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Summary of the rangelands suitable for terrestrial carbon sequestration in Shasta County

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Winrock International

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SUMMARY OF THE RANGELANDS SUITABLE FOR TERRESTRIAL CARBON SEQUESTRATION IN SHASTA COUNTY

PIER COLLABORATIVE REPORT

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Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Energy Commission), conducts public interest research, development, and demonstration (RD&D) projects to benefit California's electricity and natural gas ratepayers. The PIER Program strives to conduct the most promising public interest energy research by partnering with RD&D entities, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following RD&D program areas:

- Buildings End-Use Energy Efficiency
- Energy-Related Environmental Research
- Energy Systems Integration
- Environmentally Preferred Advanced Generation
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy Technologies
- Transportation

In 2003, the California Energy Commission's Public Interest Energy Research (PIER) Program established the **California Climate Change Center** to document climate change research relevant to the states. This center is a virtual organization with core research activities at Scripps Institution of Oceanography and the University of California, Berkeley, complemented by efforts at other research institutions. Priority research areas defined in PIER's five-year Climate Change Research Plan are: monitoring, analysis, and modeling of climate; analysis of options to reduce greenhouse gas emissions; assessment of physical impacts and of adaptation strategies; and analysis of the economic consequences of both climate change impacts and the efforts designed to reduce emissions.

The California Climate Change Center Report Series details ongoing center-sponsored research. As interim project results, the information contained in these reports may change; authors should be contacted for the most recent project results. By providing ready access to this timely research, the center seeks to inform the public and expand dissemination of climate change information, thereby leveraging collaborative efforts and increasing the benefits of this research to California's citizens, environment, and economy.

Summary of the Rangelands Suitable for Terrestrial Carbon Sequestration in Shasta County is a report for the West Coast Regional Carbon Sequestration Partnership – Phase II (contract number 500-02-004, work authorization number MR-045), conducted by Winrock International. The information from this project contributes to PIER's Energy-Related Environmental Research program.

For more information on the PIER Program, please visit the Energy Commission's website www.energy.ca.gov/pier/ or contract the Energy Commission at (916) 654-5164.

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Abstract

Winrock International evaluated the potential for terrestrial carbon sequestration through afforestation in Shasta County, California. The report presents suitability of rangelands for afforestation, potential carbon accumulation, total costs, and potential carbon supply, and also includes spatially explicit analyses illustrating attractive regions for afforestation within the county and the range of afforestation costs. Researchers determined that afforestation of Shasta County rangelands could result in the sequestration of about 17.7 million tons of carbon (t C) after 20 years at a cost of less than $20/t C ($5.45/ton of carbon dioxide [t CO_2]) or about 57.6 million tons of carbon after 80 years at a cost of less than $10/t C ($2.7/t CO_2). This opportunity, which will be tested and validated through pilot projects in Shasta County under the U.S. Department of Energy-funded West Coast Regional Carbon Sequestration Partnership (WESTCARB)—Phase II, could be replicated elsewhere in California and the WESTCARB region. The report also provides a summary of initial outreach efforts to landowners interested in conducting afforestation for carbon. The authors also include recommendations for further characterization and stratification, landowner outreach, and considerations for incorporating such projects into evolving voluntary carbon markets and regulatory programs.

Keywords: Terrestrial carbon sequestration, afforestation, rangelands, Shasta County, West Coast Regional Carbon Sequestration Partnership, WESTCARB

Executive Summary

Introduction

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven U.S. Department of Energy regional partnerships working to evaluate, validate, and demonstrate ways to sequester carbon dioxide (CO_2) and reduce emissions of greenhouse gases (GHGs) linked to global warming. Afforestation, or establishing forests on lands not currently forested, represents the largest single terrestrial carbon sequestration opportunity for California and the region. It is likewise a substantial opportunity for Shasta County and may offer landowners near-term opportunities to participate in rapidly evolving GHG markets and regulatory systems.

Purpose

This report sought to provide a concise summary of analyses to date on the opportunity to sequester carbon through afforestation of rangelands in Shasta County, including forest suitability, carbon potential, and cost considerations. The report also provides an interim summary of initial outreach efforts to Shasta County landowners.

Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB research will facilitate informed decisions by policy makers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change reduction objectives. The sequestration opportunity presented here is afforestation of rangelands.

Project Outcomes

Forest suitability modeling of Shasta County rangelands was conducted based on biophysical factors of soil water availability, mean annual air temperature, annual average precipitation, slope, and elevation. The results of suitability modeling—after excluding wooded rangelands with canopy cover greater than 40 percent and grassy rangelands dominated by wet meadows—indicate that about 600 thousand acres, or about 80 percent of Shasta County rangelands, would be potential candidates suitable for afforestation (Figure S-1).

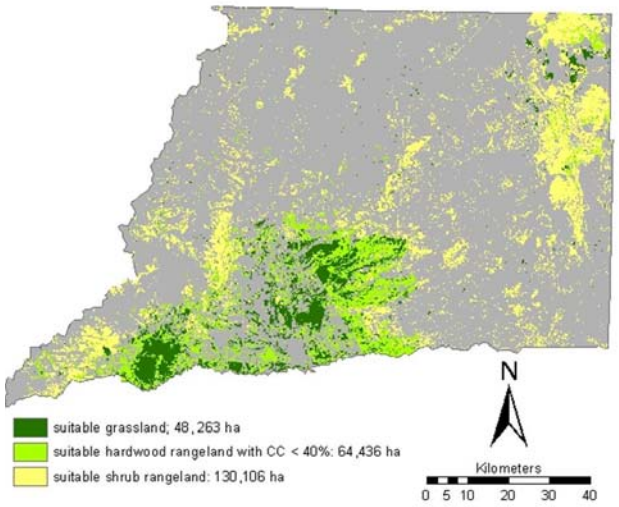

Figure S-1. Map of candidate rangelands for afforestation activities (suitable to support forest and meeting constraints)

Carbon sequestration potential varies by land type, with some lands favorable to mixed conifers that could sequester almost 200 tons of carbon per hectare (about 300 tons CO_2 per acre) over 40 years, and other lands more appropriate to oak restoration and other hardwood range types that would sequester less than 100 tons of carbon per hectare over the same project life. Figure S-2 shows the geographic distribution of sequestration potential.

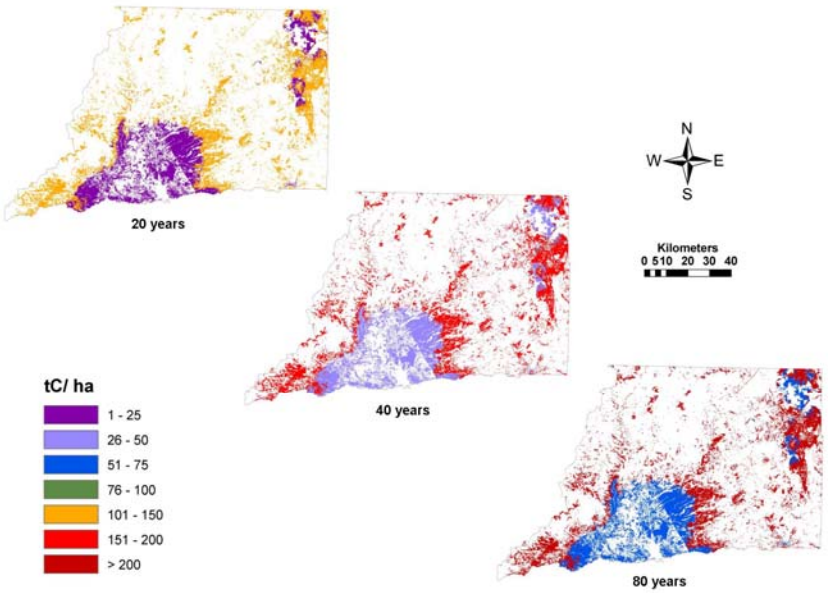

Figure S-2. Carbon sequestration potential on rangelands suitable for afforestation activities for 20, 40, and 80 years

Researchers analyzed the costs of sequestration through afforestation, including opportunity costs, conversion costs such as site preparation and planting, measuring and monitoring costs, and maintenance costs. The objective was to evaluate the net present value of total afforestation costs throughout the county, assuming that landowners would be willing to produce and sell carbon credits from afforestation if the price paid for these credits is greater than the present

value of the stream of costs incurred in producing them. To detect variations in cost based on grazing conditions and topographic locations, researchers divided the rangelands suitable for afforestation into two main classes: (1) those that are likely grazed, and (2) those not grazed, with both classes subdivided into slope classes greater and less than 30 percent slope.

