ECONOMIC DEMOCRACY ADVOCATES

AGRICULTURAL SUSTAINABILITY IN THE SAN FRANCISCO BAY WATERSHED: **A PILOT STUDY IN BIOREGIONALISM**

FIRST DRAFT

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Agricultural Sustainability in the San Francisco Bay Watershed: A Pilot Study in Bioregionalism

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Introduction

Get Back to the Land!

Fifty years ago, throngs of young people began to recognize that natural resources were being extracted and wasted at increasing rates. For a generation seeking to find its roots, this scenario seemed detrimental for human beings and even worse for the environment. Proof of this was chronicled in Rachel Carson's 1962 book, *Silent Spring*, which awakened society to the dangers of pesticides penetrating into the ecosystems.

This concern turned into a crusade across the United States. While Joni Mitchell sang, "We are stardust, we are golden, and we've got to get ourselves back to the garden," hippies with long hair and festive clothes fled the large cities to restore themselves with nature.

This simple idea was actually more complex. The diaspora to 'get back to the land' had many motives. Was this colorful tribe seeking refuge from toxic pollution? Or a place to enjoy the landscape? A place to grow food and support themselves? A place to inhabit and build community? A place to restore balance and find continuity with the natural world?

None of this was entirely clear in the 1960s. The world was a more innocent place. Earth's population stood at 3.5 billion — half of what it is today. It was a time before globalization, hypercompetition, the Internet and social media. Headlines were not filled with the challenges of population growth, non-renewable resources and climate change. There were no business reports of material or energy shortages.

The words 'sustainability' and 'relocalization' were not in common use. Technology and science had only begun to be integrated with culture and geography. Meteorologists, geographers, land planners and farmers were the trusted experts in climate, watersheds, soil and native flora and fauna. Few were predicting that increases in population or per capita consumption would lead to the depletion of finite resources.

For the activists of the Sixties Generation, returning to the land meant more than just a change in lifestyle. It was an ecology of shared identity. Inspired by the NASA photographs of our blue earth from outer space, it was becoming clear that industrial civilization needed to restore both its cities and its ecosystems as part of a coalescing planetary civilization. On spaceship earth, no community's economic growth would depend on exploiting the natural resources that belonged to everyone.

Many of these young people were actually carrying on themes that had been developed earlier. A number of pioneers in the field of natural regionalism had already created a major impact in the United States. John Wesley Powell (1834-1902) and Wallace Atwood (1872-1949) developed natural maps of the US. John Muir (1838-1914), Frederic Jackson Turner (1861-1932), Patrick Geddes (1854-1932), Lewis Mumford (1895-1990) and Howard Odum (1924-2002) also wrote extensively about geography and regional planning in America. While pursuing very different kinds of work, they all yearned for a new kind of environmentalism which challenged society to confront the barriers that separate people from their ecosystems.

These themes were reinterpreted by the new voices emerging in San Francisco and its environs. From poets and artists to land planners and historians, these new conservationists realized that a regional culture's ability to adapt and endure depends upon its ecology. Gary Snyder (1930-), Peter Berg (1937-2011), Stewart Brand (1938 -), Raymond Dasmann (1919-2002), Allen Van Newkirk (1940-2013), Kirkpatrick Sale (1937-) and numerous others called on human communities to build a deeper and more lasting relationship with their natural life-support systems.

Gradually, this eclectic group of naturalists began to call their field "bioregionalism" (*bio* is the Greek word for life; *regere* is the Latin word for a place to be managed). So, bioregionalism is essentially the idea of ***life-place*** — a way of extending the life of a community to the life of the biosphere through the ecological renewal of a particular area. The new bioregionalists wanted to combine local knowledge, beliefs and values with the unique characteristics of the climate and topography, the soils and plants, and the animals and habitats where they lived.

These ideas spread across the United States, but San Francisco was the epicenter for this people's movement. They called on citizens to stop running away from the problems of industrial economy to better understand the land around them, the limits to its resources, and how this could help meet the needs of the diverse species who live there, including homo sapiens. Their vision was the development of new social and cultural relationships within the context of geographical communities.

Bioregionalism was a unique perspective for addressing major environmental challenges on a human scale. It acknowledged that solving large ecological problems by 'thinking globally' is much too disempowering for the average person. Although 'acting locally' is clearly the practical first step, it operates on too small a scale to impact environmental governance. The activity of localization simply does not generate enough political power within small communities to stop centralized governments and markets from exploiting these decentralized *life-places* for their own ends.

The bioregionalists explained why there are so few decision-making organizations or networks at the regional levels, where the harmful ecological problems could be most effectively addressed. They showed how history and economics had prompted leaders to draw artificial local, state and national borders that seldom conformed to the ecological zones which overlap with them. Hence, natural boundaries have little correlation with our present political, economic and social boundaries and their institutions. To be sure, many ecological problems — involving personal and collective choices and action, as well as their cumulative effects on human lives — cannot be resolved within existing political jurisdictions. Ultimately, we become inhabitants separated from our own habitats.

How is cooperation over resources even possible if our geographical borders cannot be redrawn to protect and manage the environment? An engaged movement for a more ecological society cannot succeed without some kind of graphic image of the bioregional boundaries which are hidden from view.

Such a map would focus not only on a region's hydrology, geology and physiography, but also reflect its culture, history, present land-use patterns and climate.

Mapping the Bioregion

The Biocapacity Research Team of Economic Democracy Advocates set out to understand the relationship between agricultural resources and the population of the San Francisco Bay bioregion. To begin, we looked at several maps. We turned first to the Environmental Protection Agency's map of bioregions, which covers the entire United States in striking detail.

We were seeking smaller-scale physiographic measures than the EPA's maps provided. So, we analyzed many other bioregional maps, all of which differed in terms of climate, geology, topology, geography, hydrology, soils, native animals and plants. None of these focused on bioregions primarily in terms of agriculture.

Finally, we turned to the resources of the California Department of Forestry and Fire Protection (CAL FIRE). Their Fire and Resource Assessment Program (FRAP) provides a map which uses data from the Interagency Natural Areas Coordinating Committee. This map identifies the various agricultural bioregions of California, including a ten-county bioregion around the San Francisco Bay Delta Estuary.

CAL FIRE's map presented us with the smaller, practical scale that we were seeking. In addition, the map held another advantage. One of the biggest challenges of doing research on bioregions is that a lot of environmental and demographic information is collected for commercial purposes. That's not what we wanted. With the San Francisco Bay Delta Estuary, however, we had the advantage of using a unique set of data. Since the political boundaries of this region line up almost perfectly with their ecological boundaries, we could use county-level US Census Data for major portions of our research.

What Does It Mean to Live in a Place?

We did not embark on this study as a retrospective view of bioregionalism. We set out to compare the agricultural resources available in an environment with the resources sufficient to meet the needs of its population. However, as we considered the sustainability of this region, the irony was not lost on us that the modern vision of bioregionalism had emerged from the San Francisco Bay Area. We soon realized that the early activists were correct: the study of natural resource planning and demography begins with a *life-place*.

Place-based knowledge is deeply rooted in regional culture and history, which in turn is deeply rooted in the bioregional community. Community members are organisms which depend on their environmental resources for support. For this essential reason, we believe people should become more familiar with their region's own *biocapacity*, which tracks the equilibrium between the area's resources and its population.[1]

This is what led us to use biophysical measurements in this study of Alameda, Contra Costa, Marin, Napa, San Francisco, San Joaquin, San Mateo, Santa Clara, Solano and Sonoma counties.[2] We applied the data from these political jurisdictions, combined with other information, to examine the agricultural sustainability of the entire bioregion.

