Report to the Western Riverside County Regional Conservation Authority

Carbon Credits and the Western Riverside County Multiple Species Habitat Plan

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Figure 1. Roots and organic C of Coast Live Oak, an important vegetation type in southern California, growing through rock fractures, below 12' in depth. Live oaks in southern California would not survive without a deep rooting habit to access moisture during the dry summer Mediterranean Climate.

Key points:

- Atmospheric carbon dioxide (CO_2) and methane (CH_4) continues to rise globally.
- Soils are the largest terrestrial carbon sink globally. They are especially important in arid lands as root systems explore deep into the profile searching for water. These sinks are challenging to measure and largely ignored in carbon sequestration estimates.
- Net Ecosystem Exchange, the carbon accumulated annually by plants, including carbon sequestered for longer time periods, varies temporally and spatially. Native plant communities fix carbon, especially woody plant communities including forests, woodlands, chaparral, and desert microphyll woodlands. Coastal Sage shrublands and perennial grasslands fix carbon. Annual grasslands appear to be neutral annually, but lose previously sequestered, deeper stored carbon. Wetlands fix carbon, but also release methane, a potent greenhouse gas.
- Urban and suburban development releases CO_2 to the atmosphere. There are two values that should be considered. First is the direct release of CO_2 from sequestered soil and wood C, especially following conversion of wood- and shrublands to urban and suburban lots. Second is the total CO_2 released from "life cycle" sources that contribute to the C fluxes within the developed environment. These include the C costs for example, of pumping water (both for home and industrial use and for landscaping), electrical power generation (especially coal or natural gas sources), heating fuels (including natural gas and coal), and transportation (such as diesel and gasoline fuel).
- There is considerable variation in carbon sequestration between years, largely due to precipitation variation. Accounting estimates need to incorporate annual and decadal-scale variation.
- The carbon credit market includes a market exchange in California, but also through many other entities. For this report, I will use $15/ton of C as per the California Carbon Dashboard.
- Native vegetation of the WRC MSHCP could be sequestering up to 59,000 tons of new C fixed during a dry year and 175,000 tons of C annually during a wet year. At $15/ton, that would be $886,000 during a dry year and $2.6million during a wet year on the current carbon market.

Introduction.

Atmospheric carbon dioxide (CO_2) is rapidly increasing, largely due to the burning of fossil fuel, to land-use change from wildlands and forests to urban and suburban (and agricultural) development, and to the interactions of these processes. To set the stage, in 1988, when I began my research on CO_2 sequestration in California at San Diego State University, atmospheric CO_2 was between 340ppm and 350ppm. Atmospheric CO_2 was already rapidly rising (from 312ppm in the 1950s). On 18 March, 2019, atmospheric CO_2 was 414.8ppm.

CO_2 is a greenhouse gas, a fact known from classical studies of Svante Arrhenius in the 19th century, more recent climate data, and used in models and measurements of today's carbon (C) sequestration programs. A cornerstone of global C management is to keep atmospheric CO_2 from exceeding 450ppm, viewed by climate scientists as a tipping point. Globally, the last time atmospheric CO_2 exceeded 450ppm, there was no ice in Antarctica, and there were redwoods in Yellowstone. Therefore, understanding and integration of C in land management becomes a crucial element.

The western Riverside County Multiple Species Habitat Conservation Plan (WRC-MSHCP) began planning in the mid-1990s and was signed in 2004. The goal was to protect threatened and endangered species at a regional scale, and to develop a buffer for all wildland species in the region against the development of living space for the rapidly growing human population, and simultaneously, to provide stability in environmental regulations to allow development to meet that growth need. The goal called for the protection of 347,000 acres plus an additional 153,000 purchased acres creating 500,000 acres of protected lands across the planning region of 1.5 million acres of western Riverside County.

My goal here is to provide an outline of how the vegetation WRC-MSHCP can photosynthesize and lower atmospheric CO_2 (GPP) by turning it into biomass, and ultimately lead to the subsequent sequestration of C, into soil C and woody mass, as well as for the protection of T&E species. For the vegetation and development information, I have used the information from the Plan, from 2003 documents. I have not included agricultural lands, as each crop has a different exchange and few have been measured, and agricultural lands are diminishing in area in WRC. The variability is high, the measurements imprecise in time, and they are not replicated as extensively as they should be. Nevertheless, I believe that this estimate can provide a pathway both to stimulate more research to improve the precision of data and the accuracy of estimation, and to facilitate an understanding of the role of wildland ecosystems in protecting southern California carbon stocks.

Carbon Exchange by Mapping Unit.

For this report, I use the mapping units developed for the WRC-MSHCP and the amounts in the original plan. I realize that there has been considerable change, largely due to the continuing development within the plan area, and to the extended drought associated with the negative PDO (see background issues) that the region has experienced since the signing of the plan (see VanTassel et al. 2017).

I also strongly suggest that continuous measurement of at least the dominant vegetation types be undertaken at multiple sites, to obtain a far better dataset for accurate, and longer-term assessments.

