San Diego County Greenhouse Gas Inventory

An Analysis of Regional Emissions and Strategies to Achieve AB 32 Targets

Agriculture, Forestry, and Land Use Report

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For an electronic copy of this report and the full documentation of the San Diego Greenhouse Gas Inventory project, go to www.sandiego.edu/epic/ghginventory.

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1. Introduction

Agriculture, forestry, and other land-based activities may both absorb and emit greenhouse gases (GHG). This category is one of the main categories used in the California Air Resources Board (CARB) statewide inventory, which followed the Intergovernmental Panel on Climate Change protocols. This report, a component of the San Diego County Greenhouse Gas Inventory project, follows the CARB format and provides an estimate of historical and projected GHG emissions from the following two subcategories:

- Livestock Management– This includes emissions from both enteric fermentation and manure management.

- Sequestration by Land Cover –This is the net level of greenhouse gas emissions from CO_2 uptake by plant growth (sinks) and greenhouse gas releases from the destruction of existing land cover (vegetation). Our analysis includes the total amount of greenhouse gases sequestered by natural vegetation in San Diego County, the effects of development on sequestration, and emissions from wildfires during the period 1990 to 2007.

The subcategory of crop burning and soils management, which includes non-CO_2 emissions from agricultural activities, is a component of the agriculture, forestry, and other land-based activities category in the CARB statewide inventory; however, due to a lack of data – and the likelihood that emissions will be relatively very small – emissions from these activities are not included in the analysis here.

Taken together, the emissions from the above categories in San Diego County were negative in most years from 1990-2006; that is, emissions from the agricultural sector, development, and wildfires were typically offset by sequestration. Only in years with higher than average wildfires were there net positive emissions from this category. Table 1 includes emissions data for selected years. The years 2003 and 2007 are shown to demonstrate the effects that large firestorms have on greenhouse gas emissions in the region.

Table 1. Emissions from Agriculture, Forestry, and Land Use Category (MMT CO2E)

Category	1990	1995	2000	2003	2005	2007	2020
Livestock	0.1	0.1	0.1	0.1	0.1	0.1	0.0
Sequestration from Land Cover	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)	(0.7)
Emissions from Development	0.1	0.1	0.2	0.3	0.2	0.2	0.2
Wildfires*	0.2	0.6	0.2	7.8	0.3	5.8	0.3
Total Emissions	(0.3)	0.1	(0.2)	7.5	(0.1)	5.4	(0.2)

*2005 and 2020 wildfire numbers are estimates. No data was available for 2005.

Presented below are key findings from this section and more detailed summaries of each section, including an explanation of the methods used to calculate the emissions estimates for this sector.

1.1. Key Findings from the Agriculture, Forestry, and Other Land Use Category

- Largely because of two catastrophic firestorms, plant growth, fires, and development taken together over the entire period 1990 – 2007 caused a net loss of biomass in San Diego County and the corresponding release of 7 MMT CO_2. This corresponds to an average annual release of 0.4 MMT CO_2 / yr. Figure 1 demonstrates this trend.

- During the 1990s there was a net increase in plant biomass as carbon uptake due to plant growth outpaced releases due to fires and development. On the average, 0.3 MMT CO_2 was removed from the atmosphere each year during this period.

- During the period 2000 – 2007 there was a significant loss of biomass (and an increase in CO_2 emissions) due to firestorms and an increased rate of development, more than offsetting sequestration during the 1990s.

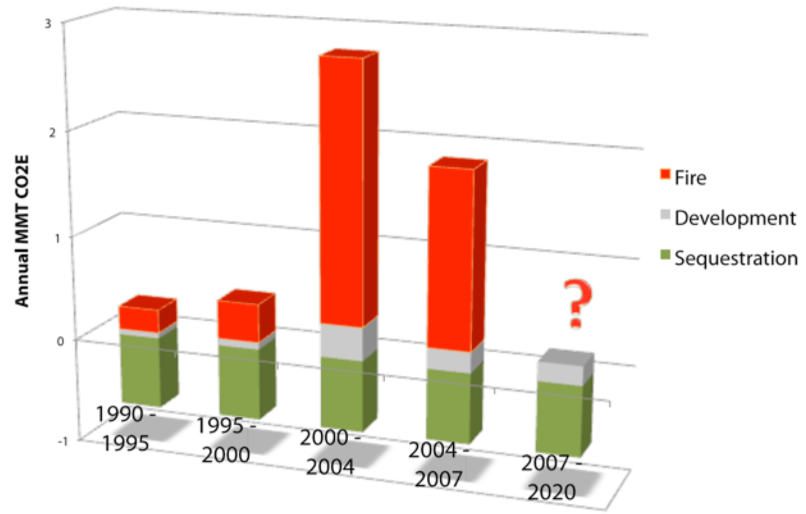
- In 2006, land cover in undeveloped areas sequestered approximately 0.7 MMT CO_2 in San Diego County, down slightly (by 2.5%) from 1990 levels due to development.

- During the period 1990 – 2020, an additional 7.5% of the County land area is projected to be developed for agricultural or urban uses. This development will reduce the CO_2 uptake by native vegetation by 5%.[1]

- The 3% of county land that is forested is responsible for 34% of the CO_2 uptake by vegetation.

- Livestock management accounts for 0.2% of overall regional GHG emissions. According to projections, without any changes to current trends, agricultural emissions are expected to decline further to insignificant levels by 2020.

Figure 1. Average Annual GHG Emissions Due to Fire, Development, and Uptake by Vegetation in Undeveloped Areas



2. Sequestration By Land Cover

Land use effects greenhouse gas levels via several processes. Carbon dioxide is taken up by growing plants, and released again by decomposing plant matter displaced by development. During wildfires, carbon dioxide, nitrous oxide, and methane are released. The amount of gases involved in these processes depends primarily on the type of ecosystems involved. The classes of vegetation in San Diego County and their relative coverage are shown in Figure 2.

Figure 2. San Diego County Land Coverage by Vegetation Class

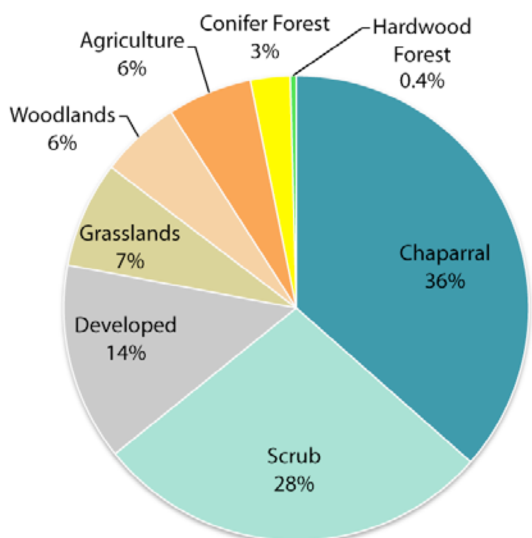


Figure 3
Vegetation of San Diego County (1995)[3]