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[1] Biocapacity is calculated by comparing the thresholds of resource availability with the allocations for meeting the needs of the population within a given area. For more on biocapacity, see page 8.

[2] For reasons of data collection and uniformity in reporting, this report does not include portions of Yolo and Sacramento counties, which also adjoin this bioregion.

CAL FIRE called the area the San Francisco Bay Delta Estuary to reflect the fact that this enormous watershed includes a delta and an estuary.[3] For our study, we call this the San Francisco Bay Watershed. Its size is extraordinary, covering nearly 60,000 square miles. It encompasses the largest estuary on the west coast of North America and the largest inland delta in the world.

The lower portion of the San Francisco Bay Estuary is home to most of the population in the bioregion. The upper section is the San Joaquin Delta. The delta is formed where the San Joaquin and Sacramento rivers come together and empty into the San Francisco Bay, draining over one-third of California. A long chain of ecosystems stretch through this delta, from sub-tidal, mud flat and salt marshes to chaparral, scrub, oak savannah, oak woodlands and conifer forests.

During the early explorations of California by the Spanish, approximately 7,000 Native American people were living in the Bay Area, dining on local animals as well as smelt, steelhead and salmon from the bay and river. In the 17th and 18th centuries, traders and settlers from Spain, France, England, Russia and the eastern US came to the Bay Area for animal fur, including beaver, river otter, marten, fisher, mink, fox, weasel, harbor and fur seals and sea otter. This fur trade, which opened California to world markets, did not last for long. By the mid-19th century, most of these species were in decline as hunters exceeded the river and marine life capacities of the area.

After the War of Independence in 1821, California joined the new Republic of Mexico. Then, in 1828, California became part of US territory. The 1849 gold rush in the Sierra Nevada Mountains drew people from all over the United States and the rest of the world. This restored the region's economy but further diminished the ecological sustainability of the delta and estuary. For instance, the metallic tailings left over from gold mining, negatively impacted photosynthesis of produce in the adjoining farm and croplands.

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[3] A *bay* is an inlet from an ocean which creates a physical refuge away from the ocean. A *delta* is a land-form that is created from the deposits of sediment carried by a river which enters a different body of water and does not transport the sediment away. An *estuary* is a landscape in which marine water combines with freshwater, generating geographic features which have both saline and freshwater characteristics.

California became a US state in 1850. As San Francisco grew, it was supported by the agriculture of its nearby areas. After World War II, there was a major movement of people to the suburbs and the surrounding hills, spurred by the growth of local railroads and automobiles. Agricultural areas like the Santa Clara Valley and the Livermore Valley gradually developed into major industrial and technological centers. As the population expanded and the real estate market grew, the estuary was dramatically transformed.

Since 1848, nearly 40% of the San Francisco Bay and more than 80% of the adjoining wetlands have been filled to accommodate the needs of water delivery, shipping, agriculture, commercial and residential districts, waste water treatment and urban drainage. This extensive landfill, along with the invasion of non-native species, resulted in major changes in the movement of the water and the topography of the landscape, altering the estuary significantly.

During this same period, the delta also underwent a transformation. It had been a very productive agricultural area until it was impacted by several factors. Before the 20th century, there were naturally occurring levees which protected farmlands from flooding by the Sacramento and the San Joaquin rivers, as excess rain and snowmelt flowed downstream to the Pacific Ocean. Reservoirs were put in place to hold back the runoff from the mountains, resulting in the reshaping of the natural levees.

Gradually, the farming practices used in the delta resulted in massive soil erosion, further modifying the path of the waterflow of the delta. Islands and channels developed along the delta area and continued to reshape the levees, creating an influx of salinity and increasing the risk of flooding. As a result, there is much less freshwater available now for farming and the levels of plant photosynthesis are also considerably lower than in the early 20th century. This infusion of brackish water also changed salt-water aquatic habitats, killed river salmon, clogged the levees with sediment and cut off access to croplands far upstream in the San Joaquin Valley.

After World War II, housing contractors looked beyond the cities and suburbs for cheaper land to develop, especially in the delta area. Thousands of subdivisions were built. The over-pumping of aquifers by farmers and corporations caused the lowering of water tables and extensive land subsidence in many areas. Much of the delta area is now either below sea level or in floodplains. As a result of shifting weather patterns, possibly due to climate change, agriculture is also impacted by serious declines in the snowmelt and stream flow from the mountain basins into the delta. All of this presents a challenging set of circumstances, particularly for agriculture.

Analysis

Biocapacity

This is a study of the agricultural sustainability of the San Francisco Bay Watershed. We recognize that many groups are actively working to develop alternative indicators for sustainability. We embarked on this study to see if calibrating *biocapacity* may offer the kind of impact valuation for agriculture which does not exist in the current market economy and its system of metrics.

Essentially, biocapacity is the dynamic balance point between the number of organisms within a given area and the amount of resources that are needed to support them within this area. Thus, agricultural biocapacity indicates the degree to which the population of a bioregion is greater or lesser than the food that is available from the bioregion to feed it.[4]

By combining scientific reason with place-based knowledge, culture and history, biocapacity provides a baseline for determining how different interventions will affect outcomes. This will allow communities to develop evidence-based guidelines for organizing their own resource sufficiency while regenerating the ecology of their life-places.

Biocapacity and Financial Reporting

We distinguish biocapacity from financial reporting because ecological sustainability is not accurately reflected in market valuations, if at all. For example, the San Francisco Bay Watershed is a significant part of California's enormous $20 billion agricultural industry. As we see in **Table 1**, the region's

[4] This research measures human sufficiency, not material well-being. We're interested in tracking the self-sufficiency of the people of the bioregion, which requires economic decentralization for development rather than goals for material welfare through centralized economic growth.

agricultural production accounts for a quarter of the State's agricultural wealth.

Table 1
Gross Value of Agricultural Production 2015
Source: California Department of Food and Agriculture

COUNTY	Gross Ag. Value x $1000
Alameda	49,902
Contra Costa	128,506
Marin	111,061
Napa	553,347
San Francisco	299
San Joaquin	2,732,900
San Mateo	130,275
Santa Clara	279,113
Solano	353,869
Sonoma	756,475
Total	5,095,747

With such a valuable product, the State of California's agricultural reports usually portray food as a highly reliable commodity. Yet, how is the sustainability of the area's agriculture measured? Actually, it's not. The implication is that the state's agriculture industry is sustainable financially because it's already sustainable ecologically. In other words, apart from possible drought or soil conditions, producers and exporters of food can always look forward to growing a steady harvest because agriculture is a renewable resource.

We do not start with this assumption. Our study originates in what is not renewable — the amount of arable land which is capable of growing food.[5] Rather, we should say, the decreasing availability of arable land which could produce food. Since available farmland is declining while population continues to increase, *arable land is a non-renewable resource*. As Mark Twain once said about land, "They're not making it anymore."

Another thing that makes this study different is that we focus on the population's need for food, not the demands or market expectations of consumers. All of the counties of the San Francisco Bay Watershed publish yearly agriculture reports which demonstrate the gross production value of their food products. This food value in the marketplace is based on a unit or weight per acre. Yet the same food products may also be valued by the amount of calories which they contain. We are interested in both of these measures, but not for their commercial potential.

To understand the sustainability of the region's food sources, we examine the biophysical relationship between the arable land available in an area and the aggregate needs of the population within that area. To do this, we use two measures for food value: biomass (pounds) and bioenergy (calories). This enables us to look at agricultural resources in terms of the thermodynamic throughput between the thresholds of food accessible in a bioregion and the allocations of food needed to support the people who live there.