Depending on the forage productivity of rangeland suited for grazing, the net present value of the total costs of afforestation after 40 years was about $500–$900 per acre on slopes less than 30 percent and $680–$1050 per acre on slopes greater than 30 percent.

On rangelands not suited for grazing, where opportunity costs are assumed to be zero, the net present value of total costs after 40 years was about $960/acre for lands with less than 30 percent slope and $1160/acre for lands with greater than 30 percent slope, suggesting that high site preparation costs more than offset zero opportunity costs. Conducting cost analysis in a Geographic Information System (GIS) makes it possible to examine the range of costs throughout the county (Figure S-3).

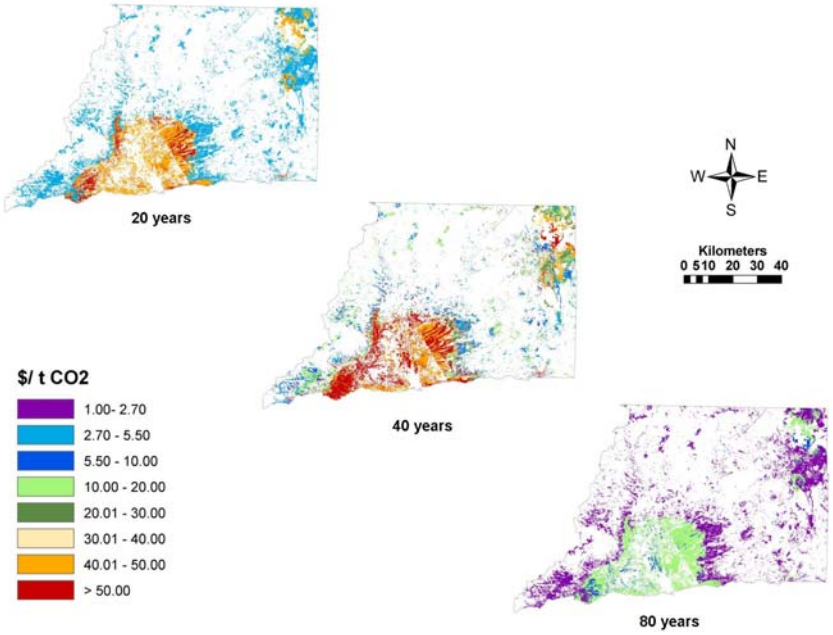

Figure S-3. Cost of CO_2 through afforestation of rangelands suitable for grazing in Shasta County

Outreach to Shasta County landowners and land managers began in October 2006 with an outreach meeting hosted by Western Shasta Resource Conservation District (RCD) and attended by a broad range of individual landowners, watershed group coordinators, state and federal agencies, private industries, and nonprofit organizations. The RCD has continued outreach through individual landowner meetings, watershed group meetings, and outreach via the Natural Resource Conservation Service. A landowner survey has been designed and will be implemented in 2007 to better understand landowner interests, required cost share levels for different project types, species preferences, and other requirements.

Conclusions

After 80 years, about 57.6 million tons of carbon (t C) could be sequestered on candidate rangelands in Shasta County at a cost of less than $10/t C ($2.7/t CO_2). In contrast, about 17.7 million tons of carbon could be sequestered after 20 years at a cost of less than $20/t C ($5.45/t CO_2). These quantities could be sequestered on about 57 percent of the rangeland suitable for afforestation.

Recommendations

More detailed land suitability analysis is needed before actual planting, including examining land capability classifications and soil series data and incorporating aspect into forest suitability modeling/afforestation planning. Landowner outreach efforts will continue, led by the RCD. Data should be collected from existing or planned afforestation efforts throughout the county, with which the project can collaborate to gather existing data or collect additional data; this will greatly expand the geographic and temporal scope of the research effort. Collaboration with other organizations is advised, particularly for implementing successful oak restoration projects. Agreements with participating landowners should be designed carefully, striking the appropriate balance between open participation to achieve research objectives and preparing landowners realistically for the requirements of future carbon markets.

Benefits to California

Results of WESTCARB afforestation pilot activities will inform both voluntary efforts, such as those by California Climate Action Registry members interested in offsetting GHG emissions through forestry, and regulatory developments, such as the process now underway by the California Air Resources Board (ARB) to design a GHG regulatory program under the California Global Warming Solutions Act of 2006 (also known as California Assembly Bill 32). Projects demonstrated to be cost-effective, verifiable, environmentally beneficial, and attractive to both regulated entities and landowners/carbon credit suppliers may become eligible for trading under the market-based compliance program ARB adopts.

1.0 Introduction

1.1 Background and Overview

The West Coast Regional Carbon Sequestration Partnership (WESTCARB), led by the California Energy Commission, is one of seven U.S. Department of Energy (USDOE) regional partnerships working to evaluate, validate, and demonstrate ways to sequester carbon dioxide (CO_2) and reduce emissions of greenhouse gases (GHGs) linked to global warming. Terrestrial (forestry and land use) sequestration options being investigated include afforestation[1] of marginal rangelands, improved management of hazardous fuels to reduce emissions from wildfires, biomass energy, and forest management. Shasta County, California, and Lake County, Oregon, were chosen for WESTCARB Phase II terrestrial sequestration pilot projects because of the diversity of land cover types present, opportunities to implement the most attractive terrestrial carbon activities identified in Phase I, and replication potential elsewhere in the WESTCARB region.

Afforestation of rangelands represents the largest terrestrial sequestration opportunity, both at the state level for California, Oregon, and Washington and within Shasta County (Brown et al. 2004; Dushku et al. 2007a, 2007b; Brown et al. 2007). For example, at the California level, it was found that at a price of < $5.5/ton of carbon dioxide (t CO_2) (< $20/ton of carbon [t C]), 345 million metric tons CO_2 could be sequestered on 2.7 million acres after 20 years and 3 billion metric tons CO_2 could be sequestered on 14.8 million acres after 40 years via afforestation using native species on existing rangelands suitable for forests (Brown et al. 2004).

Shasta County has large areas categorized as rangelands that were forested in the past and that according to forest suitability criteria would be capable of growing trees. Categories of lands in Shasta County classified as rangelands and currently in use as rangelands include open grasslands, irrigated and non-irrigated areas, riparian zones, and rangelands covered with oaks, foothill pines, and other hardwood species on which cattle may still be grazed for most of the year (Figure 1-1). Some of the lands classified as rangelands are covered by dense shrubs such as manzanita or are in a state of arrested succession to forest after fires. These rangelands are apparently not suitable for grazing, but also present an opportunity for afforestation projects.

All rangeland types could theoretically be converted back to forest through site preparation and planting with appropriate species. Afforestation of rangelands would provide a net carbon sequestration benefit equivalent to the per-unit area net change in carbon stocks of the planted forest at X age (with X representing the duration of the activity or of afforestation contracts), multiplied by the total area afforested.

[1] Under the USDOE revised 1605(b) guidelines, afforestation is the establishment of new forests on lands that have not been recently forested, that is a land-use change; reforestation is the re-establishment of forest cover, naturally or artificially, on lands that have recently been harvested or otherwise cleared of trees. In contrast, the California Climate Action Registry does not use the term afforestation and instead defines reforestation as the establishment and subsequent maintenance of native tree cover on lands that were previously forested, but have had less than 10% tree canopy cover (essentially non-forested) for a minimum time of 10 years. This report uses the term afforestation as defined by USDOE.

Such project types are relatively straightforward to measure and monitor and are well accepted in existing carbon registries, reporting protocols, and voluntary carbon offset markets. Selling carbon credits from these projects would provide a new source of revenue for landowners, supplementing other income streams. It is assumed that landowners would be willing to produce and sell carbon from afforestation if the price paid for these credits is greater than the present value of the stream of costs incurred in producing them, including opportunity costs, conversion costs, maintenance costs, and measurement/monitoring/registration costs. This may be the case, particularly for marginally profitable grazing lands and/or grazing lands where afforestation does not require permanent removal of cattle.

