-big sagebrush/Rimerock and canyon shrubland-with sagebrush

	• Western juniper-big sagebrush-cheatgrass • Western juniper-big sagebrush-Idaho fescue • Western juniper-bitterbrush-bluebunch wheatgrass • Western juniper-bitterbrush-Idaho fescue • Western juniper-bunchgrass/Ponderosa pine forest and woodland • Western juniper-low sagebrush-Idaho fescue • Western juniper-low sagebrush-Idaho fescue/Western juniper-big sagebrush-Sandbergs bluegrass • Western juniper-low sagebrush-Sandberg bluegrass • Western juniper-low sagebrush-tall bunchgrass • Western juniper-mountain big sagebrush-Idaho fescue/Ponderosa pine forest and woodland

The NLCD 1992, 2001, and 2011 datasets was categorized by class code, which is listed in Table 8; note the NLCD 1992 class code was updated to the current NLCD class code that was created in 2001(Fry et al., 2009). In order to determine change in land cover, the acres of each land cover class was compared between the years 1992 and 2001 as well as between 2001 and 2011. The acres associated with each Land Cover class code indicates a nominal integer value representing the quantity of pixels (Homer, 2004). Each pixel or cell size is a 30 by 30 meter grid (USGS, 2014), which converts to 0.00741316 acre. Computations were completed to convert the cell size to acres.

Table 8. NLCD Class Code system used in the Upper Klamath Basin - 1992 to 2001 code conversion

1992 Code	2001 Code	Land cover type	Definition
11	11	Open water	All areas of open water with less than 25% cover or vegetation or soil
12	12	Perennial ice, snow	All areas characterized by a perennial cover of ice and/or snow, generally greater than 25% of total cover.

85	21	Developed, Open Space	Includes areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses; impervious surfaces account for <25%.
21	22	Developed, Low Intensity	Includes areas with a mixture of constructed material and vegetation; impervious surfaces account for 20-49%.
22	23	Developed, Medium Intensity	Includes areas with a mixture of constructed materials and vegetation; impervious surface accounts for 50-79%.
23	24	Developed, High Intensity	Includes highly developed areas where people reside or work in high numbers; impervious surfaces accounts for 80-100%.
31, 32, 33	31	Bare Land (Rock/Sand/Clay)	Barren areas of bedrock, desert, pavement, scarps, talus, slides, volcanic materials, glacial debris, sand dunes, strip mines, gravel pits; vegetation accounts for <15%.
41	41	Deciduous Forest	Areas dominated by trees that are >5 meters tall and >20% total vegetation cover; 75% of tree species shed foliage with the seasons.
42	42	Evergreen Forest	Areas dominated by trees that are >5 meters tall and >20% total vegetation cover; canopy is never without green foliage
43	43	Mixed Forest	Areas dominated by trees that are >5 meters tall and >20% total vegetation cover; 75% of tree species shed foliage with the seasons. Neither deciduous nor evergreen species are >75% of total tree cover
51	52	Shrubland	Areas dominated by shrubs; less than 5 meters tall with shrub canopy >20% of total vegetation.
71	71	Grasslands / Herbaceous	Areas dominated by grammanoid or herbaceous vegetation; >80% total cover
81	81	Pasture / Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or production of seed or hay crops
61, 82, 83, 84	82	Cultivated Crops	Areas used for the production of annual crops and account for >20% of total vegetation.

91	90	Woody Wetlands	Areas where forest or shrub land vegetation accounts for >20% of vegetative cover / soil is periodically saturated with water
92	95	Emergent, Herbaceous Wetland	Areas with perennial herbaceous vegetation accounts for >80% / soil is periodically saturated with water

Source: Homer, et al. 2004. pp 4-6

Results

Vegetative cover analysis and change

The thematic map, Image 2, illustrates the vegetation in the UKB during 1938. Table 9 lists the percent change in vegetation cover between 1938 and 1992. The majority of the vegetative cover during 1938 was Douglas fir forest, which occupied over 60% of the total area, Ponderosa pine forest and Lodgepole pine. Wetlands, marshes, wet meadows, and alkaline grasslands covered a combined area of 127,364 acres. One cover that is not present in the UKB during 1938 is agricultural crop, pasturelands, or urban development.