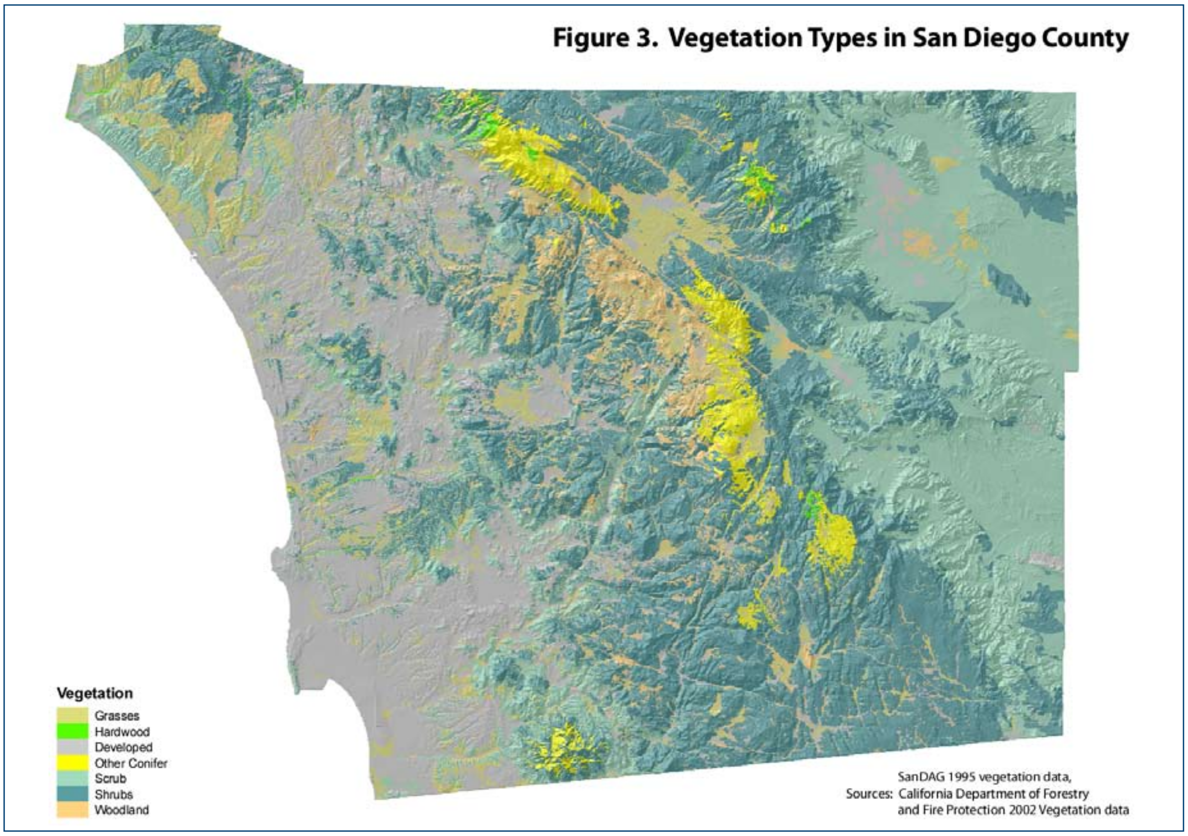
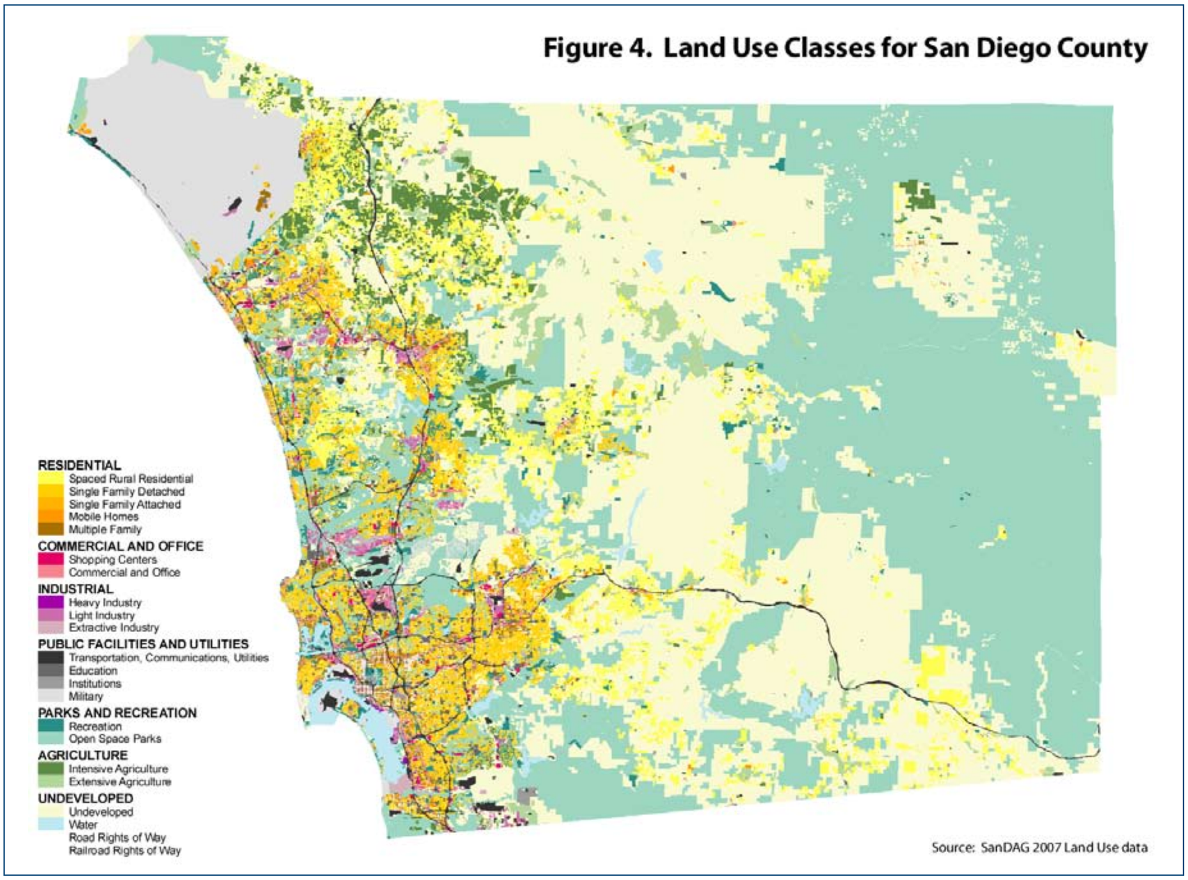


Figure 4
Land Use San Diego County (2007)

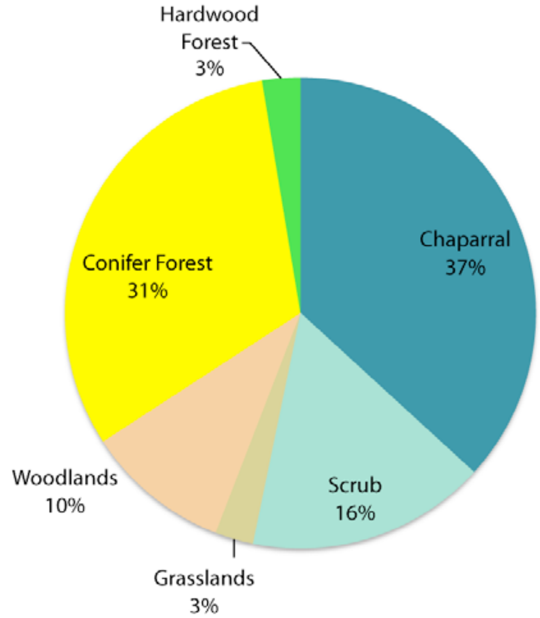


Figures 3 and 4 show maps of the vegetation areas, developed using GIS analysis of data from SANDAG and the California Department of Forestry and Fire Protection. Spatial analysis of this data reveals that only 3% of county land is forested, while another 6% is woodland (a mixture of grass and well-spaced trees). Chaparral, scrub, and grasslands are the predominant vegetation types, covering over 70% of county land area. Just less than 14% was developed in 1995, and the remaining 6% is agricultural land, predominantly orchards.[2] Our classification of a variety of ecosystem types into these categories is summarized in Section 2.5.