In this way, the metrics of biocapacity allow us to bridge a human community with the bioregion which provides its material support. This is not something that most of us think about. We rarely consider how the human population interacts with the resource system which sustains it. Our team embarked on

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[5] By arable land, we refer to both farmland and rangeland. Our data combines the categories of 'crops for human consumption' with 'crops for livestock', since crops for livestock are ultimately consumed by human beings.

this study to see what conclusions might be drawn from this kind of biophysical approach.[6]

Biocapacity for Pounds and Calories of Food

We begin by asking: is the arable land within the San Francisco Bay Watershed capable of growing enough food to support its people, now and in the future?[7]

Our preliminary analysis of biocapacity is aimed at establishing a baseline for sustainable agriculture, without qualifying factors. To do this, we compare the aggregate amount of food grown regionally with the needs of the population in the area. Food availability is based on the arable land used for growing crops, vegetables, fruit and nuts, which is expressed in pounds and calories. In turn, the population's needs are expressed in terms of the pounds and calories of food required per person.[8]

We first compare the food biomass (in pounds) and food bioenergy (in calories) that are needed by the population per year with the amount that is actually produced. We find that the bioregion has the capacity to feed 15.3 million people with the pounds and 32.2 million people with the calories of food that are produced annually.

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[6] In this text, we present background information from our research. Some of the data, but not all, is illustrated in the series of tables which accompany the text.

[7] Our research focuses exclusively on agriculture. We do not include the area's seafood production.

[8] We are not studying the nutritional quality or density of food.

US Census data states that the population of the bioregion is 7.8 million.[9] We compare this with the 15.3 million people that these pounds of food could potentially feed. We find that the area has a biocapacity of 51.2% (of pounds of food it can produce annually for its population). Based on this preliminary calculation, the region is within its capacity to be self-sufficient in the annual biomass of food that it produces. It appears to have much more capacity to feed its population with the biomass of food that it grows each year.

Next we turn to food calorie production. When we compare the average annual calories required for the population with the average annual yield of calories for the bioregion, we see that the region is producing 28.8 trillion calories of food per year. This could feed 32.2 million people. Since the population is actually 7.8 million people which consume 7 trillion calories per year, the region has a biocapacity of 24.4% (of calories of food it can produce annually for its population).

Based on this preliminary calculation, the bioregion is using a quarter of its yearly potential for producing food value in calories. Thus, the region appears to be self-sufficient in the bioenergy of food it produces and could produce far more bioenergy each year than its population requires.

At the county level, there are large variations in the annual biocapacity for both pounds and calories of food. For example, Napa County is at 10% and San Joaquin and Sonoma counties are at 15% of their yearly biocapacities for pounds of food produced. On the other hand, San Francisco County is over a million times its biocapacity for pounds of food produced per year, and Alameda, Contra Costa, San Mateo and Santa Clara Counties are also well past their biocapacities for pounds of food produced each year for their populations.

Next, we look at variations of calorie production by county. Napa County is at 5% and San Joaquin and Sonoma counties are at 7% of their yearly agricultural biocapacities for calories. At the same time, San Francisco

9 Many of our calculations use census data from 2010 and 2012. With the US Census in 2020, we will update this information.

County is 600,000% and San Mateo County is 130% past their potentials for producing calories for their populations per year.

A simple reason for these variations in biomass (pounds of food) and bioenergy (calories of food) are the wide divergences in the arable land that is available for agricultural purposes. For example, Sonoma County with its grape vineyards and orchards has 590,844 acres of arable land with a population of 483,878, while San Francisco County with its heavy residential and commercial density has a population of 805,235 with just 12 acres of available arable land.

These are preliminary findings for the biocapacity of food pounds and calories.[10] They create a baseline from which to make further calculations.

Correcting the Data for Food Loss and Food Waste

If these initial figures for food biocapacity seem optimistic, it's because they do not reflect the *entropy* (or loss of biomass and bioenergy) affecting the food production and consumption process. So we adjust our baseline data to incorporate food loss and food waste. Technically speaking, *food loss* occurs during the farm production, post-harvest handling and storage, and processing and packaging processes. In turn *food waste* is tracked during the process of distribution (supermarket, restaurant and other retail) and consumer behavior.

To estimate these figures, we use constants which come from a highly-regarded 2011 study sponsored by the United Nations Food and Agricultural Organization, *Global Food Losses and Food Waste: Extent, Causes and*

[10] In all of the counties we are studying, there is a consistent pattern in the data between the average human intake of food calories per year and the average human intake of pounds of food per year. The pattern indicates that the amount of calories generated is slightly less than half of the pounds consumed. This is partly because we use constants for the amount of pounds of food consumed per person per year, as well as the average amount of pounds of food produced per acre per year. We also use constants for both the average amount of calories consumed per person per year and the average amount of calories produced per acre per year. There is another reason for the invariable relationship in our data between pounds and calories of food, which is not the result of averaging people's physical requirements for biomass and bioenergy. Humans don't extract all the calories of food that they eat, so they must eat more pounds and calories of food to get the calories of food they need to live.

Prevention. This research indicates that the average amount of food loss (from the farm through the processing and packaging of the food) combined with the average amount of food waste (from retail outlets and consumer practices) is 35% of the annual food produced on the farm.

In factoring for food loss and food waste, in **Table 2** we find a significant drop in the number of pounds that the region could potentially produce. Rather than a biocapacity of 51.2% of the annual pounds of food that the bioregion could produce for its population, this now corrects to 78.8%.

Instead of being at half of its potential for producing food value in pounds, the San Francisco Bay Watershed requires more than three-quarters of the annual pounds of food that it could potentially produce to feed its people. This means that the bioregion is rapidly approaching the limits of its annual biocapacity to produce food biomass for its population. Many of the region's counties have already exceeded their yearly capacity for generating pounds of food to feed themselves.

Table 2

Value of Agricultural Biocapacity

Corrected for Food Loss and Food Waste 2010 - 2012

COUNTY	POUNDS % of Carrying Capacity Used	CALORIES % of Carrying Capacity Used
Alameda	245.45%	116.79%
Contra Costa	228.22%	108.59%
Marin	42.66%	20.30%
Napa	15.57%	7.41%
San Francisco	1,940,147.65%	923,181.28%
San Joaquin	23.60%	11.23%
San Mateo	420.00%	199.85%
Santa Clara	214.32%	101.98%
Solano	28.45%	13.54%
Sonoma	23.68%	11.27%
TOTAL FOR BIOREGION	78.79%	37.49%

Likewise, in adjusting the biocapacity for calories in terms of food loss and food waste, the population of the bioregion is not at 24.4% but 37.5% of its biocapacity for the food calories that it produces. Based on this data, the area is still within its yearly capacity to be self-sufficient in the production of food calories. The bioregion still has much more capacity to feed its population with the bioenergy of food that it grows.

Factoring for food loss and waste, both San Joaquin and Sonoma counties adjust from 15% to 23% of their biocapacities for pounds of food produced per year. On the other hand, San Francisco County, which previously appeared to be approximately a million times over its biocapacity for pounds of food produced, is now nearly two million times over its biocapacity per year. Similarly, the figures for Alameda, Contra Costa, San Mateo and Santa Clara Counties make considerable leaps, well past the biocapacities for annual pounds of food produced for their populations.