From the perspective of carbon offset buyers, meanwhile, such projects could provide highly credible offsets at a reasonable cost. Interest in such projects is increasing, with a general growing awareness of global warming and increasing numbers of businesses, organizations, and even individuals taking voluntary actions to manage their GHG emissions. Afforestation, already recognized by the California Climate Action Registry (CCAR) as activity from which landowners may report and ultimately sell carbon credits to entities voluntarily offsetting their emissions, may also in the future become an activity eligible for market-based offset trading under the cap-and-trade regulatory program recently established by California Assembly Bill 32, the California Global Warming Solutions Act of 2006.[2]

Figure 1-1. Variety of rangelands in Shasta County, California. Clockwise from top left: rangelands with sparse conifers in the northeast corner of the county, hardwood rangelands near Shingletown, hardwood rangelands near Igo and Ono in the southwest, and open rangelands along State Route 44.

[2] AB 32 (Nuñez), Chapter 488, Statutes of 2006.

1.2 Project Objectives

The overall goal of WESTCARB Phase II is to validate and demonstrate the region's key carbon sequestration opportunities through pilot projects, methodology development, reporting, and market validation. WESTCARB will produce methodologies, plans, data, technical papers, and reports that facilitate informed decisions by policymakers, communities, and businesses on how to invest in carbon capture and storage technology development and deployment to achieve climate change mitigation objectives.

This report focuses on one of those opportunities: afforestation of rangelands. The goal of the report is to summarize rangelands suitable for terrestrial carbon sequestration through afforestation in Shasta County, California. The report presents the results of research to date on afforestation potential in the county, provides a progress report on outreach to Shasta County landowners, and outlines next steps toward siting and implementing afforestation pilot activities during the remainder of WESTCARB Phase II.

1.3 Report Organization

The report is organized in methods, results, and conclusions/ recommendations. Section 2 presents methods for determining afforestation suitability, carbon potential and cost. The results of these analyses are summarized in Section 3. Section 2 also provides an overview of landowner outreach methods being employed in Phase II. Though landowner outreach remains in the early stages, Section 3 provides an interim report on these efforts. Section 4 provides recommendations for next steps in analysis and landowner outreach.

2.0 Project Approach

The approach used in this report generally follows that of previous work on the carbon supply from range and forest lands for the whole of California (Brown et al. 2004) and also uses information from analysis of baseline GHG emissions and removals for Shasta County (Pearson et al. 2006). The general approach was to:

- Identify the area and current use and cover of existing rangelands.
- Estimate the area and geographic location of existing rangelands that could be afforested and potential rates of carbon sequestration on these lands.
- Estimate the total cost of afforesting rangelands, including opportunity cost, conversion cost, maintenance cost, and measurement and monitoring cost.
- Determine the geographic distribution of available carbon credits at various prices.

Further detail on methods for calculating carbon supply from afforestation in Shasta County are available in Brown et al. (2007).

2.1 Identifying Rangelands for Terrestrial Carbon Sequestration

2.1.1 Forest Suitability of Rangelands

The total area of Shasta County is approximately 996 thousand hectares, of which 302 thousand (30%) are categorized as rangeland, 63% as forested land, and 6% in the non-forest/non-rangeland category comprised of barren, agriculture, urban, and water (Figure 2-1).

"Rangeland" includes not only open herbaceous and shrub lands (Wildlife Habitat Relationship [WHR] classes such as Annual Grass and Sagebrush), but also a variety of woodland classes (WHR classes such as Blue Oak Foothill Pine, Blue Oak Woodland, Chamise-Redshank Chaparral, Juniper, Mixed Chaparral, Montane Chaparral, Valley Oak Woodland, Wet Meadows).

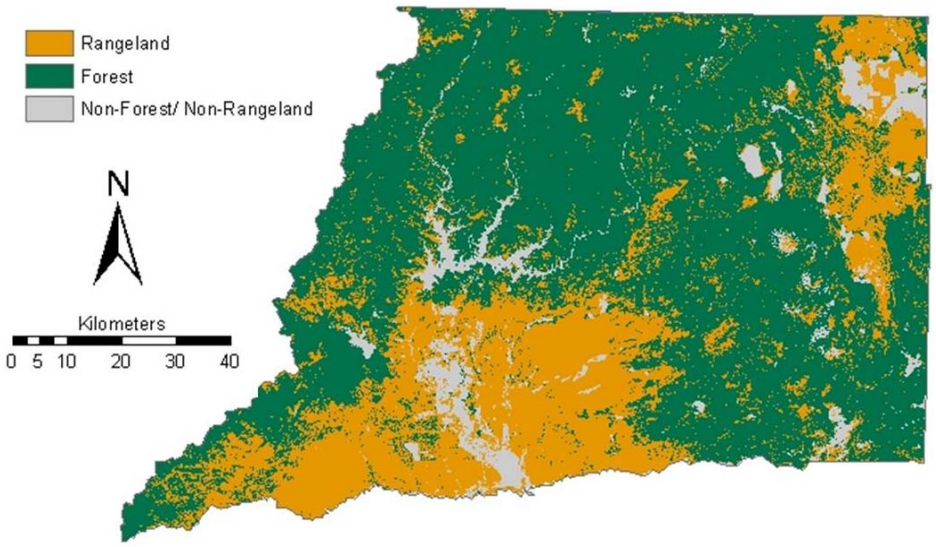

Figure 2-1. Landcover map for Shasta County identifying three land use categories: rangeland, forest, and non-forest/non-rangeland

A Geographic Information System (GIS)-based multi-factor forest suitability model was developed to identify those lands classified as rangeland but theoretically suitable to support forests. The model combined biophysical factor maps (including soil water availability, mean annual air temperature, annual average precipitation, slope, and elevation—calibrated using empirical locations of existing forests) to assign all rangelands a suitability value for forest growth, considering all five biophysical factors. To be considered suitable, a location needed to have high values across all the factor maps. Lands that fell into a category of any one of the factor maps where there were no existing forests were eliminated as candidate lands for afforestation.

A map of two landcover categories—forest and rangeland—was compared to the forest suitability map to show the range within the suitability scale where forests and rangelands currently exist, and where potential change of land use from rangeland to forestland should be explored. Forest suitability was then mapped throughout the county using the multi-factor modeling approach, showing the geographic distribution of the least to most suitable rangelands.

The next step was to identify, among the theoretically suitable rangelands, those that would be candidates for afforestation according to criteria that constitute candidate lands. From the rangelands shown in Figure 2-1, wooded rangelands with canopy cover > 40%, as well as grassy rangelands dominated by wet meadows, were assumed not to be suitable candidates for afforestation and were excluded from further analysis.

A further stratification of candidate lands was made after observation of certain areas mapped as rangeland but apparently unsuitable for grazing. These lands, classified as *chaparral* in the WHR map and falling within the perimeters of past wildfires, tend to be covered with dense shrubs such as manzanita and are generally impenetrable for livestock. They appear to represent a sort of arrested succession to forest. Intuitively it would be possible to convert these lands to forest for a net carbon gain. Because they are not suitable for grazing, opportunity costs might be small to nonexistent, making them attractive candidates for afforestation, but site preparation needed to allow forest to establish may be costly.

2.1.2 Carbon Sequestration Potential

To estimate the net carbon sequestration benefit of converting rangelands to forest, it is necessary to consider not only the change in area from one land use to another, but also the estimated difference in average carbon stocks between the two land uses. The net carbon benefit per unit area will be the difference in carbon stocks between the forest that is to be planted—at a given age such as 20, 40, or 80 years—and the baseline carbon stocks in the current land use. The total net carbon benefit will be the difference in carbon stocks multiplied by the area converted from rangeland to forest.