2.1. Emissions Sequestered by Land Cover

The carbon uptake rates of each class of ecosystem are listed in Section 2.5. Developed and agricultural lands are excluded from this analysis. (Note that total agricultural biomass in the county is decreasing.) In 1995, 0.7 MMT CO_2 was sequestered by vegetation in undeveloped areas in San Diego County. Other yearly totals are listed in the inventory. Because of higher rates of CO_2 uptake by forests, chaparral and conifer / hardwood forests contribute almost equally to this total, with chaparral accounting for 37% and forests for 34% of carbon uptake. Chaparral, scrub, and grasslands were ignored in the California Air Resources Board statewide GHG inventory due to the substantial forested areas of the Sierra Nevada, the Coast Range, and Northern California. However, we estimate that these ecosystems together are responsible for well over half of the total carbon uptake in San Diego County.

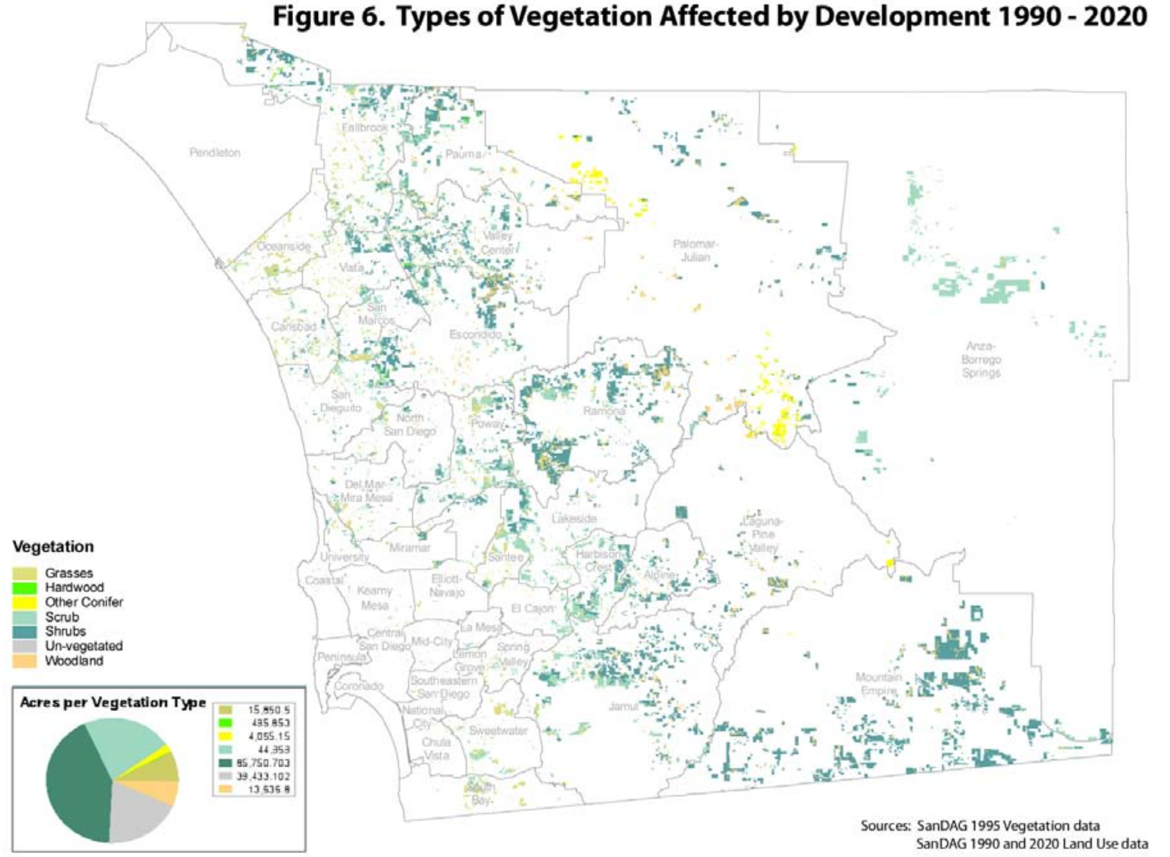
Figure 5. Estimated CO_2 Uptake by Vegetation Class (1995) [4]



2.2. The Effect of Development on Land Cover Sequestration

During the period 1990 – 2020, it is projected that a total of 7.5% of San Diego County land area will have been converted from undeveloped into agricultural and developed land use categories (Figure 6).[5] Development has two effects on greenhouse gases via vegetation. First, it directly releases carbon stored in displaced vegetation as CO_2. The amounts of carbon stored by each vegetation class are listed in Section 2.5. Second, it reduces the amount of net uptake in subsequent years.

Figure 6. Types of Vegetation Affected by Development 1990 - 2020



Sources: SanDAG 1995 Vegetation data
SanDAG 1990 and 2020 Land Use data

Spatial analysis of the data shown above indicates that over the period 1990 – 2020 an average of 0.132 MMT CO_2 is released annually from biomass removed to make way for development (or agriculture). This counteracts about 20% of the total CO_2 uptake by vegetation and reduces the vegetated areas that can absorb CO_2 in the future. Because development occurs disproportionately away from forested areas in San Diego County, the reduction in CO_2 uptake by native vegetation during the period 1990 – 2020 is estimated to be 5% (rather than 7.5%).

More detailed analysis of SANDAG land use data from 1990, 1995, 2000, 2004, 2007, and 2020 (projected) indicates that development occurs at uneven rates, corresponding with local economic cycles.