With food loss and waste considered, Napa County is at 7% and San Joaquin and Sonoma counties are at 11% of their annual agricultural biocapacity for calories. At the same time, San Francisco County is over 900,000% and San Mateo County is at 200% of its biocapacity for calories per year.[11]

Adjusting the Data for Water Loss

Of course, water is a central factor in the agricultural biocapacity for feeding the population of the San Francisco Bay Watershed. We want to understand how the loss of water due to evaporation might affect the region's agricultural sustainability. Using a methodology created by Ward E. Sanford and David L. Selnick, we compare precipitation with evapotranspiration (the sum of ground surface *evaporation* and plant *transpiration* to the atmosphere).[12] This rate varies across different areas of the United States. The study indicates that 83.5% of average rainfall is retained each year within the soil, plants, groundwater and surface water in the San Francisco Bay Watershed.

This data enables us to adjust United States Geological Survey data for the bioregion to compare the *water needed* (the demand for water) with the *water available* (the aggregate supply of water) from both groundwater and surface water sources.[13] First, we find that 46,274 gallons of water are needed and that 72,656 gallons of water are available to generate the annual pounds of food that are necessary to meet the needs of each person in the bioregion. Comparing these figures, we see that the bioregion is at 64% of its annual

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[11] The wide differences between San Francisco and San Joaquin counties represent a typical dispersion of agricultural potential within a watershed, which we will discuss subsequently.

[12] Sanford, Ward E. and David L. Selznick, 2012. *Estimation of Evapotranspiration Across the Conterminous United States Using a Regression with Climate and Land-Cover Data*. Journal of the American Water Resources Association, 1-14, January 20, 2010.

[13] For water needed, we use figures from the United States Geological Survey for aggregate water withdrawals by the public. For water available, we use USGS data for the total amount of water available for all purposes — from public, domestic and industrial uses, to irrigation, aquaculture, mining and thermoelectric uses.

biocapacity for the water necessary to produce enough food biomass to feed its population.

Next, we find that 22,019 gallons of water are needed and 34,572 gallons of water are available to generate the calories of food that are necessary to meet the annual needs of each person in the bioregion. Comparing these figures, we see that the bioregion is also at 64% of its annual biocapacity for the water necessary to produce enough food bioenergy to feed its population.[14]

The San Francisco Bay Watershed is at slightly less than 2/3 of its biocapacity for the water needed and available for annual food production. This indicates that the bioregion is still within its capacity for self-sufficiency in water for agricultural use. Given the continuing conditions of drought, low precipitation, aquifer exploitation and water table depletion, many people believe that Northern California is nearing its limits for supplying the water necessary to produce enough food for its own population. Our data suggests that there is no major shortage of water in the bioregion at this time, although extreme shortages are inevitable since water is still being overdrawn from the ground at a rate greater than the area can supply.

Institutional conflicts in distribution and allocation also contribute to this problem. Groundwater extraction is almost entirely unregulated and unmeasured, which makes it practically impossible to estimate the total amount of water available. Still, in terms of agricultural sustainability, our analysis suggests that water is less of a factor presently than the lack of arable land and the willingness of the planners and communities in the bioregion to join together to discuss a bioregional strategy for water allocations.

[14] There is no difference between the amounts of water needed for pounds and calories (both at 64% of their annual biocapacity) because the same water that is used to produce pounds of food is also used to produce food calories.

Net Inflows and Net Outflows of Food

We want to compare how much of the annual production of pounds and calories of food is retained in each county with the amount that does not remain. For this, we do not use import and export measures for agriculture in terms of volume traded or its market value. Instead, we compare the annual net amount of locally-produced food that is available for consumption within the county (based on average human requirements) with the annual net amount of locally-produced food which does not stay in the region.

A *net outflow* means there is an oversupply of food pounds or food calories and the area could meet all of its food requirements from within the region. Some crops which are commonly eaten, such as wheat, citrus fruits and avocados, may not be easily produced within the bioregion, while other crops are produced only during certain seasons. Hence, net outflows are not food exports — they are the number of pounds and calories of food that the area can generate beyond what it consumes.

On the other hand, a *net inflow* means there is a deficit of food pounds or food calories in the area. This is not a measure of imports — it indicates the annual number of pounds and calories of food that the area can generate below what it consumes.

In short, net outflow and net inflow are functions of the available food thresholds in relation to food allocations for the population of the area. Thus, we compare the pounds or calories of food *produced* with the pounds or calories *consumed* within the area. This creates a baseline for net outflows and net inflows — *a preliminary stage before we correct these figures for food loss and food waste*.

Aggregating the ten-county data, the population of the San Francisco Bay Watershed consumes 15.7 billion pounds of food each year. The bioregion also produces 30.6 billion pounds of food per year. Thus, there is an annual net outflow of 14.9 billion pounds of food for the bioregion. This means that the bioregion as a whole is under its biocapacity for annual pounds of locally-grown food. The area has the capacity to feed its own population with the biomass of food that it produces annually.

The population of the San Francisco Bay Watershed consumes 7 trillion calories of food every year. The bioregion also produces 28.7 trillion calories of food per year. Thus, there is an annual net outflow of 21.7 trillion calories of food for the bioregion. Similar to the result for pounds of food, the region as a whole appears to be within its biocapacity for annual calories of locally-grown food. The bioregion has the capacity to feed its own population with the food bioenergy that it produces each year.

Table 3
Net Flows of Food
Into or Out of Counties and the Bioregion, 2010 - 2012

COUNTY	POUNDS + = OUTFLOW ? = IN-FLOW	CALORIES + = OUTFLOW ? = IN-FLOW
Alameda	-1,127,266,348	428,500,158,250
Contra Costa	-683,822,792	390,992,900,000
Marin	1,315,581,236	1,484,863,251,750
Napa	2,424,055,344	2,412,269,183,000
San Francisco	-1,610,342,296	-719,961,398,750
San Joaquin	7,565,113,572	7,783,825,109,500
San Mateo	-910,559,322	-147,884,806,750
Santa Clara	-1,005,436,732	810,306,641,500
Solano	3,643,643,730	3,831,017,128,000
Sonoma	5,320,005,848	5,475,732,098,500
TOTAL FOR BIOREGION	14,930,972,240	21,749,660,265,000

Next, we focus on individual counties. Here we see wide variances in both pounds and calories of food, as **Table 3** indicates. In comparing the annual consumption with the annual production of pounds of food calories, five counties record a net inflow and five counties a net outflow. For example, San Joaquin County has an annual net outflow of 7.6 billion pounds of food. Similarly, Sonoma County has an annual net outflow of 5.3 billion pounds of food. These net outflows indicate that San Joaquin and Sonoma counties are still below their maximum biocapacity for pounds of food and have the capacity to be self-supporting with the food pounds which are locally generated.

On the other hand, San Francisco County has an annual net inflow of 1.6 billion pounds of food and Alameda County's annual net inflow is 1.1 billion pounds of food. These net inflows mean that the counties have exceeded their annual biocapacity for pounds of food, meaning that their needs are being supplied from elsewhere. San Francisco and Alameda counties produce less food biomass per year than their populations require.

In **Table 3**, we also focus on the annual consumption and production of calories of food in each county. We subtract the calories consumed from the calories produced. In this case, eight counties have an annual net outflow and two have a net inflow. For example, San Joaquin County has an annual net outflow of 7.8 trillion calories and Sonoma County has an annual net outflow of 5.5 trillion calories of food. San Joaquin and Sonoma counties are still within their biocapacity, having the capability of feeding themselves annually with the biomass of locally-grown food.

The two counties which have net inflows of calories are San Francisco County with an annual net inflow of 720 billion calories and San Mateo County with an annual net inflow of 148 billion calories. These counties exceed their annual biocapacity for food calories, which means that their needs are being supplied from elsewhere. San Francisco and San Mateo counties are not capable of supporting themselves annually with the bioenergy of locally-grown food.