Estimates of carbon sequestration potential for forest planted on rangelands relied on Wildlife Habitat Relationship (WHR) forest classes aggregated into three larger classes hardwood, hardwood range, and mixed conifer that correspond to species groupings in the USDOE revised 1605(b) guidelines (USDOE 2006). This classification is shown in Table 2-1. By applying carbon

values in t C/hectare (ha) to each simplified species group, based on USDOE 1605(b), U.S. Forest Service Forest Inventory and Analysis data (USDA Forest Service 2002), Winrock data from measurements in Shasta County forests, and other Winrock experience, it was possible to estimate potential carbon stocks from afforestation of suitable rangelands for each species class, as shown in Table 2-2.[3]

Table 2-1. Reclassification scheme of WHR classes according to USDOE (2006) classification

WHR	Birdsey (USDOE 2006) class
Montane Riparian	Hardwood
Montane Hardwood	Hardwood
Aspen	Hardwood
Blue Oak Woodland	Hardwood Range
Blue Oak Foothill Pine	Hardwood Range
Valley oak Woodland	Hardwood Range
Juniper	Hardwood Range
Subalpine Conifer	Mixed Conifer
Closed Cone Pine-Cypress	Mixed Conifer
Lodgepole Pine	Mixed Conifer
Sierran Mixed Conifer	Mixed Conifer
Eastside Pine	Mixed Conifer
Klamath mixed Conifer	Mixed Conifer
Jeffrey Pine	Mixed Conifer

Table 2-2. Estimates of the potential carbon stocks from afforestation of suitable rangeland areas

Forest class	Carbon stock at 20 yr (t C/ha)	Carbon stock at 40 yr (t C/ha)	Carbon stock at 80 yr (t C/ha)
Mixed conifer	132.4	170.3	411.1
Hardwood	24.8	77.4	217.5
Hardwood range	12	37	59

2.1.3 Afforestation Costs

Cost is a key factor affecting landowner interest in afforesting rangelands for carbon. The costs analyzed included opportunity costs, conversion costs such as site preparation and planting, measuring and monitoring (M&M) costs, and maintenance costs (Brown et al. 2007). Not included in the analysis were transaction costs—for example, costs to a potential buyer of seeking out willing landowners, costs to both buyer and landowner of concluding contracts, and potentially costs to one or both parties of registering and reporting projects. Total costs indicate a price at which landowners might be willing to change management of their lands, usually under a contract of some duration agreed between the landowner and a buyer of carbon credits.

To detect variations in cost based on grazing conditions and topographic locations, the rangelands suitable for afforestation were divided into two main classes: (1) those that are likely grazed, and (2) those not grazed, with both subdivided into two slope classes (greater than and less than 30% slope). Those with grazing would have an associated opportunity cost, whereas those not grazed

[3] For further detail on the approach to estimating carbon accumulation potential for different species groups, see Brown et al. 2006.

would not. However, the shrub rangelands not suited for grazing have a high conversion cost of about $900–$1100/acre ($2223–$2717/ha) compared to $450–$600/acre ($1112–$1482/ha) for grassland and woody rangelands. Slope primarily affects conversion and maintenance costs.

2.1.4 Geographic Distribution of Costs

By dividing the present value of the total cost of afforestation ($/ha) by the net potential carbon gain (t C/ha) at a given pixel on a map of candidate rangelands, it is possible to estimate the total cost of carbon ($/t C or $/t CO_2) for each pixel. This gives an indication of the least to most expensive areas within Shasta County for carbon sequestration through afforestation.

2.2 Methods for Landowner Outreach

Model-based analyses of rangeland forest suitability, carbon potential or cost only suggest which rangelands within Shasta County might successfully be converted for carbon purposes, or where within the county might be the most attractive regions to look for afforestation opportunities. Moving to actual afforestation pilot activities, it is necessary to identify specific landowners in the regions that appear attractive and assess their level of interest and potential concerns about planting forests on a portion of their lands and/or participating in carbon markets. Opportunities for landowners to participate in such activities in California are increasing; there is potential for landowners to secure additional income streams from carbon markets in the immediate, near and long-term as these markets and policy developments continue to evolve. The benefits are various and cannot be reduced to purely monetary considerations. However, participating in carbon sequestration activities also entails costs and constraints that landowners must consider.

2.2.1 Outreach/Stakeholders Meeting in Anderson

To begin this dialogue, Shasta County stakeholders—landowners, land managers, ranchers, foresters, and others—were invited to a WESTCARB Shasta County outreach/stakeholders meeting hosted by the Western Shasta Resource Conservation District (RCD) in Anderson, California, on October 26, 2006. Partner, landowner and stakeholder mailing lists were compiled and meeting invitations sent through flyers, e-mails, regular mail, and outreach via the RCD's watershed groups throughout the county. A one-page summary of WESTCARB afforestation pilot activities planned for Shasta County was prepared for the meeting (see Appendix A).

At this meeting, the WESTCARB team reported on the results of research to date into forestry and land use opportunities that can sequester carbon and outlined opportunities for Shasta County landowners and land managers to participate in afforestation, fuel management, and forest management activities under WESTCARB. The objective of the meeting was to provide an overview of project opportunities, benefits and costs to landowners, evolving carbon credit markets, requirements for implementing, measuring and reporting projects, and related issues.

2.2.2 Ongoing Landowner Outreach

Following the October 26 meeting, Western Shasta RCD has continued to conduct in-person follow-up meetings with landowners. Outreach is also being coordinated via the watershed groups and partner agencies.

The RCD is currently contacting public and private interests to compile a list of restoration, planting and/or fuel management projects planned to be implemented in Shasta County between 2007 and 2009. In collaboration with the Natural Resource Conservation Service (NRCS), an information packet and landowner information release form was developed. This packet has been sent to NRCS clients identified as potential participants. Appointments have been made to meet with private land managers and agency representatives to obtain information on additional planned projects.

The RCD Watershed Coordinator met with the Shasta-Tehama Shedhead Watershed Coordinator Group and is in communication with the Sacramento River Area Conservation Forum regarding the Shasta County pilot project. The Watershed Coordinator is scheduling meetings with individuals to identify planned projects and possible collaboration opportunities.

3.0 Project Outcomes

Results of county-level analysis and outreach are presented here.

3.1 Identifying Rangelands for Terrestrial Carbon Sequestration

3.1.1 Forest Suitability of Rangelands

Historical evidence suggests that a large proportion of rangelands, in Shasta County and California as a whole, were once forested. Forest suitability analyses suggest that forests could successfully be established and maintained on many rangelands in Shasta County.

Figure 3-1 shows that there is a substantial overlap of forest classes in areas that exhibit the same biophysical characteristics as current rangelands from an approximate suitability score of 45 to 85. About 50% of the total rangeland area overlaps with scores that currently support forests.

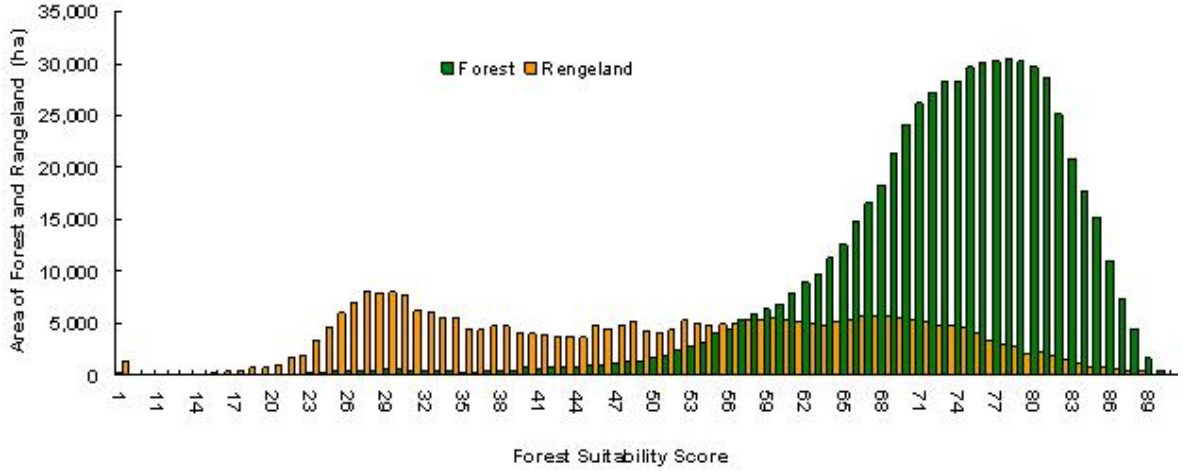

Figure 3-1. Distributions of areas of current rangeland and forest across forest suitability classes

Figure 3-2 shows the range in forest suitability across Shasta County rangelands according to the multi-factor modeling approach. Lands currently classified as *forestland* have been removed from this map, so the high suitability values on the map represent rangelands that may theoretically be converted to forest with a net carbon benefit due to the higher carbon stocks of forests compared with rangelands.