Suburbia. Based on the average enhancements of atmospheric CO_2 concentration for Ontario, CA, collected from the CO_2 sensors of the Verhulst and colleagues Los Angeles Megacity Carbon Project, I estimated that the ecosystem respiration (R_{eco}) to the atmosphere would be 0.1 tons/acre/y. Thus, the developed lands of the Plan (2003) of 218,260 acres, R_{eco}, are losing 22,000 tons C/y. As the developed land area has increased since the Plan was formulated (2003), this value is a clear underestimate, but represents a working value for this document (Figure 2).

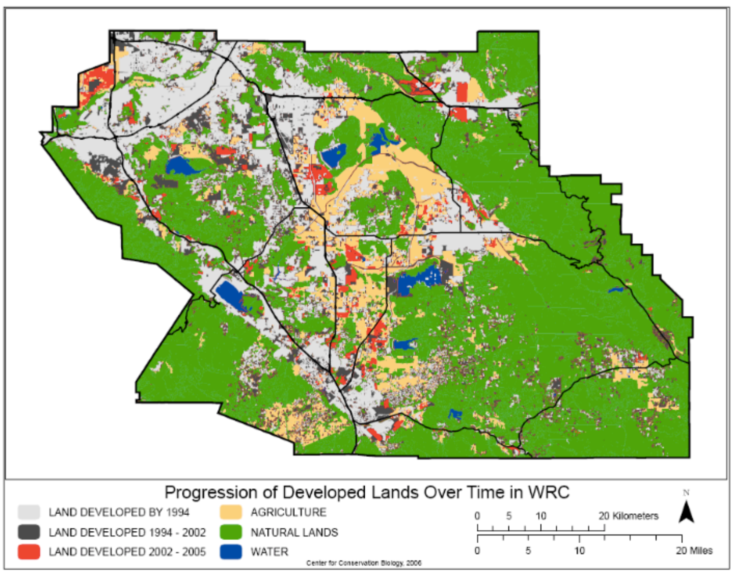

Figure 2. Changes in the development from 1994, as MSHCP planning commenced, to 2005, from VanTassel et al. (2017).

Importantly, that value does not include the C used to pump water (for urban water supply and irrigation of landscaping), point sources for energy development (refineries, power plants), or a large fraction of the non-point sources for transportation. These estimates, based on accounting techniques (for one example, see CoolClimate Maps, may add to as much as 5 million tons C/y loss for this region.

Chaparral represented 35% of the vegetation coverage in the Plan, or 434,950 acres. During dry years (the majority of the time since approval of the Plan, Chaparral is fixing an average of 36,000 tons C/y. With extended drought, as deep water sources dry, that NEE may drop to very low rates. During a wet year, which is highly likely for the next decade as we move to a positive PDO cycle, both successional and old-growth stands of chaparral could fix 104,000 tons C/y. Chaparral may also have as much as 23 tons C/acre or up to 10 million tons C already stored across the WRC MSHCP that could be lost with development.

Non-native grasslands comprised 151,440 acres at the time of the Plan and range from no net change, to a net loss of C. There are no flux estimates for the Riverside Plan area. Estimates suggest that annual grasslands could fix as much as 2 tons C/acre/y, but lose as much as 3 tons C/acre/y, largely from that fixed plus C from millennial-long accumulation from runoff from neighboring shrublands. More work on this vegetation type is needed for southern California.

Perennial grasslands could accumulate C, at up to 0.01 tons C/acre/y, but they represent only 2,700 acres, or 0.2% of the Plan. They could net as much as 37 tons C/y. There are no estimates of stored perennial grassland soil C for southern California.

Coniferous Forests comprise 29,910 acres, or 2.4% of the Plan area. The James Reserve mixed-conifer forest fixes between 0.2 and 1.15 tons C/acre/y, or up to between 6,000 and 34,000 tons C/y. There are no good estimates of the stored C in Riverside-area coniferous forests. In large part, this is due to the fact that there is a large pool of deep C that is put into the bedrock as roots to extract water to sustain these forests. Up to 50% of the plant's water can come from deep roots on an annual basis.

Oak Woodlands. There are no good estimates of C accumulation rates in evergreen woodlands of southern California, comprising of another 34,300 acres, or 2.7% of the land area. The deciduous blue oak savannah averaged a C sink of 0.5 tons/acre/y, with a high of 1.07 tons/acre in 2010, and remained a sink even during the 2013-15 drought. Assuming that evergreen oaks and deciduous sycamore woodlands fix at least as much as the deciduous oaks, then there could be 17 to 36 tons per year of fixed C. This suggests that the southern California Live Oak evergreen woodlands could be a very large C sink. Because of both the large amount of wood, and the deep root system that is required to sustain the evergreen leaves (Fig 1), there could be as much as 44 tons C/acre or 1.4 million tons C already stored.

Coastal Sage Scrub comprises 156,450 acres. It is deciduous, and therefore sensitive to drought, losing leaves and shutting down carbon fixation. It may have accumulated up to 12 tons/acre, or up to 150,000 to 1.8 million tons of C.

Total Native vegetation across the WRC-MSHCP could be sequestering between 59,000 and 175,000 tons of C annually, worth up to $2.6 million on a C credit market. There also may be as much as 16 million tons of C stored, that would be lost proportionally to the type and amount of land developed. This is based on the vegetation map from the Plan, and is subject to change as maps are updated.