Many factors are affecting these variances. One is that hilly and mountainous areas like Alameda, Contra Costa, San Mateo and Santa Clara do not have much arable land available for growing agricultural products. Consequently, they have not evolved an infrastructure for self-sufficiency and must depend on surrounding counties or reach outside of the bioregion for their food.

In addition, heavily urbanized areas cannot develop a structure of food sufficiency for obvious reasons. Instead of agricultural terrain, these are densely populated regions where there is little arable land. **Metropolitan Statistical Areas (MSA)** are defined by the U.S. Office of Management and Budget as geographical regions with relatively high population density areas and close economic integration. The MSA in this bioregion is San Francisco/Oakland/Hayward.

Table 4
Net Flows of Food
Into and Out of the Metropolitan Statistical Area, 2010 – 2012

COUNTY	POUNDS + = OUTFLOW ? = INFLOW	CALORIES + = OUTFLOW ? = INFLOW
Alameda	-1,127,266,348	428,500,158,250
Contra Costa	-683,822,792	390,992,900,000
Marin	1,315,581,236	1,484,863,251,750
San Francisco	-1,610,342,296	-719,961,398,750
San Mateo	-910,559,322	-147,884,806,750
TOTAL FOR SF/ OK/Hay MSA	-3,016,409,522	1,436,510,104,500

This MSA, by far the largest population cluster in the bioregion, is at 153% of its biocapacity for annual food pounds produced and 73% of its biocapacity for annual calories of food produced. In **Table 4**, we see that there is an annual net inflow of 3 billion pounds of food into the MSA.

This indicates the annual biomass of food which the San Francisco Bay MSA must obtain to meet the needs of its population is over and above its capacity to grow food for itself. Alameda, Contra Costa, San Francisco and San Mateo counties are clear examples of places where the consumption of locally-grown pounds of food has exceeded its biocapacity.

On the other hand, there is an annual net outflow of 1.4 trillion calories of food from this MSA. This demonstrates how many fewer calories of food Alameda, Contra Costa, San Francisco and San Mateo counties produce than their populations require for bioenergy.
In **Table 3**, we noted some interesting variations in the data between counties, particularly in counties with the highest population levels. We see this again in **Table 4**. Alameda (1.5 million people), Contra Costa (1 million people) and Santa Clara (1.8 million people) have net inflows of food pounds but net outflows of calories per year. A similar discrepancy or imbalance applies in the San Francisco/Oakland/Hayward MSA (4.3 million people), an area with net inflows of pounds and net outflows of calories per year. These places appear to produce an overabundance of calories but under-produce pounds of food.

But there is a reason for this seeming paradox. A lot of food which is grown never reaches the intended population because of food loss and food waste during the process of production and distribution. So we correct our figures to account for this entropy (or depletion of food biomass and bioenergy).

Table 5
Net Flows of Food Into and Out of the Counties of the Bioregion Corrected for Food Loss and Waste

COUNTY	POUNDS Adjusted for losses + = OUTFLOW [?] = INFLOW	CALORIES Adjusted for losses + = OUTFLOW [?] = INFLOW
Alameda	-1,789,912,826	-194,170,841,750
Contra Costa	-1,178,924,815	-74,241,100,000
Marin	678,441,503	886,160,251,750

Napa	1,480,097,174	1,525,257,183,000
San Francisco	-1,610,386,992	-720,003,398,750
San Joaquin	4,437,609,622	4,844,994,109,500
San Mateo	-1,094,779,259	-320,991,306,750
Santa Clara	-1,900,683,276	-30,932,358,500
Solano	2,079,027,625	2,360,789,628,000
Sonoma	3,119,289,201	3,407,778,098,500
TOTAL FOR BIOREGION	4,219,777,956	11,684,640,265,000

When we adjust these annual net inflows and outflows by the combined food loss and food waste at the rate of 35% of the food produced, a new picture emerges. The number of food pounds produced by the San Francisco Bay Watershed actually drops from 30.6 billion to 19.9 billion pounds per year. Even with these adjustments, as we see in **Table 5**, there is still an annual net outflow of 4.2 billion pounds of food for the bioregion. This means that the bioregion as a whole is within its biocapacity for annual pounds of locally-grown food and can feed itself without help from outside.

The exceptions to this are Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties, which have annual net inflows of pounds of food. They do not produce enough biomass of locally-grown food to feed their own populations. Once again, we see that the Metropolitan Statistical Area at the bottom of the watershed is the biggest food drain on the region. It has a net inflow of 5 billion pounds and 423 billion calories per year, indicating that it is far past the agricultural biocapacity of its population.

In similar terms, the number of annual calories produced by the bioregion drops from 28.8 trillion to 18.7 trillion calories of food, when corrected for food loss and waste. Based on this adjusted figure, in **Table 5** we see a net outflow of 11.7 trillion calories of food per year from the bioregion. As with the previous result for pounds of food, this data shows that the San Francisco

Bay Watershed is within its biocapacity for producing calories of food and is self-sufficient in providing locally-grown food for its population.

At the county level, **Table 5** also lists Marin, Napa, San Joaquin, Solano and Sonoma counties as having annual net outflows of calories, indicating they are self-sufficient in producing the bioenergy of food calories for their local populations. Yet the annual net inflows of calories in the counties of the San Francisco/Oakland/Hayward MSA (excluding Marin) are moving steadily against the tide of self-sufficiency. They are becoming a calorie sink which lowers the agricultural biocapacity of the entire bioregion.

What's striking here is the role of San Joaquin County. When adjusted for food loss and waste, San Joaquin County drops from an annual net outflow of 7.6 billion to 4.4 billion pounds of food. Compare this with the net inflows of the Metropolitan Statistical Area in San Francisco Bay Area in **Table 5**. *San Joaquin County's annual net outflows of 4.4 billion pounds of locally-produced food nearly compensate for the heavy net inflows of 5 billion pounds within Alameda, Contra Costa, Marin, San Francisco and San Mateo counties per year.*

Even more interesting is San Joaquin County's annual net outflow of food calories compared with those same counties. Adjusted for food loss and food waste, the annual net outflow of calories produced per year in San Joaquin County declines from 7.8 to 4.8 trillion calories. At the same time, the MSA of the Bay Area declines from 5.3 trillion to 3.5 trillion calories produced per year, when adjusted for food loss and food waste. *San Joaquin County has net outflows of 4.8 trillion annual calories of locally-produced food, which greatly exceed the 1.3 trillion calorie inflows of the combined area of Alameda, Contra Costa, San Francisco and San Mateo counties per year.*

These intra-regional findings for biomass and bioenergy indicate several things. For one, this is a classic example of the asymmetry that develops for those living on the opposite ends of a watershed. Downstream communities nearly always depend on upstream communities for the quality, quantity and timely delivery of their water, and thus for their agricultural development. In addition, the agricultural soil is typically much richer upstream, allowing for more and better crops to be produced in these areas than downstream.

Quite literally, the ecological value of food biomass and bioenergy declines the farther it moves downstream, while the economic price of this food increases. Thus, in abundant areas like San Joaquin County, different kinds of ecological impacts and management decisions must be made regarding water and agricultural resources than in the dense metropolitan districts like the San Francisco Bay Area. Unfortunately, this often sets up a political rivalry or commercial competition over agricultural inputs, especially water sources.