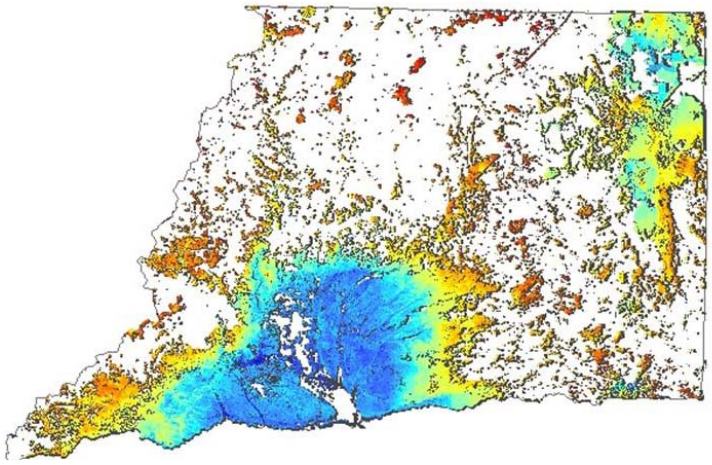

Figure 3-2. Suitability for forest growth on existing rangelands of Shasta County. The high values represent high suitability for rangelands to support forest

After exclusion of wooded rangelands with canopy cover > 40% and grassy rangelands dominated by wet meadows, the total remaining area of candidate rangelands is about 243 thousand ha, which represents about 80% of all rangelands in Shasta County, including 64,436 ha of woody rangelands with canopy cover < 40% suitable for afforestation (Figure 3-3).

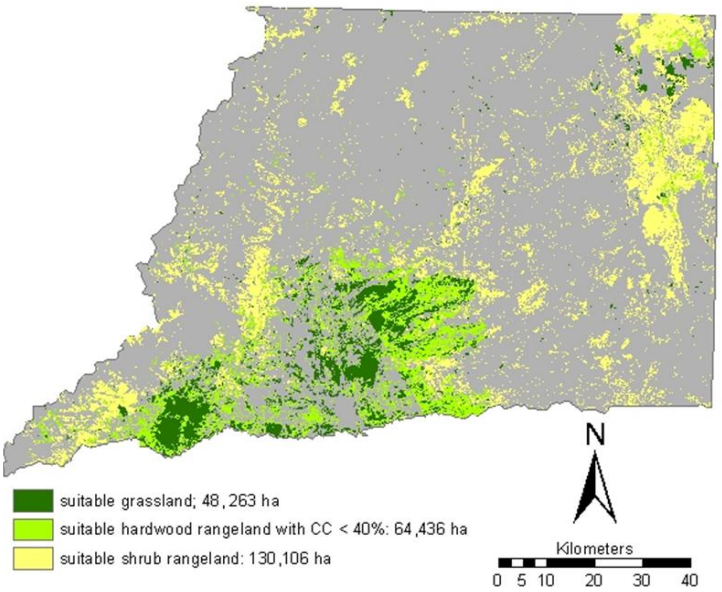

Figure 3-3. Map of candidate rangelands for afforestation activities (suitable to support forest and meeting constraints)

Finally, the results of further stratification of candidate lands into classified rangelands suitable and unsuitable for grazing is shown in Figure 3-4.

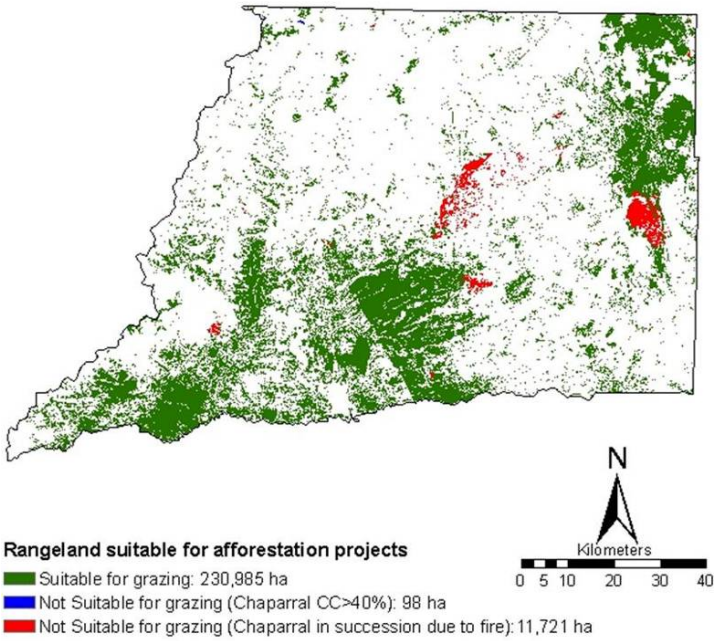

Figure 3-4. Distribution of rangeland suitable and not suitable for grazing. Rangelands not suitable for grazing represent chaparral areas in arrested succession due to past fires.

3.1.2 Carbon Sequestration Potential

Applying the carbon stock estimates in Section 2.1.2 to the map of rangelands suitable for afforestation results in a map of carbon sequestration potential throughout the county for 20-, 40-, and 80-year project durations (Figure 3-5).

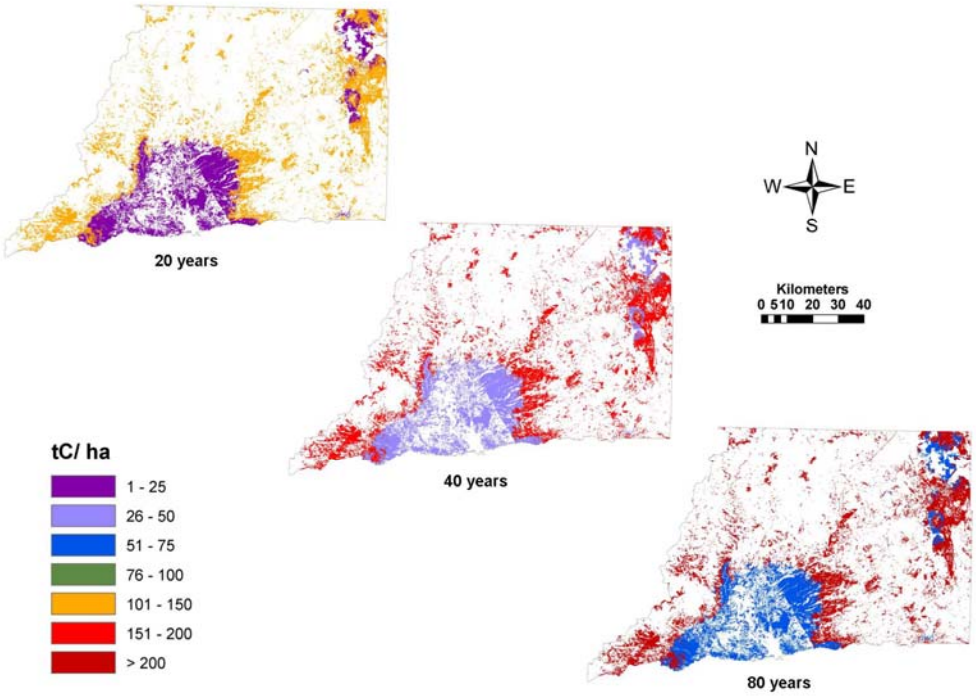

Figure 3-5. Carbon sequestration potential on rangelands suitable for afforestation activities for 20, 40, and 80 years.

Carbon sequestration analysis showed that carbon could be accumulated at faster rates, for all project durations, on rangelands in the southwestern and northeastern part of the county, east and north of Redding (Figure 3-5). These areas provide favorable conditions for planting fast-growing species that could accumulate carbon at rates above 100 tons per hectare in the first 20 years of afforestation projects and above 200 tons per hectare over 80 years.