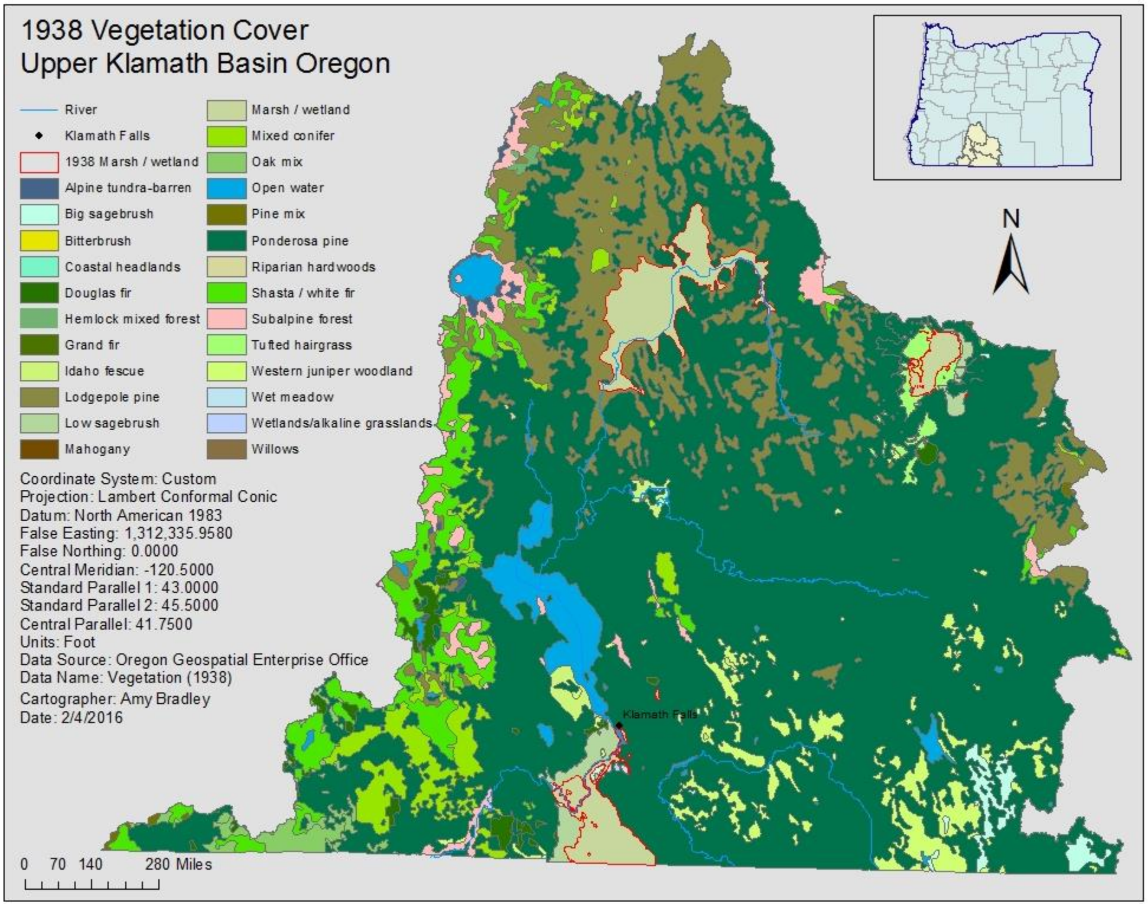

Image 2: 1938 Vegetation Cover in the Upper Klamath Basin of Oregon

For comparison, the data for the vegetation in the UKB during 1992 was processed and the 1938 Marsh / Wetlands layer was added, which resulted in the following thematic map, Image 3. The areas that showed change in wetland vegetation coverage are highlighted with a red square and are represented on the corresponding large-scale map, Image 4.