Closely related to this is the *extreme disproportion between the annual net inflows and outflows of food on the opposite sides of the San Francisco Bay Watershed, whether measured in terms of pounds or calories*. Even though the bioregion as a whole is still within its biocapacity, this disparity is a red flag. In physiological terms, the metabolism of the bioregion is inverting to a condition of catabolism (a breakdown in the quality of biophysical energy).

Cooperative, intra-county policies are becoming necessary to restore a healthy balance between the resources and population. The collaboration of communities, elected officials, businesses and bioregional associations is needed to address these huge and potentially polarizing imbalances and maintain the San Francisco Bay Watershed within its agricultural biocapacity.

Calories Produced by Farm Labor

We investigate how many calories the region's farmworkers generate. We also want to know how many acres of land could be developed into farmland, how many new farmworker jobs may be created and how many additional food calories might be generated by employing more farmworkers. In this section, we do not compute for pounds of food. Our interest is in the bioenergy of food calories, which enables us to focus on productive labor and its bearing on sustainable agriculture.

Corrected for food loss and waste, the bioregion has the capacity to feed 20.9 million people with the calories that it produces each year — more than twice as much as its current population. In **Table 5**, we see that the outflow from the bioregion is 11.7 trillion calories of the 18.7 trillion calories that it produces each year. Since the annual amount of outflow is greater than the 7 trillion calories that are consumed by the people of the area, the bioregion is still self-sufficient in the production of calories to feed itself.

We also see in **Table 5** that most of the food production in the bioregion is taking place beyond the MSA. Marin, Napa, San Joaquin, Solano and Sonoma counties have the capacity to produce more than enough of the annual calories to meet the needs of their populations. Of these counties, San Joaquin is particularly strong in generating 4.9 trillion calories annually. But Alameda, Contra Costa, San Francisco, Santa Clara, and San Mateo counties could not feed their populations with the annual calories they produce.

Table 6
Calories from Farmworkers

County	Actual Farm Workers	Potential Farm Workers	Potential Calories from Potential Farm Workers
	People	People	$Cal.x10^6$
Alameda	1,378	24,438	1,755,890.00
Contra Costa	2,867	8,793	1,024,970.00
Marin	1,511	32,403	447,866.76
Napa	13,697	53,578	230,899.45
San Francisco	0		0.00
San Joaquin	40,865	30,773	3,650,790.00
San Mateo	2,135	25,009	472,420.00
Santa Clara	7,599	75,495	2,291,769.01
Solano	4,939	10,989	2,962,960.00
Sonoma	20,091	115,347	991,601.93
TOTAL FOR BIOREGION	95,082	239,291	13,829,167.16
Alameda	1,378	24,438	1,755,890.00
Contra Costa	2,867	8,793	1,024,970.00
Marin	1,511	32,403	447,866.76
San Francisco	0		0.00
San Mateo	2,135	25,009	472,420.00
TOTAL FOR SF/ OK/Hay MSA	7,891	70,600	3,701,146.76

In **Table 6**, we note that the San Francisco Bay Watershed has 95,082 farmworkers. They work primarily in areas outside the MSA, which employs just 7,891, or 8% of the total farmworkers of the bioregion. By contrast, San Joaquin County has 40,865 or 43% and Sonoma County has 20,091 or 21% of the bioregion's farmworkers. The other 3 counties account for 28% of the total farmworkers. Again, we notice the growing asymmetry of the bioregion.

Next, we look at the capacity for generating new agricultural jobs and greater numbers of calories in the San Francisco Bay Watershed. The column, 'Potential Farm Jobs' in **Table 6** combines the potential farm jobs which could be created from the farmland that is now available, already being used or needing to be upgraded. Based on the total potential acres of farmland in the bioregion, there are 239,291 potential jobs for farmworkers, instead of the 95,082 farmworker jobs that now exist. This suggests that the number of farmworker jobs in the bioregion could be increased by 252% if all the arable land were available for farm production. The bioregion could theoretically eliminate most of its unemployment of 356,388 jobs with these 239,291 potential jobs for farmworkers.

In **Table 7***,* we also see that 840,000 acres of land are being farmed in the bioregion per year. There is additional land such as pasture and grazing areas, scrub land and hilly areas that could be converted into farming. This amounts to an additional 1.9 million potential acres of arable land that could be farmed. A total of 18.7 trillion potential calories could be created yearly from all of the potential farmland.

Thus, if the amount of farmworker jobs were increased by 239,291 jobs, as noted in **Table 6**, 13.8 trillion calories could be created for the bioregion. Beyond this, in **Table 7** we see that the bioregion could further boost this potential bioenergy production from farmworkers to 18.7 trillion calories per year by emphasizing the development of potential farm acreage.

The prototypical watershed dynamics — a greater capacity for generating agricultural sustainability upstream than downstream — are at work here again. **Table 6** indicates that San Joaquin County, with its fertile soil and irrigated cropland could produce 3.7 trillion food calories in addition to its annual production by reaching its optimal farmland acreage and also generating potential farmworker jobs. At the other extreme, San Francisco County has little capacity to create food calories since it has practically no farmland acreage or farmworker jobs.’

Table 7
Calories from Farmland

County	Harvested Cropland	Calories Produced from Harvested Cropland	Potential Farmland	Potential Calories from Potential Farmland
	Acres	$Cal . x10^6$	Acres	$Cal . x10^6$
Alameda	9,901	99,010	157,559	1,575,590
Contra Costa	33,420	334,200	86,393	863,930
Marin	7,868	78,680	156,649	1,566,490
Napa	52,180	521,800	190,383	1,903,830
San Francisco		0	3	30
San Joaquin	484,804	4,848,040	321,748	3,217,480
San Mateo	4,033	40,330	40,982	409,820
Santa Clara	23,128	231,280	202,004	2,020,040
Solano	133,171	1,331,710	250,428	2,504,280
Sonoma	91,307	913,070	460,212	4,602,120
TOTAL FOR BIOREGION	839,812	8,398,120	1,866,361	18,663,610
Alameda	9,901	99,010	157,559	1,575,590
Contra Costa	33,420	334,200	86,393	863,930
Marin	7,868	78,680	156,649	1,566,490
San Francisco		0	3	30
San Mateo	4,033	40,330	40,982	409,820
TOTAL FOR SF/ OK/Hay MSA	55,222	552,220	441,586	4,415,860

Market Value of Calories

Market values for agriculture are usually determined by biomass, or pounds of food. To develop an alternative set of financial indicators, we look instead at food bioenergy for the amount of calories concealed in the market value of food.
In **Table 8**, we see that the bioregion has annual net outflows of 11.7 trillion calories.The bioregion produces a total of 18.7 trillion food calories per year. This creates $4.6 billion in food production revenue which is worth $248 for every million calories that are produced per year. The annual calorie production of the bioregion has an ecological value of $2.9 billion—the monetary value of calories that are produced beyond what is used to feed people in the local area.[15]

San Joaquin County produces 5.5 trillion calories per year. This creates $2.3 billion in annual food production revenue, which is worth $412 for every million calories it produces. The outflow of 4.8 trillion calories from San Joaquin county has an ecological value of $2 billion. By contrast, the MSA of San Francisco/Oakland/ Hayward creates 3.5 trillion calories annually, with $315 billion in food production revenue which is worth $91 for every million calories it produces. However, the 423 billion calorie inflow to the MSA creates a negative ecological value, a loss of $39 million per year.

This demonstrates a hidden economy of scale in calorie production: *the more calories that a local area creates as surplus, the more monetary value these calories have*. Conversely, the more calories that inflow to a local area through shipping, the more their monetary value decreases. We see this dynamic of ecological value at work in the annual net outflows of calories for San Joaquin County and the annual net inflows of calories for the MSA.