3.1.3 Afforestation Costs

Depending on the forage productivity of rangeland suited for grazing, the net present value of the total costs of afforestation (opportunity, conversion, maintenance, and monitoring costs) after 20 years was about $1300–$1900/ha on slopes less than 30% and $1700–$2300/ha on slopes greater than 30%. On rangelands not suited for grazing, with no opportunity cost assigned, the net present value of total costs after 20 years was about $2400/ha for lands with less than 30% slope and $2900/ha for lands with greater than 30% slope—considerably higher than for lands suited for grazing—suggesting that high site preparation costs more than offset zero opportunity costs (Table 3-1). Whereas all costs appear relatively high, several points are important to note. First, Table 3-1 shows costs in $/ha; to convert to $/acre, divide by 2.47. Second, there is considerable variation, not only depending on forage production but by land type.

Finally, it should be emphasized that the important consideration for landowners is not so much the total cost per hectare, but rather how the net present value of a stream of costs compares to the net present value of the revenues available from sale of carbon credits. The total revenues to landowners will depend on the eventual price ($/t CO_2) paid for carbon and the quantity sequestered (t CO_2), which varies throughout the county.

Table 3-1. Net present value of total costs, in $/ha over the time period, for afforesting rangelands in Shasta County for three time periods

Forage production	Total costs		
Lbs/acre.yr	20 year	40 year	80 year
Suitable for grazing with slopes <30%			
100	$1,298	$1,312	$1,317
500	$1,432	$1,507	$1,552
1000	$1,599	$1,751	$1,847
1500	$1,767	$1,995	$2,142
2000	$1,934	$2,239	$2,437
Suitable for grazing with slopes >30%			
100	$1,668	$1,682	$1,687
500	$1,802	$1,878	$1,923
1000	$1,970	$2,122	$2,218
1500	$2,137	$2,366	$2,513
2000	$2,305	$2,610	$2,807
Unsuitable for grazing with slopes <30%			
100	$2,376	$2,375	$2,369
500	$2,376	$2,375	$2,369
1000	$2,376	$2,375	$2,369
1500	$2,376	$2,375	$2,369
2000	$2,376	$2,375	$2,369
Unsuitable for grazing with slopes >30%			
100	$2,870	$2,869	$2,863
500	$2,870	$2,869	$2,863
1000	$2,870	$2,869	$2,863
1500	$2,870	$2,869	$2,863
2000	$2,870	$2,869	$2,863

3.1.4 Geographic Distribution of Costs

It is assumed that landowners would be willing to produce and sell carbon credits from afforestation if the price paid for these credits is greater than the present value of the stream of costs incurred in producing them. Generally, the cost per ton of carbon produced is greater for shorter time periods (20 years) and less for longer time periods (80 years), due to the effect of the economic discount rate in calculating the present value cost of carbon (the longer the time period the greater effect discounting has on the costs), and also rates of carbon accumulation over time (the longer the duration the greater the change in carbon stock). Figure 3-6 shows the range of costs on rangelands suitable for grazing and Figure 3-7 the range of costs on rangelands unsuitable for grazing.[4]

[4] CO_2 is calculated by multiplying carbon stocks by 3.667.

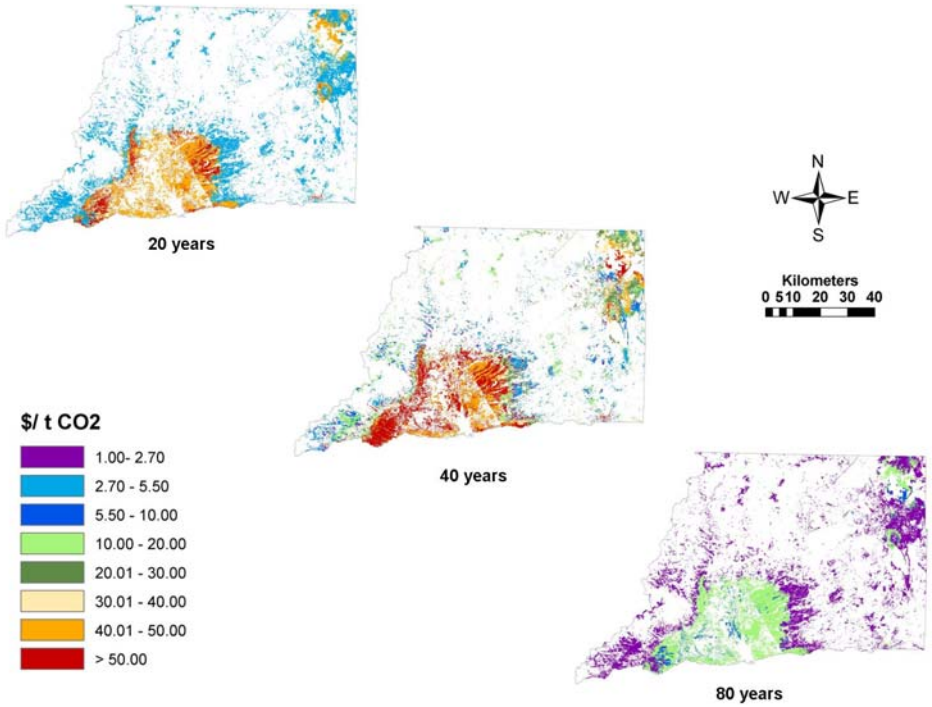

Figure 3-6. Cost of CO_2 through afforestation of rangelands suitable for grazing in Shasta County

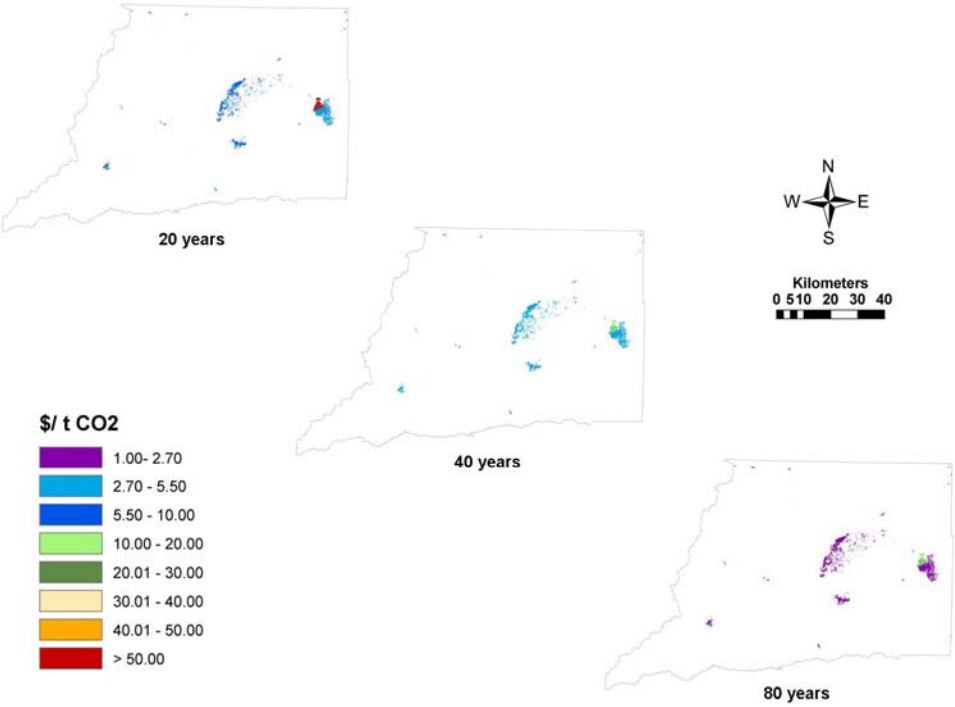

Figure 3-7. Cost of CO_2 through afforestation of rangelands unsuitable for grazing in Shasta County

The most expensive carbon on lands suited for grazing (> \$40/t CO_2) is located in the south to southwest part of the county. The least expensive carbon over any of the three time intervals is located in the east and northeastern part of the county (Figure 3-6). These are the areas, not necessarily where the magnitude of carbon sequestration is greatest, but where carbon may be sequestered most cost-effectively through afforestation. The small amount of rangeland unsuited for grazing produces carbon at a mid-range of costs (Figure 3-7).