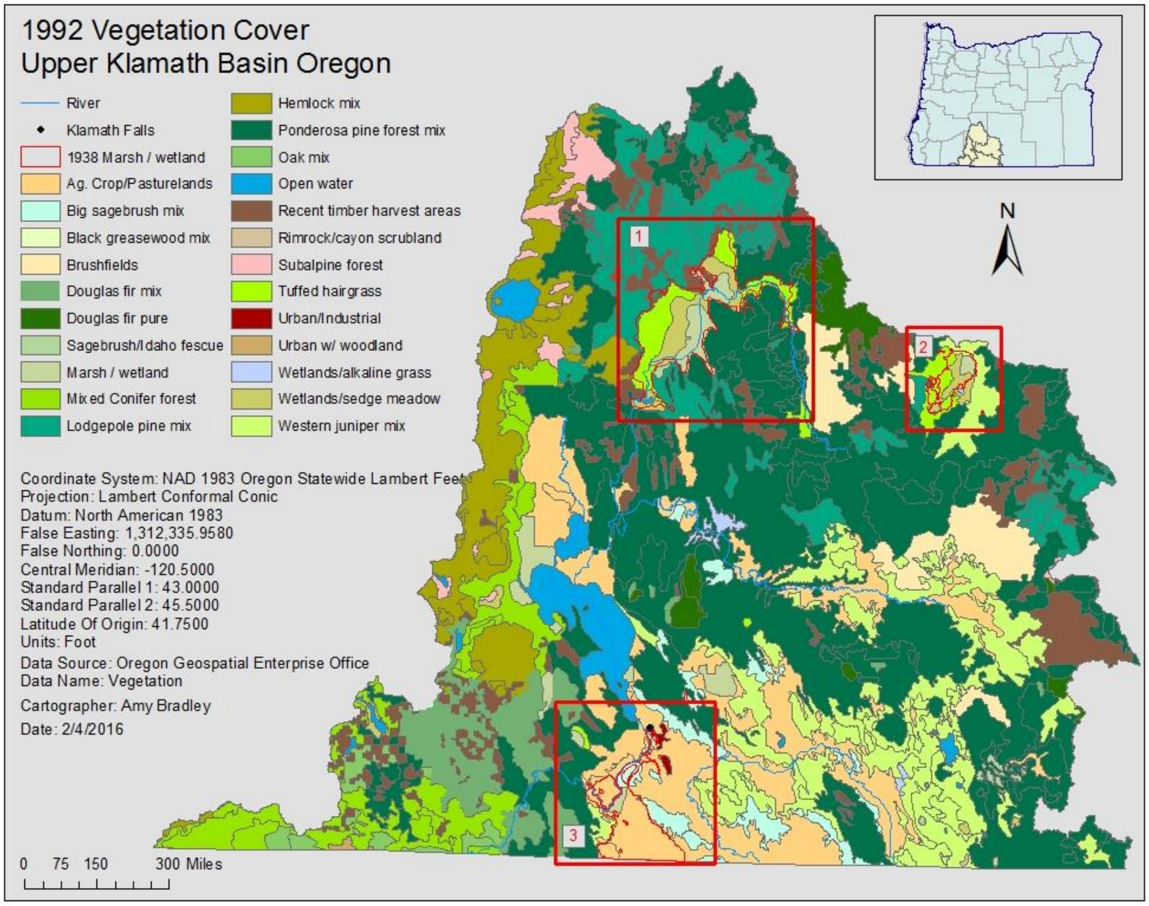

Image 3: Vegetation cover in the Upper Klamath Basin of Oregon during 1992

As evident by the data presented in Table 9, by 1992 there was ~0.6% loss in acreage of Alpine tundra-barren land, ~231% loss in acreage of Lodgepole pine forests, ~16% loss in acreage of Shasta/white fir forest acreage, and ~569% loss in acreage of Douglas fir forest. Gains were seen in agricultural crop and pasturelands acreage, which increased by ~21% and Western juniper woodlands acreage, which gained ~13%.

Table 9.
Comparison of vegetation cover in the Upper Klamath Basin
Between 1938 and 1992 (acres)

Vegetation Name	% Change	Vegetation Name	% Change
Ag. Crop/Pasturelands	21.149	Oak mix	-0.569
Alpine tundra-barren	-0.673	Open water	-0.364
Black greasewood mix	0.006	Pine mix	-0.401

Big sagebrush	2.063		Ponderosa pine	-231.892
Bitterbrush	-0.004		Ponderosa pine forest mix	96.081
Brushfields	6.145		Recent timber harvest areas	16.665
Coastal headlands	-0.002		Rimrock/cayon scrubland	0.026
Douglas fir mixed forest	7.380		Riparian hardwoods	-0.085
Douglas fir pure	-569.383		Shasta/white fir	-16.062
Hemlock mixed forest	24.625		Subalpine forest	-1.922
Grand fir	-0.088		Tufted hairgrass	1.910
Idaho fescue	-0.856		Urban/Industrial	0.164
Lodgepole pine	-59.054		Urban mosaic w/ woodlands	0.103
Lodgepole pine mix	16.236		Western juniper woodland	13.469
Low sagebrush	-1.495		Wet meadow	-0.076
Low sagebrush/Idaho fescue	0.296		Wetlands - alkaline grasslands	0.472
Mahogany	-0.001		Wetlands - sedge meadow	1.984
Marsh / wetlands	-4.083		Willows	-0.005
Mixed conifer	7.688			

Visual analysis of the land cover change showcased in Box 1 of the map presented as Image 4 reveals a slight change in vegetation from 1938 to a mix of tufted hairgrass-bluegrass montane meadows, sedge montane meadows & wetlands, and low sagebrush-Idaho fescue.