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[15] The higher the ecological value, the more anabolic (or healthy) the metabolism of the area. Of course, other ecological benefits of locally-produced food include lower shipping costs, a smaller carbon footprint from transportation and a higher nutritional value. Often, food that is shipped long distances must be harvested before it is ripe, which reduces the nutritional value.

The 4.8 trillion calories that outflow from San Joaquin County are 41% of the net outflow of calories from the entire bioregion per year. Their ecological value of $2 billion is 69% of the ecological value of calories for the entire bioregion per year. The outlier here, once again, is San Francisco County, which has almost no annual market value for the calories it produces since it has virtually no agricultural production. Alameda, Contra Costa, San Mateo and Santa Clara counties also need to import food calories.

Table 8
Monetary Value of Calories

County	Market Value 2012	Annual Calories Produced	Market Value per Million Calories	Net Calories + = OUTFLOW ? = INFLOW	Ecological Value + = OUTFLOW ? = INFLOW
	$\$ x 10^3$	$Cal. x 10^6$	$	$Cal. x 10^6$	$\$ x 10^3$
Alameda	57,522	1,156,389	49.74	-194,170.84	-9,658.60
Contra Costa	89,358	864,006	103.42	-74,241.10	-7,678.23
Marin	91,809	1,111,877	82.57	886,160.25	73,171.30
Napa	536,147	1,647,308	325.47	1,525,257.18	496,423.29
San Francisco				-720,003.40	
San Joaquin	2,250,158	5,457,829	412.28	4,844,994.11	1,997,497.95
San Mateo	75,889	321,483.5	236.06	-320,991.31	-75,772.81
Santa Clara	243,829	1,562,301	156.07	-30,932.36	-4,827.63
Solano	307,418	2,730,422.5	112.59	2,360,789.63	265,801.07
Sonoma	974,393	3,840,486	253.72	3,407,778.10	864,608.05
TOTAL FOR BIOREGION	4,626,523	18,692,180	247.51	11,684,640.27	2,892,078.77
Alameda	57,522	1,156,389	49.74	-194,170.84	-9,658.60

Contra Costa	89,358	864,006	103.42	-74,241.10	-7,678.23
Marin	91,809	1,111,877	82.57	886,160.25	73,171.30
San Francisco		78		-720,003.40	
San Mateo	75,889	321,483.5	236.06	-320,991.31	-75,772.81
TOTAL FOR SF/ OK/Hay MSA	314,578	3,453,833.5	91.08	-423,246.40	-38,549.63

Table 8 also shows that the bioregion adds $4.6 billion in value to its economy annually through calorie production, yet consumes all but $2.9 billion of these calories in feeding its population. Thus, the bioregion has ample food calories to support its population, but, as we will discuss, does not fully support itself agriculturally. The agriculturally non-productive MSA of San Francisco/Oakland/Hayward is a major factor. In addition, some popular crops cannot be produced within the region and many can be produced only during certain seasons.

But the primary reason for the lack of agricultural self-sufficiency is the external food trade: agricultural export is generating great wealth for the bioregion.[16] There is certainly enough income generated by food production to purchase what is locally produced. But the profit seems to be going into financial investment, rather than spending for programs that reduce food loss and food waste, expand arable land, increase the percentage of locally

[16] In reading this study one may think that self-sufficiency is not important because this bioregion generates a lot of financial wealth and can easily afford to import agricultural products from outside the area. Of course this is true, but in maintaining that "we can always turn to outside sources to import what we need to eat" changes the conversation away from the actual self-sufficiency of the region. That is not the point of this study. What we are seeking are norms or guidelines for self-sufficiency. We want to know if the food resources produced in the area are actually enough to support the population in the area. That is not a question that is answered by the supply and demand of the marketplace. Commercial measures for imports and exports tell us nothing about self-reliance, they only mask its significance. The calculations in this study were developed to determine the annual net inflows and net outflows of food from each county in terms of their biocapacity, not their commercial transactions or trading distributions.

produced-food that is locally consumed, generate farmworker jobs and undertake other practices for agricultural sustainability such as agroecology.

Long-Term Projections

Thus far, we see that for the typical county in the bioregion, the population is increasing but the land available for growing food is declining. Now we want to determine if the populations of each county, the MSA and the bioregion exceed their agricultural biocapacities for calories. Here, we do not calculate yearly data. Rather, we extrapolate county data over a prolonged period to know if and/or when their viability for food production no longer exists.

For this last part of our analysis, we make some projections about the long-range sustainability of agriculture by applying aspects of differential equations. For this, we use data on land and population from the years 2007 and 2012, available from the USDA, US Census Bureau and other records. We also use the biocapacities for the counties, the MSA and the bioregion which are previously established in this study. From these figures, we develop long-term change rates for the population and land in each county.

Several interesting things emerge from the analysis of this extended time-period. For instance, Solano County decreases slightly in population (0.13% per year). Also, the amount of land available to be farmed increases annually in Marin (4.7%), Napa (3.3%), Solano (2.8%) and Sonoma (2.6%) counties. San Francisco City/County has essentially no farmland and the remaining counties all have decreases in farmland.

Factoring for food loss and waste, five counties exceed their agricultural biocapacities (their populations are already larger than the food available from those counties to feed their populations). These include Alameda, Contra Costa, San Francisco, San Mateo and Santa Clara counties.

Examining the MSA of San Francisco/Oakland/Hayward, we see that the decline in agricultural biocapacity is accentuated the nearer our analysis approaches population-dense San Francisco. The Bay Area MSA greatly exceeds its self-sufficiency. How can this widening imbalance be reversed so that the entire bioregion stays within its agricultural biocapacity?

To address this question, we consider some further possibilities. We vary our parameters to see how various interventions might change the outcomes:

- if the food losses and waste were reduced by 10%, from 35% to 25% per year
- if the rate of change of farmland availability were increased by 0.5% per year
- if the rate of change of the population were reduced by 0.5% per year

These experiments in data projection are revealing. Reducing the losses and waste from 35% to 25% causes both Contra Costa and Santa Clara counties to have a viable food supply (by 3.4% and 9.8% respectively). Also, due to its size, the sustainability of Contra Costa County makes the entire MSA sustainable in food production (but only by 0.03%). However, these projections lose their agricultural sustainability (that is, the population again exceeds each of these counties' capacity to feed itself through internal food production) in less than 2 years' time.

In **Table 9**, we consider how many years it will take until the population exceeds its biocapacity for generating calories. We do this by cutting food loss and waste to 25%, cutting population growth by 0.5% and increasing the availability of arable land by 0.5%. From our previous discussion, we know that San Francisco and San Mateo counties have little or no farm production. Their populations far exceed their biocapacities for calories. Also for Marin, Napa, Solano, and Sonoma counties, the pace of land-change runs ahead of the rate of population change in all cases tested. These counties remain self-sufficient indefinitely based on the data from our Census projections.

That's true also for the whole bioregion when we implement the reduction of food loss and waste from 35% to 25% and either reduce population change by 0.5% or increase farmland availability by 0.5% per year. With Alameda, Contra Costa, San Joaquin, and Santa Clara counties and the MSA as a whole, there are clear progressive benefits from using one, two, or all of these approaches together. We see improvements in calorie biocapacity from reducing food loss and waste from 35% to 25%; reducing food loss and waste to 25% while reducing population change 0.5%; reducing food loss and waste to 25% and increasing farmland availability by 0.5%; and all three of these changes combined.

In the column to the far right in **Table 9**, we 'idealized' losses and waste reduction by 15% while retaining the population reduction at 0.5% per county and the increase of farmland availability at 0.5%. Not surprisingly, by continuing to reduce food loss and waste, this improvement in calorie biocapacity continues.