3.2 Landowner Outreach

Efforts by Western Shasta RCD, Winrock International, and other WESTCARB partners to conduct outreach to Shasta County landowners for afforestation projects are currently in the early stages. The October 26 outreach/stakeholders meeting in Anderson was attended by approximately 20 people, including several watershed group coordinators through whom the RCD expects to reach a large number of landowners. Attendees also included representatives from state and federal agencies, private industry, nonprofit organizations, and individuals. Dialogue at the meeting helped to highlight landowner interest, concerns, additional information needs, and further analysis tasks that are currently being undertaken by Winrock International, the RCD, and other WESTCARB partners.

The RCD District Manager, Winrock International, and WESTCARB representatives were interviewed by local television station KRCR Channel 7 which resulted in a story on the evening news.

A "Shasta County Landowner Willingness to Participate Survey" was developed to assist in further planning and siting of afforestation projects. The objectives of the survey are:

1. To understand the interest of Shasta County range landowners in planting forest plantations for the purposes of carbon sequestration.
2. To determine cost-share levels at which landowners will be willing to plant additional lands to forest plantation.
3. To assess the extent and type of land that individual landowners would be willing to plant if their expectations for cost-share support were met.
4. To evaluate species preferences for plantation on their lands.
5. To validate survey commitments by providing selected landowners with opportunities to plant their lands with pilot project funding.

This survey will be administered by the RCD beginning in late 2006/early 2007. The target sample size is at least 20 landowners in each of three landowner strata: multigenerational family landholdings; absentee owners with part-time interests in the lands and likely fewer financial investment constraints; and owner-occupants who are first-generation owners.

4.0 Conclusions and Recommendations

4.1 Conclusions

It is assumed that landowners would be willing to produce and sell carbon credits if the price paid for these credits is greater than the present value of the stream of costs incurred in producing them. Generally, the cost per ton of carbon produced is greater for shorter time periods (20 years) and less for longer time periods (80 years) (Figure 4-1).

After 80 years, about 57.6 million tons of carbon could be sequestered at a cost of less than \$10/t C (\$2.7/t CO_2). In contrast, about 17.7 million tons of carbon could be sequestered after 20 years at a cost of less than \$20/t C (\$5.45/t CO_2). These quantities could be sequestered on about 57% of the rangeland suitable for afforestation (Figure 4-2). The costs rise steeply with limited additional carbon on the remaining 44% of the rangelands suitable for afforestation because these tend to be on lands most suited for rangeland hardwoods with low rates of carbon sequestration.

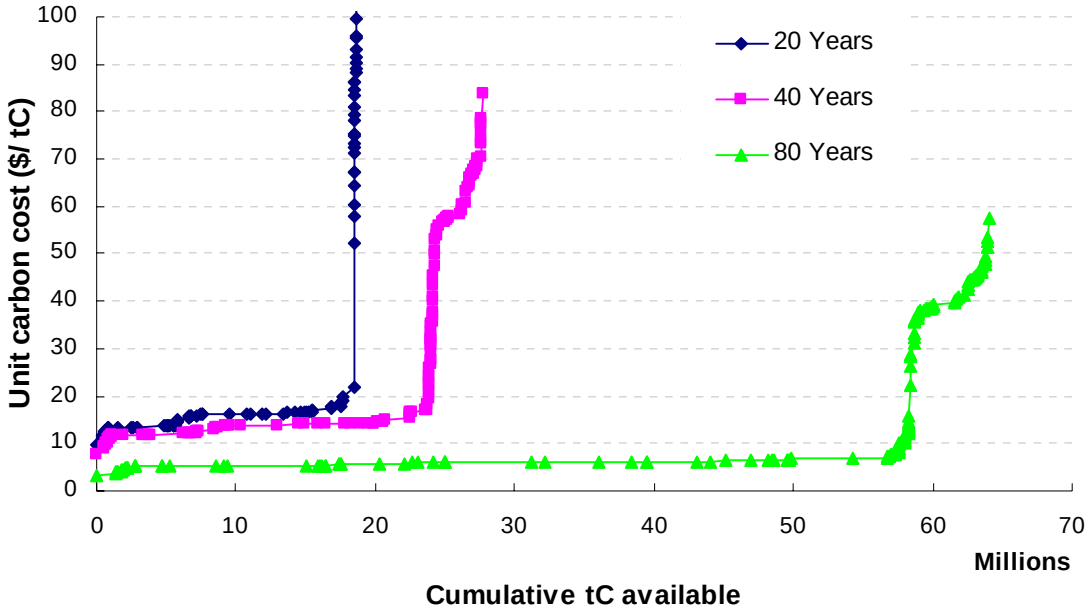

Figure 4-1. Carbon supply curves for afforestation activities on rangelands at 20, 40, and 80 years

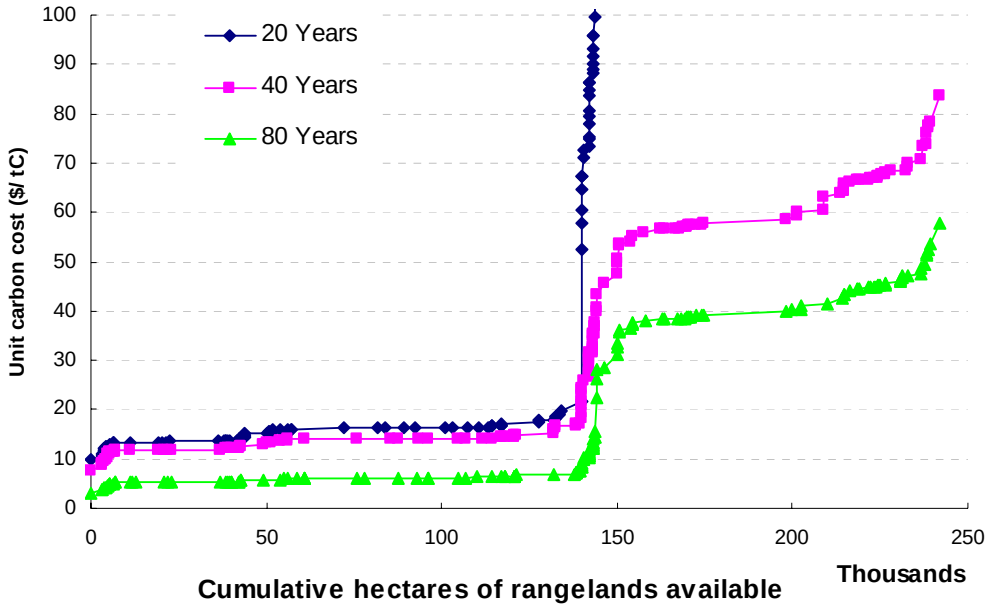

Figure 4-2. Land supply curves for afforestation activities on rangelands at 20, 40, and 80 years

4.2 Recommendations and Next Steps

The analysis presented above indicates regions within the county generally attractive for terrestrial carbon sequestration through afforestation. Though conducted at a finer level of resolution than similar state-level analyses, this model is not sufficient to conclude that a particular location (land parcel or pixel on the map) should be planted to trees, with X species at X cost yielding X tons of carbon. For this level of afforestation project planning, additional and more detailed land suitability analysis is needed prior to actual planting. This analysis is recommended to include further examination of land capability classifications and soil series data from the U.S. Department of Agriculture (USDA)-NRCS soil surveys for Shasta County and modeling growth of particular tree species based on site productivity.

In addition, it will be important to add the factor of aspect (direction lands face) to the five biophysical factors analyzed thus far. Trees planted on lands identical in slope, soil water availability, temperature, precipitation, and elevation—but different in aspect—may perform very differently in terms of growth and even survival.

Efforts are currently under way to procure seed and seedlings appropriate to the afforestation regions identified, even in advance of specific site selection, due to the long lead times for seedling procurement, seedling growing industries, site preparation, and planting. Use of improved seed stock wherever possible is recommended, including consideration of hardy or fast-growing hybrids.

Efforts are also under way by the RCD, Winrock, and WESTCARB partner W.M. Beaty & Associates to collect data on existing or planned afforestation efforts throughout the county, with which the project can collaborate to gather existing data and collect additional data,

without necessarily funding afforestation directly. This will greatly expand the geographic and temporal scope of afforestation activities included in the research effort.