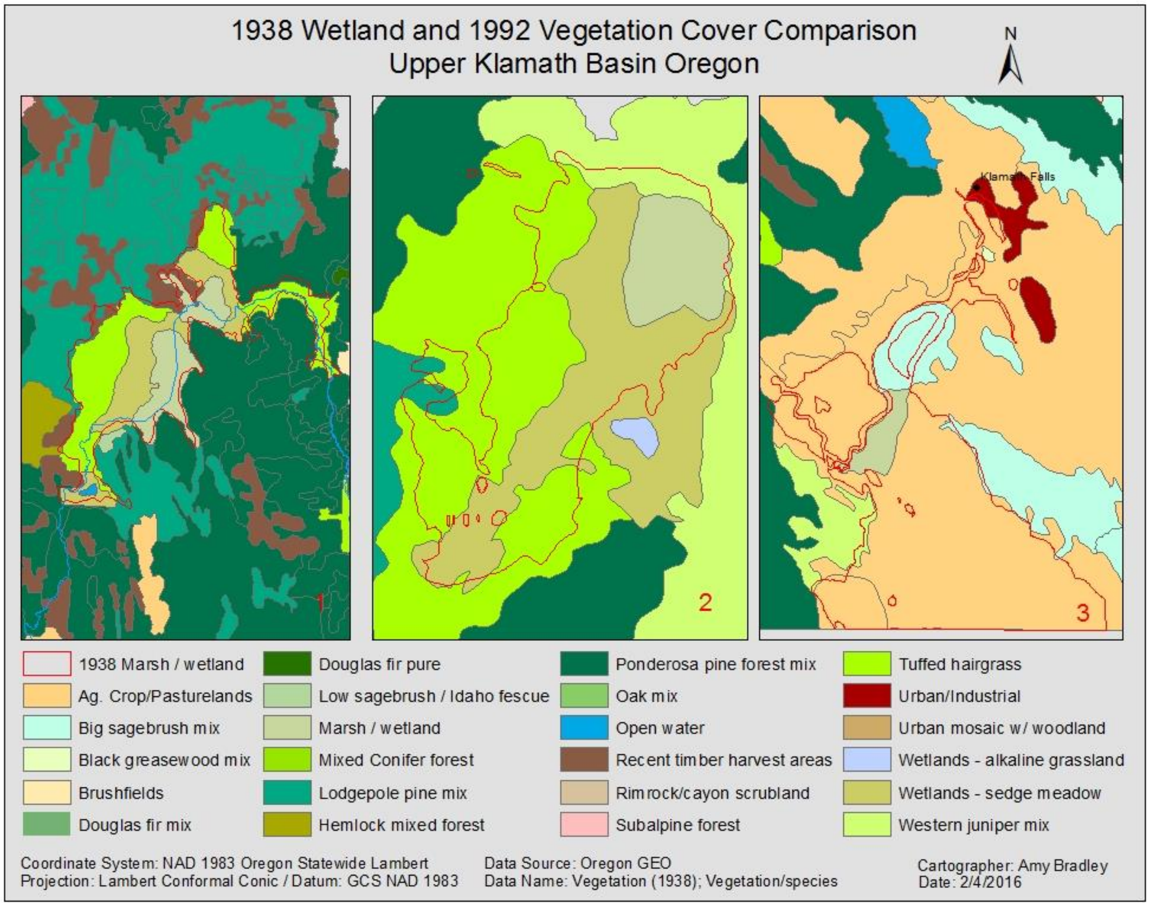

Image 4: Comparison between wetlands present in 1938 and the vegetation cover in 1992 in the UKB of Oregon

The land cover change, as illustrated in Box 2 of Image 4 is slight with the majority of the vegetation cover remaining wetlands and marsh with a small area of tufted hairgrass-bluegrass montane meadow. The majority of the change is visible in Box 3 of the map presented in Image 4, which revels a large change in land cover from wetlands to agricultural cropland / pastureland, big sagebrush / Idaho fescue, urban / industrial development, and a small area of hardstem bulrush-casttail-burred marsh.

Land cover analysis and change

The NLCD for 2001 and 2011 in the UKB was processed with ArcMap to which was added the 1938 Marsh / Wetlands layer in order to produce the two corresponding thematic maps, Image 5 and Image 6.