2.3. Emissions Due to Fires

Analysis of charcoal in coastal ocean sediments off of Santa Barbara, California, indicates that over the past six centuries, at least 20 large firestorms have burned in that region.[6] Two to five firestorms per century have occurred since 1425, and this rate is probably typical for the entire coastal Southern California region. Firestorms have affected Southern California twice in the last decade. GIS burn area data for 1990 to 2003 and 2007[7] was combined with vegetation data from the previous section to determine amounts of each type of land cover burned each year. Figures 7 – 9 summarize this data.[8]

Figure 7. Land Area Burned by Wildfires in San Diego County by Vegetation Class

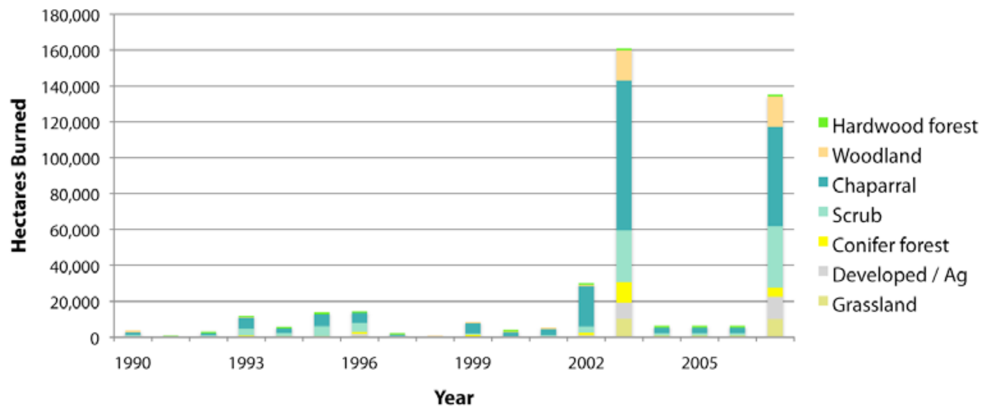


Figure 8. Area Burned in San Diego Wildfires by Year

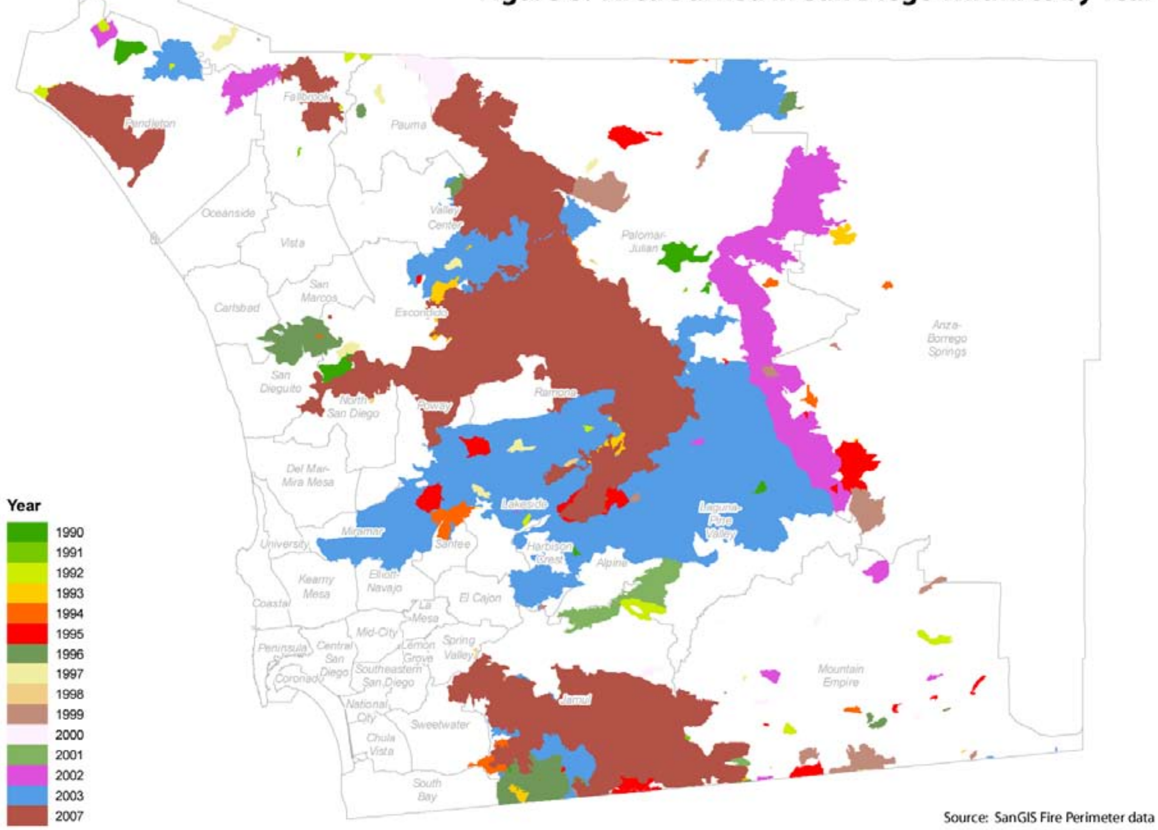
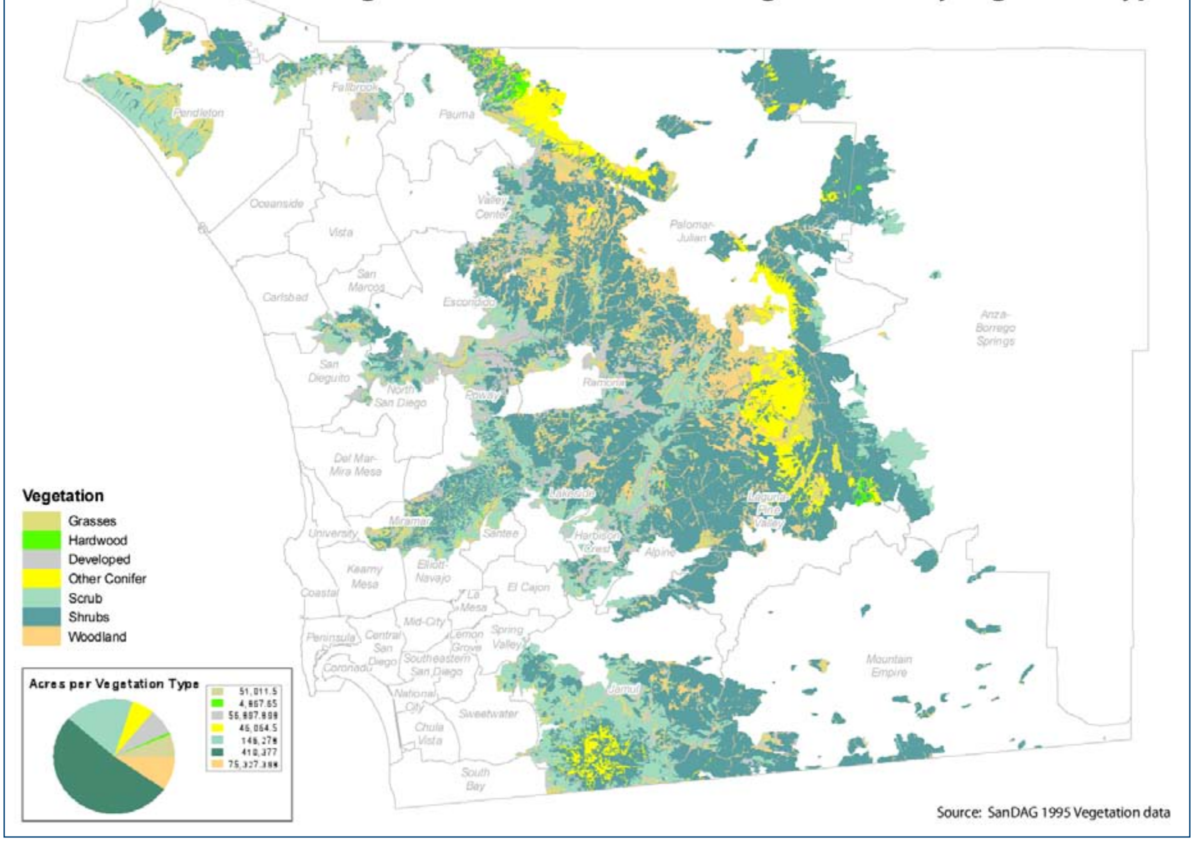