Background issues. Carbon in southern California.

Measurements. Carbon in the terrestrial biological skin of the planet is largely measured as the standing crop, that is the biomass carbon present per unit land surface. One approach is harvesting the standing crop of plants, from grasses to trees, at multiple times during the year, and determining differences through the year. This approach has been updated by digital harvesting of vegetation using multiple spectral signals mounted on satellite images (NDVI). Another approach was to measure flux of CO_2 per unit time. Initially, this was accomplished by attaching a chamber to leaves and measuring the difference between the CO_2 entering the chamber (ambient levels), and that leaving the chamber, the difference was that fixed by the leaf. Today, all approaches have been updated by many technological changes, ranging from satellite imagery to ground penetrating radar, and from rapid (up to 10*x*/sec) and continuous sensor datasets to isotopic signatures that provide historical measurements. All work, but are subject to methodological constraints and different assumptions.

C in soil is extremely challenging to measure. The first step is to separate roots from surface soils. This has been accomplished from multiple approaches, ranging from coring to forced-water extraction. Turnover ranges from isotopic measurements to minirhizotron (cameras inserted into clear tubes inserted into soil) observations. For deep C, road cuts, mines, or simple blasting and digging approaches have been used. Roots are known to reach depths greater than 135' in oaks and 175' in mesquite.

Evergreen versus deciduous and water distribution. Southern California is quite different from northern and central California ecosystems, in large part because of the evergreen nature of chaparral, conifer forests, live oak woodlands, and desert microphyll woodlands. The evergreen nature of these plants could not persist through the summer drought, characteristic of Mediterranean-climate ecosystems. Importantly, all of these vegetation types form roots that penetrate through cracks caused by earthquake fracturing of the bedrock, cracks caused by water percolation, or through dissolving mineral substrates. Both roots and associated microorganisms permeate deep into southern California substrates, often greater than 12 to 15', with C forming the primary element, up to 80% of the plant material in complex chemical forms (e.g., suberin, lignin, cellulose) and a large, but unknown amount of complex microbially-transformed C (e.g., glomalin, chitin, melanin). As much as 60% of the water during the summer months could be derived from groundwater deep in the bedrock.

Climate variation-long-term, ENSO, PDO. Southern California is subject to high variation in precipitation and temperature, which affects the amount of C fixed or respired. Southern California and the WRC-MSHCP have a Mediterranean-type climate, with a cool winter with most of the precipitation, and a hot summer, with only infrequent rainfall events that are generally monsoon-driven.

El Niño-Southern Oscillation is a reasonably known climate cycle phenomenon that tends to create a high degree of variation in precipitation. During the El Niño events, wetter-than-normal winter rainfalls in Southern California predominate. During La Niña events, drought predominates.

The Pacific Decadal Oscillation (PDO) is beginning to be better understood. This is a decadal (or longer) cycle that interacts with the ENSO cycle. When positive, such as during the 1990s, El Niño is accentuated, with a lesser impact of La Niña. When negative, which has predominated nearly 20 years, La Niña tends to be stronger, and El Niño weaker. This means that measurements taken in the 1990s occurred during periods of higher than average precipitation, and those taken over the past two decades, lower. It is likely that a positive PDO is emerging, which would increase sequestration of C in native wildlands, compared with the past two decades of drought.

Of course, we do not know how these patterns will be affected by global climate change, currently a major area of research.

Flux measurements needing synthesis. All measurements of C flux and sequestration in southern California have been taken during either the positive PDO (1990s) or negative PDO (last 20 years), but rarely both. The instrumentation and expertise exists in southern California, at UCR, UCI, CSU-San Marcos, and San Diego State University. In many cases, the instrumentation is in place, and recording, but no one has the funding to synthesize the data. A long-term C monitoring program should, and could be readily undertaken based on preliminary estimates of C credits.

Fire note

Terminology

Carbon credits is an element of California cap and trade program developed from California's Global Warming Solutions Act of 2006, AB32, <http://calcarbondash.org/>. As of this writing, the value was approximately $15/ton of emitted C.

GPP (Gross Primary Productivity) is that total amount of carbon fixed by plants.

Reco is the ecosystem respiration, or C lost from respiration by plants, microbes, and animals.

NEE (Net Ecosystem Exchange) is instantaneous net ecosystem exchange, of the carbon between the terrestrial ecosystem and the atmosphere, per unit of earth surface.

Standing crop is the total amount of C per unit land surface. This is important in that it is of variable age ranging from leaves, fine roots, and that may live hours to days, to woody tissue that can be up to several hundreds of years old.

organic C is the carbon resulting from the fixation of CO2 into carbohydrates. This includes that transformed by organisms that feed on plant material.

inorganic C is the carbon fixed by chemical means. In southern California, the largest pool of concern to us is $CaCO_3$, calcium carbonate, or caliche. This carbon sink is formed by carbonate, from CO_2 in solution, binding to calcium. This can occur in water bodies, or in soil, and especially in the rhizosphere as roots and microbes respire.

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