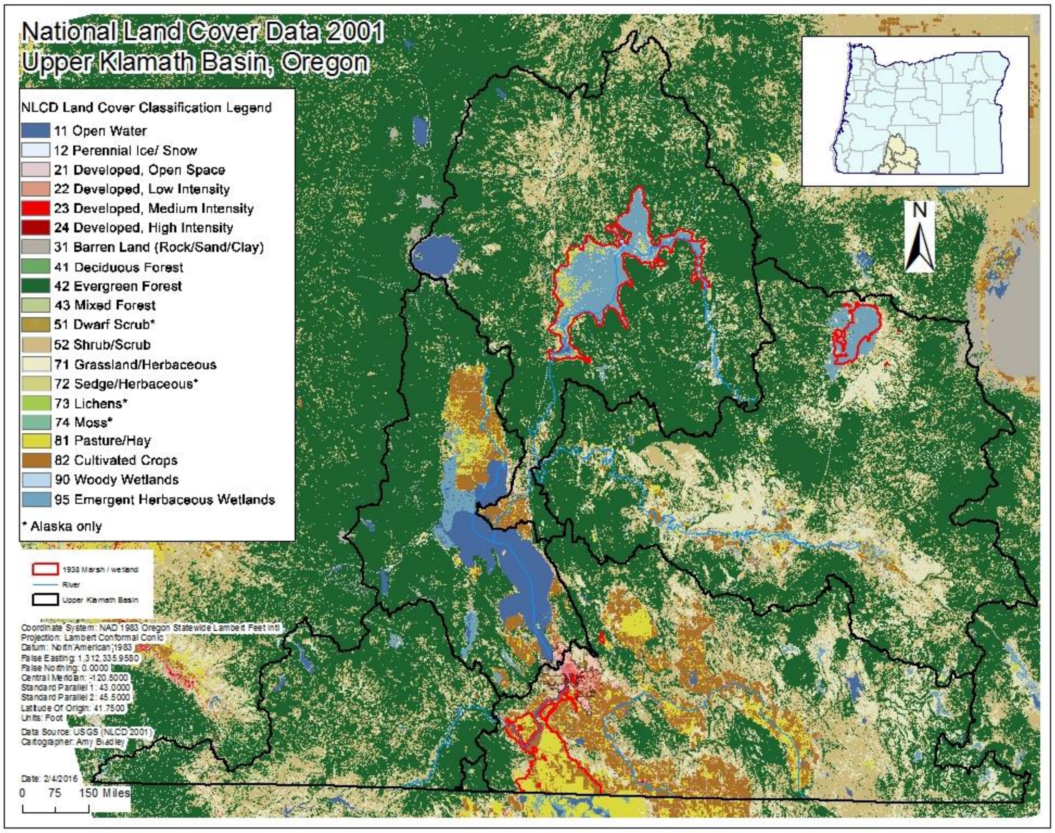

Image 5: Upper Klamath Basin, National Land Cover Data from 2001

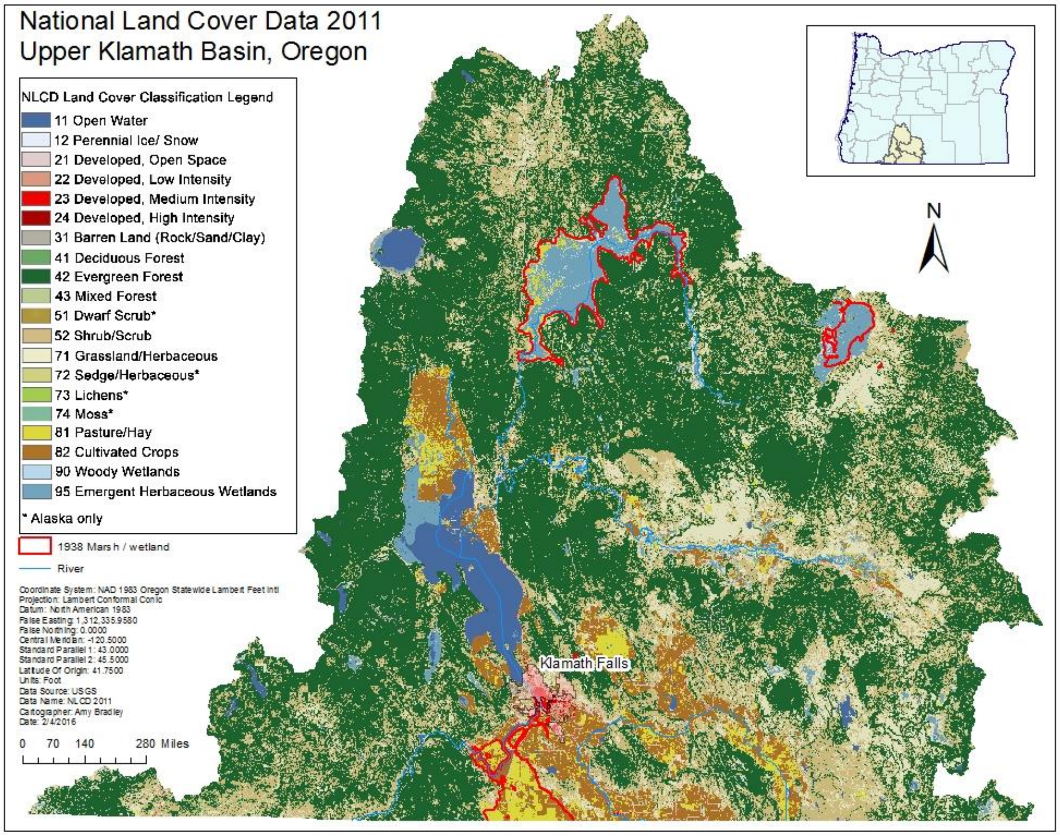

Image 6: Upper Klamath Basin, National Land Cover Data from 2011

Figure 4 illustrates the land cover change that occurred between 2001 and 2011 in the UKB of Oregon. Analysis of the data revels the greatest change in land cover was of grassland/herbaceous land, which lost 16,638 acres.

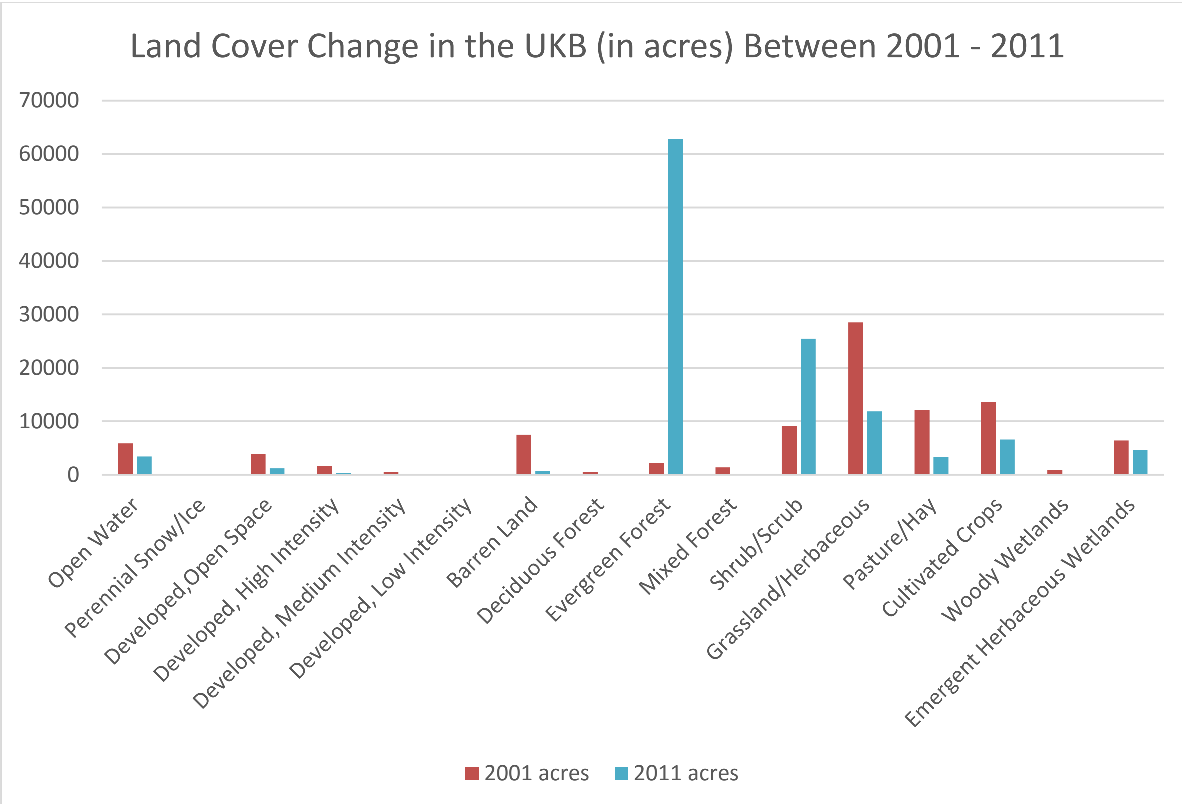

Figure 4: Upper Klamath Basin, Land Cover Change between 2001 and 2011

Additionally, there was a reduction of open water (-2,444 acres), pasture/hay land cover (-8,757 acres), and cultivated crops (-7,006 acres), all types of developed land (open space and low, medium and high intensity), barren land, deciduous forest, mixed forest, woody wetlands, and emergent herbaceous wetlands. Gains were seen in evergreen forests, which gained approximately 60,590 acres and shrub/scrub lands that gained approximately 16,337 acres. Wetland land use in the UKB decreased by 701 acres of woody wetlands and 1,772 acres emergent, herbaceous wetlands, as indicated by Table 10.