Figure 9. Area Burned in San Diego Wildfires by Vegetation Type[9]

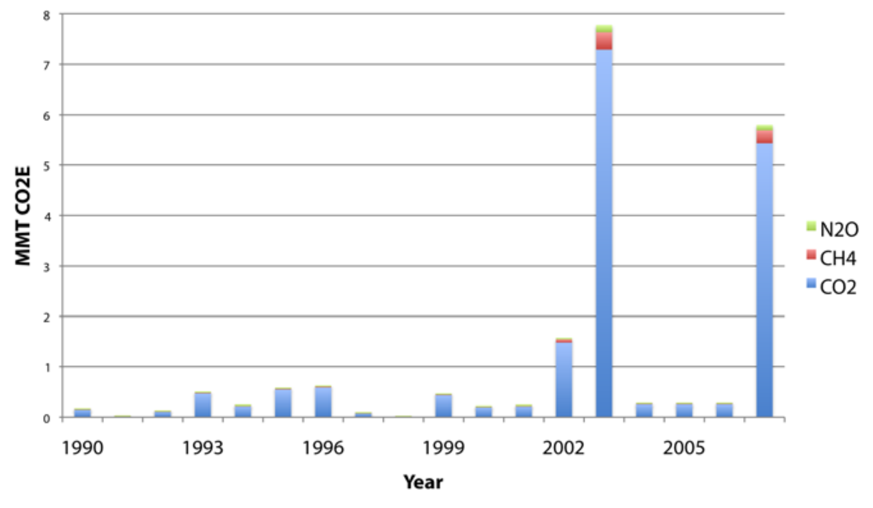


The burn areas of the firestorms in the county in 2003 and 2007 were each about 10 times larger than annual totals seen during the non-firestorm years 1990 – 2001.

A summary of yearly fire emissions is shown in Figure 10. The method of Wiedinmyer (2006) was adapted to make these estimates, as summarized in Section 2.5. The 2003 firestorm was slightly larger in size and burned more heavily vegetated areas than the 2007 firestorm, resulting in a larger loss of county biomass and greater emissions. The two firestorms together released a total of 14 MMT CO_2E (mostly as CO_2). Thus, two full decades of CO_2 uptake by vegetation were reversed in only two weeks of disastrous fires.

It is not yet possible to predict the severity of future fire seasons, and we cannot conclude that there has been a change in fire frequency based on two recent firestorms. However, if the local climate should change and become either hotter, drier, or both, the severity of fires would be expected to increase, making long-term carbon sequestration through plant growth in undeveloped areas a challenge.

Figure 10. Estimated GHG Emissions from Wildfires in San Diego County[10]



2.4. Greenhouse Gas Reduction Strategies

There are three possible strategies for minimizing the negative impact of development and restoring carbon uptake by plant growth to 1990 levels. First, urban growth could be directed away from high-biomass ecosystems: chaparral, woodlands, and especially forests. Second, programs encouraging tree planting and preservation in the urban area ("urban forestry") could be launched. Finally, fire ignition prevention efforts and firefighting capabilities could be increased to limit the extent of future wildfires while maximizing carbon biomass. The effects of these three actions are quantified below.

If zoning laws were changed to require that 75% of living tree biomass be preserved during development of forest and woodland parcels (or if the development of 75% of these parcels is redirected to low biomass ecosystems), the biomass equivalent to 0.3 MMT CO_2 would be preserved during the period 2007 – 2020, which equals 0.03 MMT CO_2E annually. In addition, the annual CO_2 uptake in 2020 would be larger by 0.005 MMT CO_2, for a total reduction in 2020 of 0.03 MMT CO_2E.

We have not included the effects of urban forestry thus far in our analysis of carbon sequestration due to lack of data. However, we estimate that an additional 10% of the developed area in San Diego County could be converted to the equivalent of woodlands by 2020 through a vigorous urban forestry program. The resulting increase in vegetation would result in 0.02 MMT CO_2 of additional uptake, with more benefits by 2050. Increased shade provided by these trees could reduce the demand for air conditioning, and the corresponding electricity consumption, at some locations. However, this benefit has not been quantified.

Once fires start during strong Santa Ana conditions, containment has proven to be extremely difficult. Attempts to limit ignitions through backcountry closures and strategic power line deactivation during times of extreme fire danger could reduce the likelihood of future firestorms. Fuels management, while successful in maximizing biomass in forested regions, may not be effective for the chaparral and scrub ecosystems common in San Diego County. The environmental benefits of preventing firestorms cannot be quantified considering the natural variability in wildfire frequency and extent. However, success in preventing firestorms and thereby increasing the carbon biomass of natural areas would be a significant help in limiting the buildup of atmospheric carbon dioxide.

2.5. Methodology

Carbon uptake by vegetation was estimated using CARB methods (Winrock[11]) for forests, woodlands, and riparian environments, which are dominant in carbon uptake at the state level. However, because these ecosystem types are rare in San Diego County, other types of ecosystems that were ignored in the CARB California statewide GHG inventory, namely scrub, chaparral, and grasslands, play a significant role here.

San Diego County vegetation data was downloaded as GIS shapefiles from the SANDAG website.[12] Data from outside the county border was removed. Data gaps in the eastern third of the county were filled in using 2002 raster data with 100 m resolution from the California Department of Forestry and Fire Protection.[13] Due to limited resolution, these data sets do not include information on urban trees unless they are in parks or open space preserves. The 130 vegetation types in the SANDAG dataset were re-categorized into the 7 classes listed in Table 5. "Scrub" is a new class; other classes are used in the CARB (Winrock) study. Ecosystem types classified as scrub include coastal sage scrub and Sonoran desert scrub. Most of the classifications are either obvious or were specified in the CARB (Winrock) study. Other broadleaf ecosystems were classified as hardwood forest or woodland depending on typical tree size and density, with the higher woody biomass ecosystems classified as hardwood forest.

Table 2: Ecosystem Classification System Used in this Study.