As afforestation site selection proceeds, it will be important to consider recent wildfire sites as afforestation opportunities. Site preparation costs in these locations may be greatly reduced, provided planting can be done relatively quickly, before competing vegetation reclaims the site.

For oak woodland restoration/afforestation efforts, collaboration with the University of California's Integrated Hardwood Range Management Program (IHRMP) is recommended. Initial contacts have been made. The IHRMP has ample experience in siting, seed considerations, and techniques for successful oak restoration, including techniques to protect seedlings from cattle so that afforestation may be done without foregoing grazing income.

An issue presently under consideration is whether landowners participating in WESTCARB afforestation activities should incur any short- or long-term obligations as a condition of cost sharing. The California Climate Action Registry requires, in order for forestry projects to be certified and reported, that project lands be placed under perpetual easement. This appears to be a barrier to participation for many landowners. WESTCARB afforestation projects will not have any such easement requirement, and need not necessarily stipulate any landowner obligations beyond those necessary for accomplishing research objectives—maintenance of the project and access for measurements through 2009. However it is possible that at least a short-term obligation could be useful; for example, WESTCARB could adopt the model of the California Forest Improvement Program, which requires in return for cost share funds that program participants not convert lands to uses incompatible with forest management for a minimum of 10 years. Other issues under consideration for possible landowner agreements include management/maintenance activities permitted, management/maintenance activities required, data sharing and access for ongoing measurements, notification in cases of disturbance or loss, and other issues. If WESTCARB concludes formal agreements with afforestation project participants, it will be important to consider these issues carefully and strike the appropriate balance between open participation in order to achieve research objectives and preparing landowners realistically for the requirements to participate in future carbon markets. Investigating landowner interest/uptake at different levels and lengths of obligation is in itself a useful research objective, as the State of California designs its policies for market-based carbon offset programs under current voluntary programs and future regulation.

4.3 Benefits to California

The State of California recently enacted the Global Warming Solutions Act of 2006, which directs the Air Resources Board (ARB) to develop GHG emission regulations to meet the state's target of statewide emissions at 1990 levels by 2020. Regulations will be developed over the next several years and take effect in 2012. By Executive Order on October 17, 2006, Governor Schwarzenegger directed the ARB to develop a comprehensive market-based compliance program as part of these regulations, which would allow the state to achieve the most cost-effective emission reductions and also permit trading with the European Union and the northeastern states' Regional Greenhouse Gas Initiative. One of ARB's tasks will be to decide

what types of activities will be eligible for trading under the market-based compliance program, including what types of forestry activities and what specific protocols or requirements will need to be met in order for credits from such projects to be traded. Results from WESTCARB afforestation pilot projects in northern California will help to inform State policy developments and market eligibility questions, while also addressing issues of landowner uptake, project costs, measurement, monitoring, and verification.

In addition to informing regulatory developments, WESTCARB afforestation activities will provide valuable information to the increasing number of companies and organizations in the state taking voluntary actions to manage their GHG emissions. For example, CCAR members may undertake forestry projects for which CCAR has existing Forest Sector, Forest Project, and Forest Certification Protocols. These protocols will be "road-tested," and new protocols developed, through WESTCARB. Pacific Gas & Electric Company has proposed a voluntary Climate Protection Tariff, offering its ratepayers the option to become "climate-neutral" by paying an additional monthly tariff; PG&E would then contract for carbon offset projects, initially forestry projects, for equivalent tons of CO_2. Afforestation activities in Shasta County would be eligible to supply credits into PG&E's program, provided they meet the requirements of the relevant CCAR Forest Project Protocol. Thus WESTCARB afforestation activities will provide a near-term opportunity for landowners to sell carbon, while also informing PG&E, CCAR, and related state efforts about landowner concerns and constraints to broader participation in such programs. PG&E's program has been tentatively approved by the California Public Utilities Commission, to begin in spring 2007, and other utilities in the state are considering developing similar programs.

5.0 References

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6.0 Glossary

ARB	California Air Resources Board
CCAR	California Climate Action Registry
CO_2	carbon dioxide
GHG	greenhouse gas
GIS	Geographic Information System
ha	hectare
IHRMP	Integrated Hardwood Range Management Program
M&M	measuring and monitoring
NRCS	Natural Resource Conservation Service
RCD	Western Shasta Resource Conservation District
USDA	United States Department of Agriculture
USDOE	U.S. Department of Energy
WESTCARB	West Coast Regional Carbon Sequestration Partnership
WHR	Wildlife Habitat Relationship

Appendix A

WESTCARB Afforestation Pilot Projects in Shasta County

This one-page outreach document was prepared for the October 26, 2006 landowner outreach/stakeholders meeting in Anderson, California.

WESTCARB Afforestation Pilot Projects in Shasta County

Winrock International is working with the US Department of Energy, California Energy Commission, and Shasta County federal, state and private landowners to implement afforestation pilot projects under the West Coast Regional Carbon Sequestration Partnership WESTCARB. The goal of these projects is to demonstrate one of California's most promising climate change mitigation options: sequestering carbon by increasing forest cover on selected rangelands. Pilot projects in Shasta will provide on-the-ground experience in site preparation, planting and maintenance techniques for afforestation; help refine estimates of net carbon sequestration potential using field measurements and improved growth models; synthesize information on costs and benefits to landowners; and provide guidance to landowners considering undertaking afforestation to generate CO_2 credits for reporting to the California Climate Action Registry and/or for sale to carbon offset credit buyers.

Sites

Eligible lands for WESTCARB afforestation projects include federal, state and private land. Of Shasta County's approximately 746,000 acres of rangeland, initial analyses show 600,000 acres as suitable for afforestation, including grassland, hardwood rangeland, and shrub rangeland types. This includes both rangelands suitable for grazing (570,000 acres) and some densely vegetated sites, classified as rangeland but unsuitable for grazing and likely representing arrested succession to forest after fires. The most cost-effective regions for afforestation, in terms of cost per ton CO_2 sequestered, appear to be in areas to the southeast, southwest, and east and west of Redding, and in the northeast corner of Shasta County. Specific sites will be chosen in the remainder of 2006 and 2007, based on landowner interest, with site preparation and planting to take place in the 2007 and 2008 seasons.

Species

Three species groups are currently being considered for afforestation (though others may be added, in consultation with WESTCARB partners and landowners): mixed conifers for higher-elevation sites, including chaparral/arrested succession areas; mixed rangeland oaks for lower-elevation rangelands; and grey pine for lower elevation rangelands and transitional zones. These species all have excellent survival and performance in Shasta County, with seedlings available and experience among WESTCARB partners to ensure successful planting. Many of the highest-carbon, least-cost carbon sequestration opportunities are in the near term in mixed conifer areas; however, mixed conifers may be unable to grow successfully on many of the available sites. Grey pine, though of questionable value as a timber species, performs well across a broad range of sites and may also have value as fuel for biomass energy facilities.

Costs and Benefits to Landowners

Afforestation costs include opportunity costs (potential loss of rangeland forage production and thus profitability), conversion costs (for example fencing, site preparation, planting), measuring and monitoring costs, and maintenance costs. Lands classified as rangeland, but actually representing arrested succession to forest after fires, are unsuitable for grazing and may have zero opportunity cost, but high site preparation costs offset some of this advantage. Opportunity costs may be minimized by the fact that afforesting rangelands may not require foregoing grazing, perhaps only protecting seedlings or excluding cattle for a few years until seedlings are established. Costs in $/acre and $/ton CO_2 sequestered vary throughout the county. Landowners are expected to weigh potential revenues from carbon credits (t CO_2 sequestered over the life of a project, valued at current or projected prices per ton) against the present value of afforestation costs. Total costs could include the costs of reporting and certifying projects for the California Climate Action Registry in order to make these projects eligible for sale to carbon credit buyers requiring Registry participation. Demand for carbon credits, and the price offered per ton CO_2, are expected to increase as California moves toward mandatory regulation of greenhouse gas emissions, with the recent passage of the California Global Warming Solutions Act of 2006 (AB32) being a significant step in this direction.

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