Table 10. Land cover change in the Upper Klamath Basin of Oregon between 2001 and 2011 in acres. Data source: UGSG, NLCD 2001 and 2011. The description of the values is found in Table 4.			
	2001 (acres)	2011 (acres)	% Change
Open Water	5,866	3,423	2.0
Perennial Snow/Ice	2	2	0.0
Developed,Open Space	3,898	1,186	2.2
Developed, High Intensity	1,589	376	1.0
Developed, Medium Intensity	538	115	0.3
Developed, Low Intensity	186	43	0.1
Barren Land	7,509	702	5.5
Deciduous Forest	475	62	0.3
Evergreen Forest	2,210	62,800	-49.3
Mixed Forest	1,355	81	1.0
Shrub/Scrub	9,114	25,450	-13.3
Grassland/Herbaceous	28,497	11,859	13.5
Pasture/Hay	12,108	3,351	7.1
Cultivated Crops	13,615	6,609	5.7
Woody Wetlands	812	111	0.6
Emergent Herbaceous Wetlands	6,417	4,645	1.4

Discussion

As evident by the water crisis in the UKB in Oregon, change in land cover and land use over time leads to degraded water quality, insufficient water quantities, and loss of wildlife. Unsustainable government policies and regulations lead to the mismanagement of the natural resources in the UKB, which resulted in the degradation of aquatic resources in the area are severely impaired due to agricultural pressures including flow alteration and over-pumping for irrigation (TNC, 2015). Moreover, the application of high levels of fertilizers in fields adjacent to waterways causes further degradation of the water quality as does increased sediment entering the waterways.

The interconnectedness of the elements in an ecosystem requires a holistic management strategy that considers not only the current usage but also future usage and output production; thus the need for sustainably managing natural resources, including wetlands and cultivated agricultural lands. Managing agricultural lands sustainability reduces the pressure to covert wetlands and encourages restoration and creations of wetlands.

The key principles of sustainable agriculture, according to Pretty (2008) are to:

> i. integrate biological and ecological processes, such as nutrient cycling, nitrogen fixation, soil regeneration, and [healthy] food production process,
> ii. minimize the use of those non-renewable inputs that cause harm to the environment or [society],
> iii. make productive use of knowledge and skills of farmers [for instance] thus improving their self-reliance and substituting human capital for costly external inputs, and
> iv. make productive use of people's collective capacities to work together to solve common agricultural and natural resource problems. (p. 451)

A suggested technique for sustainable agriculture includes the concept of livestock integration, as described by Pretty (2010), specifically the zero-grazing cut and carry system, which involves cutting the grain feed and carrying it to the livestock that is kept in a barn instead of the field, so as to prevent soil erosion and conserve water. Animal waste is collected and dry-staked before reapplied as fertilizer.

Areas, such as the one indicated by Image 7 shows land use areas that are candidates for wetland restoration and/or creation as they were areas of historic wetlands. Both restoration and creation of wetlands involves the establishment of the natural hydro-logic conditions and suitable vegetation communities that will self-regulate and self-maintain (Mitsch and Gosselink, 2007).

Wetland design should be based on a concept of self-design meaning native propagule (transplants, seeds, or spores) are introduced. However, success should not only depend on the presence of wildlife, yet the ability of the ecosystem to adapt and change according to the physical environment (Mitsch and Gossilink, 2007).

Recommended techniques include creating a trench across the property that empties into a low depression. Drainage pipes are installed in the cultivated irrigated fields, which empty into the depression. These pipes will collect and direct the run-off water into the wetland, which will cycle the nutrients before they enter into the watershed’s waterway. Aggressive planting techniques should be used including planting willow along the shores of the trench and depression as well as planting sedges and shrubs around the depression.