Holland Vegetation Code	Holland Description	Winrock Classification
11100	Eucalyptus Woodland	Woodland
11200 – 11300	Non-native, disturbed	Grassland
12000	Urban / Developed	Unvegetated
13100 – 24000	Unvegetated, agricultural, and dunes	Unvegetated
29000 – 36120	Scrub	Scrub [14]
37000 – 39000	Chaparral	Shrubs [15]
42000 – 52440	Grasslands, marshes	Grasslands
60000 – 61000, 62400	Riparian bottomland forest / sycamore – alder	Hardwood forest
61300 – 62000, 63810	Riparian oak / cottonwood / mesquite / tamarisk	Woodland
62200, 63300 - 63310	Riparian scrub, drywash	Scrub
63320	Riparian willow	Shrubs
71000 – 71182, 77000 - 79000	Woodlands, oak	Woodland
72300-72320	Woodlands, pinyon / juniper	Shrubs [15]
81100, 83140 – 85100	Forest, evergreen	Conifer forest
81300, 81340	Forest, black oak	Hardwood forest
81310 – 81320	Forest, live oak	Woodland

Table 3 lists carbon uptake rates, biomass amounts, and fire emissions data for the seven classes of land cover in San Diego County. The uptake rates for hardwood forests, conifer forests, and woodlands were specified in the CARB (Winrock) study. Other uptake rates had to be estimated from other sources. Annual carbon uptake rates for chaparral and grassland ecosystems were estimated to be 0.9% and 1.2%, respectively, of the total carbon stock in each ecosystem type, estimated using biomass data taken from Wiedinmyer et al.[16] (2006) and shown in the fuel loading column. (Chaparral was assigned to the “shrubland” category. A 44.4% carbon content in shrubland and grassland biomass was taken from Wiedinmyer et al.) For chaparral, this amount of carbon uptake matches integrated field measurements performed on young and on mature local chaparral ecosystems by Luo.[17] Since grasslands reach maturity sooner, a slightly higher percentage (1.2%) of total carbon stock was used to estimate annual carbon uptake rates. Since scrub is in between grassland and shrub / chaparral in terms of the amount of biomass present, values for carbon uptake and biomass were selected that were in between the other two categories but closer to grasslands.

Table 3: Carbon Uptake, Biomass, and Fire Emission Data for San Diego County Ecosystems (All tons are metric)

Ecosystem Type	Carbon Accumulation Rate	Fuel Loading *B*	Woody Fraction *w*	Combustion Efficiency *E*		Emission Factors *F*		
	ton C / ha yr	ton biomass /ha		woody	herbaceous	kg CO2 / ton biomass burned	kg CH4 / ton biomass burned	kg N2O / ton C released
Hardwood Forest	1.05	120	0.85	0.3	0.9	1569	4.5	0.079
Conifer Forest	1.93	140	0.79	0.3	0.9	1569	4.8	0.079
Woodlands	0.3	95	0.84	0.3	0.98	1569	4.5	0.079
Chaparral	0.17	43	0.39	0.3	0.98	1630	3.1	0.079
Scrub	0.1	20	0.2	0.3	0.98	1630	3.1	0.079
Grasslands	0.06	11	0.08	0.3	0.98	1630	3.1	0.079
Unvegetated	0	0	na	na	na	na	na	na

Annual carbon uptake by each type of land cover was calculated by multiplying its land area in a given year times the appropriate uptake rate listed in the table. We have assumed that over the period 1990 – 2007 developed lands and agricultural lands neither accumulated net carbon (because of regular harvesting) nor released greenhouse gases during wildfires in significant quantities. Thus, after land is developed or farmed it makes no further contributions to greenhouse gas uptake or release in this analysis.

Carbon dioxide emissions due to land use conversion were estimated for farmland development using reported declines in agricultural carbon stocks at the county level for 1987, 1992, and 1997 from the Winrock study (2004).

Carbon dioxide emissions caused by vegetation removal for the conversion of undeveloped lands into farmland or developed areas were quantified using GIS analyses of SANDAG land use data at the parcel level for 1990, 1995, 2000, 2004, 2007[18] and SANDAG projections for 2020.[19] Lands classified as preserve open space (7603), landscape open space (7606), and undeveloped (9101) were all considered undeveloped, while all other land uses were considered developed. The change in developed land area was quantified by comparing 1990 and 2020 land use data and locating land parcels that had switched out of undeveloped designations. Intermediate year land use data was used to quantify the variability in rates of development during the 30-year period. Once "developing" land parcels were located in each period, they were overlayed with the county vegetation dataset described earlier to determine types and acreages of vegetation displaced. These acreages are multiplied by the biomass amounts ("fuel loading") listed in Table 3 and multiplied by 0.4 to determine the mass of carbon displaced. As recommended by the CARB (Winrock) study, we assume that the carbon stock from land that is developed is immediately released as carbon dioxide to the atmosphere. Thus, the displaced carbon is multiplied by the factor 44/12 to determine the mass of CO_2 released.

Emissions due to forestry from slash decomposition and fuel wood were assumed to be zero because of the negligible amount of forest harvest that currently occurs in San Diego County.

Fire burn areas downloaded from the SANGIS website[20] were overlaid on vegetation maps by GIS to determine types of ecosystems burned each year from 1990 – 2003 and 2007. (Burn areas for 2004 – 2006 are not yet available. Average burn areas for the non-firestorm years 1990 – 2001 were used for this period.) Carbon dioxide and methane emissions released by wildfires in San Diego County were estimated using the method of Wiedinmyer et al. (2006), who uses the equation:

$$Emission = AB\left(wE_w + hE_h\right)F \times GWP$$

where A is the burn area of a given land cover class in hectares, B is the biomass per hectare ("fuel loading"), w is the woody fraction, h is the herbaceous fraction (where w + h = 1), E is the combustion efficiency of a given fraction, F is the emission factor for the greenhouse gas in question, and GWP is the greenhouse warming potential of the gas. Values for the variables B, w, E, and F (except F_{N2O}) are taken from Wiedinmyer et al. (2006) and are listed in Table 3. GWP is defined as 1 for carbon dioxide. We used a GWP of 21 for methane and 296 for nitrous oxide. The result of the calculation is in units of kg of CO_2 equivalents, which is multiplied by 10^9 to get MMT CO_2E.

Nitrous oxide (N_2O) emissions were estimated using the same method[21] as in the CARB inventory. This method, where both carbon and N_2O emissions are in the same mass units, is shown below (Eq 2). If the carbon emitted term is removed from the equation, the result is an emission factor for N_2O which can be used in equation 1. This emission factor (after unit conversions) is listed in Table 3.

$$N_2O_{emitted} = \frac{Carbon_{emitted} \times 0.005 \times 0.01 \times 44}{28}$$

Fire emissions calculated using these methods for the firestorm years 2003 and 2007 were consistent with the CARB (Winrock) method for fires with an intensity between medium and high, which seems appropriate.

Limitations of the Methodology / Error Analysis

Results using the Wiedinmyer method have lower uncertainties than the CARB (Winrock) method, which failed to distinguish between different fuel types. The Wiedinmyer method is reliable to within a factor of 2, but has not been directly validated due to a lack of measurements. Thus, our calculated emissions due to development and fire have the same level of uncertainty. The methods of the Winrock study for estimating CO_2 uptake by vegetation have an estimated reliability of ±38%. Since we have extended this method to include chaparral, scrub and grasslands (based on Luo's two 2007 measurements on chaparral ecosystems) our estimations of CO_2 uptake are also reliable only to within a factor of 2.

These uncertainties will be reduced only by measurements of biomass content, fire emissions, and CO_2 uptake in local ecosystems. Very few measurement studies have focused on the types of ecosystems that cover most of San Diego County due to their low biomass compared to forests.