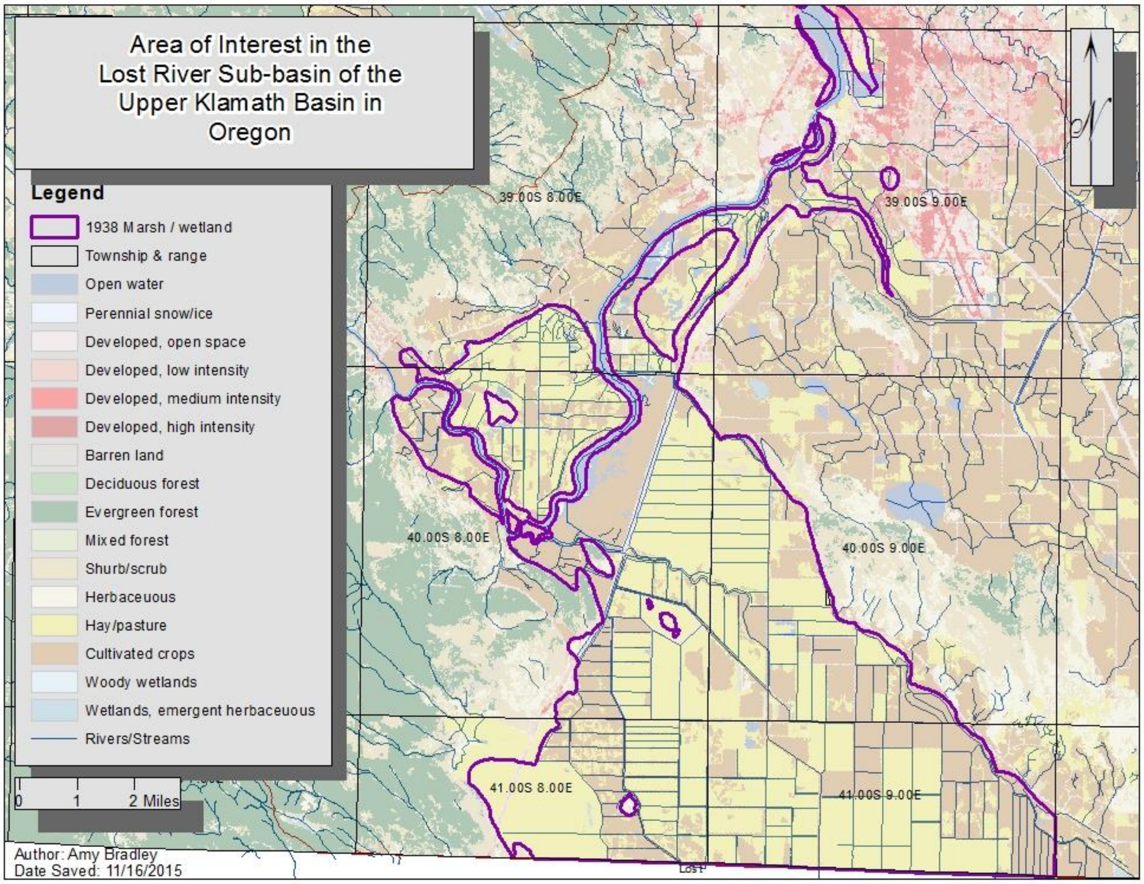

Image 7: Area of interest in the Upper Klamath Basin of Oregon for wetland restoration projects

Strategies to improve wetland conservation include changes to patterns of production and consumption, which will affect the need to expand agricultural lands at the cost of destroying wetlands. While changing patterns of consumption is a matter of changing society's habits, changing the pattern of production is a task attainable through government regulations that focus on managing food production in a sustainable manner. Suggestions on how to change the patterns of production and consumption includes:

- focus on locally produced food,
- increase number of small farms,
- increase variety of crops coming from each farm,
- focus on seasonal food local to each area

- educate the public on how to prepare and cook seasonal local foods
- promote, where possible, backyard gardening and poultry raising
- develop several urban gardens for each neighborhood
- use greenhouse systems in areas with shorter growing season
- use mixed systems such as fish cultivation with hydroponic vegetable systems
- increase the use of electric delivery trucks on farms
- begin partnership program with community members to assist low income, elderly, and disabled community members
- begin educational programs to teach gardening, food preparation, and food storage skills
- initiate programs aimed at reducing waste amongst public and private intuitions (e.g. schools, hospital, prisons) (Pretty, 2010)

The Klamath Basin Restoration Agreement offers a solution to the wicked problem of insufficient water supplies in the UKB. This plan understands and appreciates the values of both the Dominant Management Paradigms and the New Management Paradigm and offers a solution that both sides agree too. Tactics as to how to gain support for community participation in restoration agreements include appealing to their values, explain the logic, offer financial incentives and lastly implement fines for those who will not comply.

Conclusion

Geographic Information Sciences (GISc) provides an opportunity to analyze and evaluate land cover change making it a valuable tool to natural resources managers. This case study demonstrated the usefulness of GISc to conceptualize land cover change, vegetation change, and to locate areas as potential restoration sites.

Changes in vegetation and land cover and use affect an area's ecosystem services as evident by the water crisis in the UKB, which stemmed from decades of unstainable natural resource mismanagement. The UKB provides a good example as to why sustainable natural resource management is important because it considers managing the biosphere's ecosystem services, which are the life-support system (Floyd et al., 2001) for all life on Earth. Wetland restoration and creation is one way to improve ecosystem services that were destroyed through the original reclamation of the wetland.

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