3. Emissions From Livestock Management

San Diego County has a vibrant agricultural sector; however, much of the activity is associated with cut flowers and avocado farming, rather than typical field crops and large-scale livestock operations. San Diego County's relatively small livestock operations are mainly responsible for regional greenhouse emissions from the agricultural sector.

The statewide greenhouse gas inventory conducted by the California Air Resources Board (CARB) includes several different sectors of agricultural activity, including in agriculture, forestry, and other land uses sector. CARB's inventory includes the following emissions sources.

- Livestock emissions from enteric fermentation and manure management;
- Land emissions from forest land; and,
- Emissions from aggregate sources such as biomass burning, liming, managed soils, and rice cultivation.

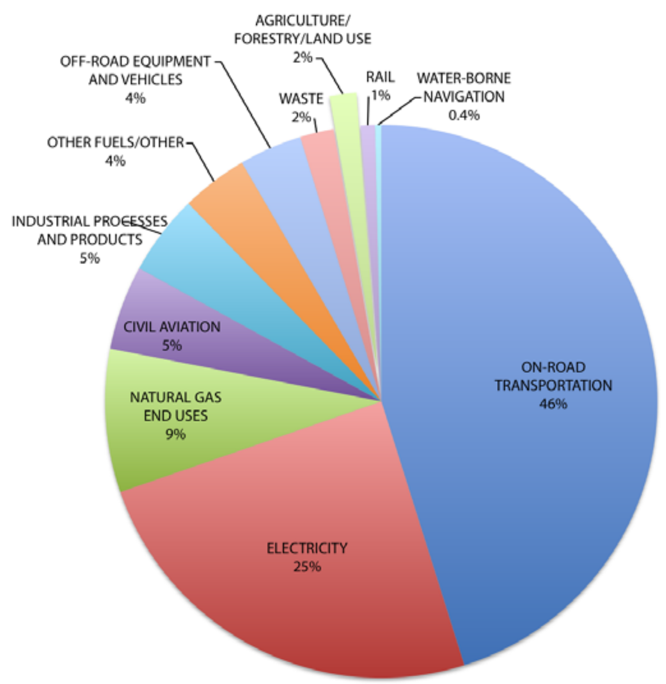
This section focuses on the livestock emissions. Land use is covered in the previous section, and data on biomass burning, fertilizer rates, and soils management were not readily available. Emissions from these activities are likely to be insignificant. Also, it is important to note that emissions included in this section do not include emissions associated with electricity, natural gas, and other fuel consumption by the agricultural sector. Emissions associated with these activities are captured in other sections.

3.1. Livestock Emissions Overview

Agriculture emissions make up only a small portion of the greenhouse gas inventory for San Diego. As seen in Figure 11, emissions from livestock are less than 1% of the total regional greenhouse gas emissions levels.

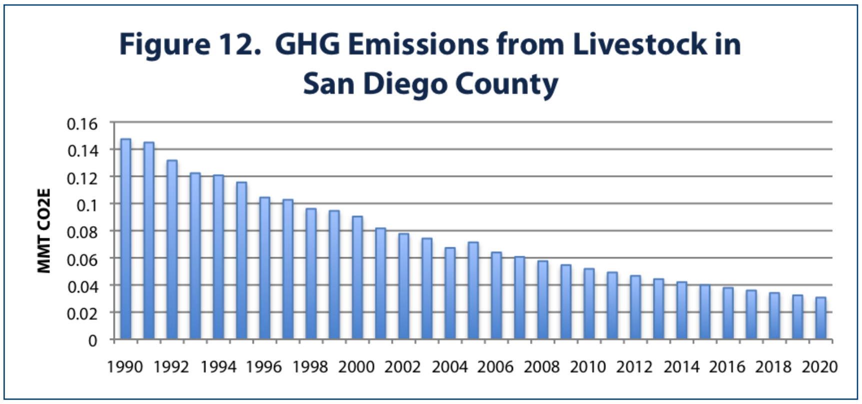
Livestock emissions have consistently been decreasing each year during the period of 1990-2006. Figure 12 shows this trend of declining emissions, which is directly proportional to the decrease in livestock populations over the years. This decrease is likely due to the displacement of farms by urban growth extending into rural areas of the county.

Figure 11. San Diego County GHG Emissions by Category (2006)

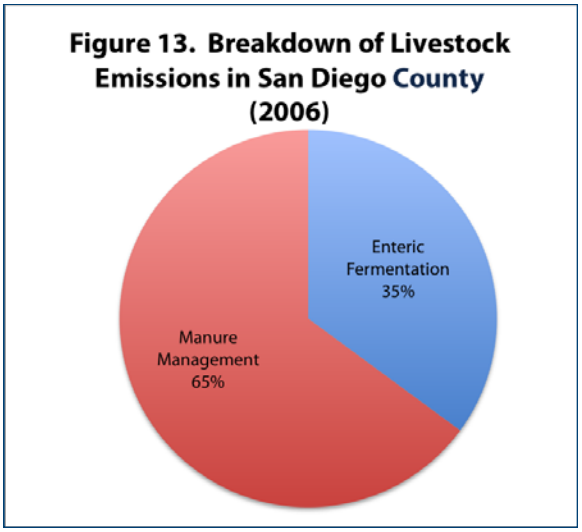


Projected emissions from the agriculture sector will be approximately 0.03 MMT CO_2E in 2020 under a business as usual scenario (Figure 2). Since agriculture emissions have actually decreased by 0.12 MMT CO_2E (79%) from 1990 levels, the AB 32 goal of 1990 levels has already been achieved. To get to the Executive Order goals of 80% below 1990 levels by 2050, emissions from this sector would have to be reduced just 1% more from 2020 levels, an additional reduction of just over 0.001 MMT CO_2E. Due to the existing downward trend in livestock population and emissions, it is likely that these levels will be achieved well before 2050.

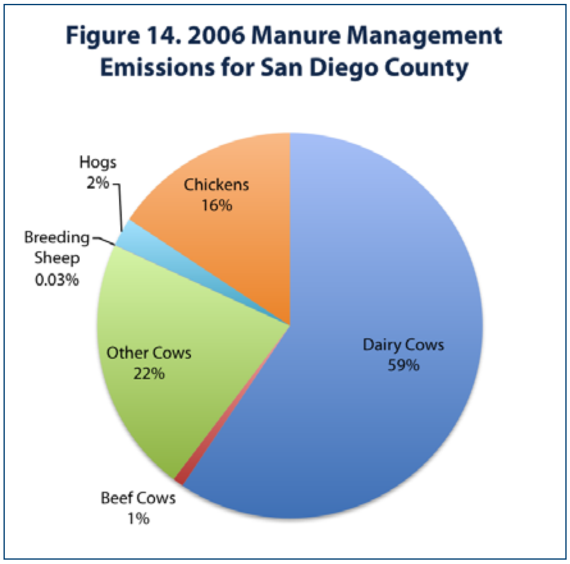
3.2. Livestock Emissions by Sector

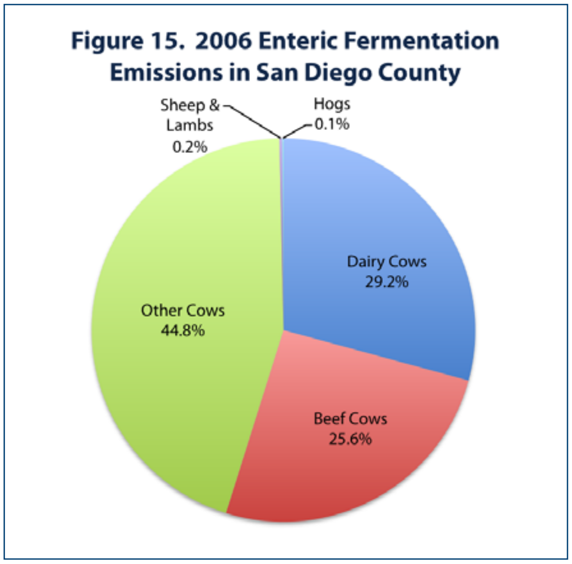


Livestock emissions are divided into two categories based on the emissions source: enteric fermentation and manure management. Enteric fermentation is defined as a fermentation process that takes place in the stomach of ruminant animals. This process produces methane that is released through belching and flatulence. Manure management is the process of gathering and disposing of manure from livestock. Management practices vary by type of livestock, but in the case of dairy cows, manure is often collected and stored in lagoons. As the manure breaks down, methane is released. As shown in Figure 13, manure management accounts for 65% of livestock emissions, while enteric fermentation accounts for just 35%.



As shown in Figure 14, the amount of emissions contributed by each animal type varies, in some cases dramatically. Dairy cows account for nearly 60% of greenhouse gas emissions from the manure management sector. Other cows (22%) and chickens (16%) are the second and third largest emitting class of animals in this sector. Enteric fermentation emissions in San Diego County come mainly from cows, with only an insignificant amount emitted form sheep and hogs. Other cattle, which are cattle not counted as dairy or beef, emit nearly 45% of all the methane from enteric fermentation, more than any other class of animal. Figure 14 shows this breakdown. It is also important to recognize the various populations of each animal type. Chickens greatly outnumber cows, hogs, and sheep in San Diego County.





3.3. Livestock Emissions Reduction Strategies

Although livestock only account for a small percentage of overall emissions in San Diego County, many other parts of the state and country are conducting research on methods to reduce emissions in this sector. One strategy to reduce emissions from manure management that is being used in dairy cow operations is to collect manure and capture methane via anaerobic digesters for use in electricity production or for injection into the existing natural gas transmission system. Several large digester projects in the Central Valley of California will generate biogas that will be treated to natural gas quality and then fed into the natural gas supply system. One dairy in San Diego County (Van Ommering Dairy) already uses an anaerobic digester to capture biogas to generate electricity.

Other strategies also exist to reduce livestock emissions. The US EPA suggests improving the productivity and efficiency of livestock populations to reduce enteric fermentation emissions (CH_4).[22] Efficiency can be improved by the following:

- Nutritional improvements
- Dietary supplementation
- Genetic improvements
- Grazing management
- Soil testing
- Water quality control

Other suggestions from the US EPA on manure management emission reductions for N_2O and CO_2 gases also include efficiency improvements and improved livestock management.[23]

3.4. Livestock Emissions Calculation Methodology

The project team used data from two different sources to calculate livestock emissions: the San Diego County Crop Report[24] and U.S. Department of Agriculture (USDA) National Agricultural Statistics.[25] Neither data set was complete and some interpolation and extrapolation was necessary to complete each set. The sets were then combined to serve as the basis for livestock emissions calculations. USDA data included information for the years 1990-1992 and 2001-2007, so we used a linear regression analysis to estimate livestock populations for the missing years, 1993-2000. USDA livestock population data included only the categories of dairy cows, beef cows, and all cattle. To determine the population of the "other cow" category, we subtracted data from the "milk (dairy) cows" and "beef cows" categories from the "all cattle" category included in the USDA data set.

The San Diego County Crop Report provided livestock population data for sheep and lambs, hogs, and chickens for the years 1995-2006. A linear regression analysis was used to backcast livestock population to 1990.

3.4.1. Emissions Calculations

To calculate livestock emissions, the project team used a direct calculation provided in the CARB statewide greenhouse gas inventory. For each sector CARB provides a 'per unit activity', which is based on the total emissions for that sector divided by the unit of activity. As an example, in 1990, California's 1,115,000 dairy cows emitted 143,547 tons of CH_4 (3,014,481 tons CO_2E), which yields per cow emissions of 128,741 g of CH_4 per head of Dairy Cows (2,703,571 g CO_2E per head of dairy cows). We multiplied the total head count for each animal type by this CARB activity factor to estimate emissions form livestock in San Diego County.

3.4.2. Livestock Emissions Projections

The project team projected both manure management and enteric fermentation emissions estimates to 2020 using a logarithmic decay model. First we calculated the log of historical emissions and plotted the results versus the year. From this plot, we performed a linear regression analysis to fit the line. From this line, the antilog of the slope and y-intercept component (right side of equation) was taken. The year 2020 was then plugged into the equation and the emissions for that year were predicted. This model produced more reasonable projections than a linear model.

End Notes

1. Development data is available for 1990, 1995, 2000, 2004, 2007, and 2020.
2. Total land area is 2.73 million acres.
3. Agricultural lands are classified as "developed" in the map. Forests are highlighted in yellow (conifer) and bright green (hardwood).
4. Developed and agricultural lands are not included. Total uptake is 0.68 MMT CO2.
5. Figure 6 includes areas that have been converted or are projected to be converted from undeveloped to farmland or developed land, 1990 – 2020, by vegetation class.8
6. Mensing, S.A., J. Michaelsen, and R. Byrne, A 560-year record of Santa Ana fires reconstructed from charcoal deposited in the Santa Barbara Basin, California. Quaternary Research, 1999. 51(3): p. 295-305.
7. http://www.sangis.org/
8. 2004 – 2006 burn areas are unknown. The 1990 – 2001 average was inserted in Figure 7 for these years due to lack of data.
9. The "shrub" designation refers to chaparral.
10. 2004 – 2006 burn area data is not yet available. Average emissions from 1990 – 2001 have been substituted for these years.
11. Brown, S., T. Pearson, A. Dushku, J. Kadyzewski, and Y. Qi. 2004. Baseline Greenhouse Gas Emissions and Removals for Forest, Range, and Agricultural Lands in California. Winrock International, for the California Energy Commission, PIER Energy-Related Environmental Research. 500-04-069F.
12. SANDAG GIS shapefiles download available at: http://www.sandag.cog.ca.us/resources/maps_and_gis/gis_downloads/senlu.asp
13. Statewide vegetation data with 100 m resolution available from CA DFFP's Fire and Resource Assessment Program (FRAP) available at: http://www.frap.fire.ca.gov/data/frapgisdata/download.asp?spatialdist=2&rec=fveg02_2
14. New category.
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23. Ibid.
24. See http://www.sdcounty.ca.gov/awm/crop_statistics.html.
25. U.S. Department of Agriculture National Agricultural Statistics Service http://www.nass.usda.gov/QuickStats/Create_County_Indv.jsp#top