Applying the three basic changes does not raise the projections for these counties and the MSA beyond 2 years. Optimizing food losses and wastes, along with reduced population and increased farmland availability, extends this calorie biocapacity to approximately 4 years on average. On the other hand, San Joaquin County, which is already rich in food production, would benefit from these same interventions for hundreds or thousands of years.

Table 9

Years Until Population Will Exceed Calorie Biocapacity

(Controlling for Food Loss and Waste, Population and Land in Farms)

County	Cutting Food Loss	Cutting Food Loss and Population Growth	Cutting Food Loss and Increasing Arable Land	Cutting Food Loss and Population Growth and Increasing Arable Land	Cutting Food Loss and Population Growth and Increasing Arable Land
Loss and Waste Variation	L & W 25%	L & W 25%	L & W 25%	L & W 25%	L & W 15%
Population Variation		Pop. -0.5%		Pop. -0.5%	Pop. -0.5%
Arable Land Variation			Land +0.5%	Land +0.5%	Land +0.5%
Alameda					3.74
Contra Costa	0.55	0.6	0.61	0.67	3.18
Marin					
Napa					
San Francisco					
San Joaquin	229.46	454.26	456.53	29,551.76	31,155.08
San Mateo					
Santa Clara	1.59	1.74	1.74	1.92	4.50
Solano					
Sonoma					
TOTAL FOR BIOREGION	546.86				

These long-term projections corroborate our earlier results. As before, we find the bioregion operating like a conventional watershed, with the least calorie biocapacity downstream and the highest calorie biocapacity upstream, where there is fertile valley soil and abundant water for irrigation. Thus, the agricultural viability of the bioregion is mostly dependent on counties outside the MSA. San Joaquin County by itself (with a 2012 population of 701,151) has the capacity to provide bioenergy (calories) to 6 million of the bioregion's 8 million people without any of the changes we tested in the projection process.

Based on the 2007 and 2012 numbers for Marin, Napa, Solano and Sonoma counties, farmland availability is growing fairly rapidly (a minimum of 2.5% per year). It will be interesting to see if this pattern continues through the 2020 US Census data. Ultimately, the growth in land availability is limited by the population, if not by the size of the county.

For San Joaquin County and the bioregion as a whole, we consider 25 years as a reasonable window for planning. The wide variances within the bioregion today and its declining sustainability over the next few decades are significant enough to bring all stakeholders of the bioregion into cooperative discussions immediately. Reducing the rate of food loss and waste, increasing the rate of change of farm land availability and reducing the rate of change of the population would have a momentous impact in certain counties and for the bioregion as a whole. Without such interventions, most of the bioregion will be agriculturally unsustainable within two to three decades.

Conclusion

Fifty Years After

Today, a half-century after a young subculture realized that people have the responsibility to speak for the natural life-systems and ecological relationships of their area, we take a look at the general progress made during this period. Fifty years ago, the population of the San Francisco Bay Watershed and its aggregate resource use were relatively low. Since that time, the population has doubled from 4,200,000 in 1968 to 8,500,000 today, accompanied by a dramatic increase in productivity and wealth.

Yet the high demand and low supply of homes is now making housing unaffordable, which is also driving up the cost of living. In the last quarter of 2017, more residents left San Francisco than any other city in the US.[17] Meanwhile, residential and commercial density and sprawl have overtaken the surrounding natural environments, raising the per capita level of resource use. How did this happen?

San Francisco's hippies used to say that society must evolve beyond consumerism to avoid the possibility of extreme environmental degradation. The Sixties Generation reminded us that, sooner or later, communities must be integrated with their life-places.

Since then, the local media and universities of the area have done an excellent job in creating public awareness around the fragmentation of the regional habitat and the need for environmental protection. Most of the counties in the bioregion have adopted land-use policies to protect agricultural lands through conservation, wetlands restoration, land trusts and other programs. Tens of thousands of acres of open-space land have been set aside for watersheds and recreation.

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[17] http://www.businessinsider.com/san-francisco-housing-so-expensive-people-leaving-2018-4

But this green enthusiasm has not generated a significant change in social behavior. The generations of the 70’s and 80’s wholeheartedly embraced free trade and new technologies without fully understanding how this might impact the regional environment and its residential and consumer culture. Indeed, many of the early workers and investors in Silicon Valley were former environmental radicals.

Perhaps the most hopeful development since the 90’s is the *relocalization* of communities, which has emerged as a vibrant movement by encouraging the growth of local agriculture and ‘eat local’ programs. This includes the proliferation of farmers markets, roadside stands, community supported agriculture, community kitchens, edible gardens and other food distribution platforms and hubs. Yet relocalization has become more of a reformist movement than a network for systemic change. Citizens of the San Francisco Bay Watershed may realize that their own neighborhood exists within a bioregion, but the area still lacks the broader identity of an ecological culture.

So, what have we learned? The first thing that stands out is how much has changed in fifty years. Instead of fleeing the cities to save the remote rural areas, our transport vehicles, snarled traffic, sprawling population growth and housing explosion have blurred the differences between town and country. Now we speak of urban, suburban, ex-urban, rural and wilderness as parts of a continuum with little identity other than the roads which link them together.

Commercial buildings, housing, pavement, highways, technology and external trade generally leave city dwellers feeling that they are not part of a watershed or distinct bioregion. We see this in the dispersion of metropolitan values from San Jose, San Francisco and other urban areas into much of the bioregion.

For many people living now in the area, not much is known about how its life-systems relate to each other. Like most people in the United States, residents of the San Francisco Bay Watershed have been slowly desensitized to their local ecosystems, habitats, plants and animals. Little attention is given to restoring or maintaining the natural systems that are native to a locale, how this might relate to satisfying basic human needs or what the flora and fauna around these activities are like. People tend to forget that urban environments are built upon these natural foundations.

The second thing we noticed is the extreme degradation of the ecology due to human activity. Pollution is worse in the Metropolitan Statistical Area of San Francisco/Oakland/Hayward, and the impact is felt throughout the bioregion. Like elsewhere on the planet, the San Francisco Bay Watershed has been assaulted by industrialization, chemicals, mechanical removal of landscapes, disruption of rivers, accelerated destruction of ecosystems and rapid disappearance of habitats.

Flooding from rising sea levels poses major risks to all of the low-lying communities in the Bay Area. Drought, fire, earthquakes and severe storms are also challenging the people of the bioregion to reconsider their personal safety. Along with the rapid extinction of species and the pollution of soil, air and water, the quality of human life has also diminished. People are losing their health and culture along with their social incentives for cooperation.

Instead of developing an agricultural culture which unifies the bioregion, the dense urban environment, with its pace of life, job pressures and commuting, can make people oblivious as to where their food comes from or who is producing it. San Francisco County, for example, is deeply dependent on outside sources of food. Although vertical urban gardens are now beginning to spring up in San Francisco, their small scale will have little impact on the agricultural biocapacity of the region during the next few decades.

It will not be possible for the San Francisco Bay Watershed to remain within a self-reliant range as long as agriculture is geared primarily for external domestic and foreign markets. Our study notes that the bioregion adds $4.6 billion in value to its economy through calorie production, but only $2.8 billion worth of these calories are left after it feeds its population. This makes it harder to take the notion of *life-place* seriously as long as citizens continue to outsource their ecological sustainability.

It appears that much of the environmental damage in the region is due to the production of agriculture mainly for the export market rather than for the immediate needs of people who live in the region. The San Francisco Bay Watershed is at 79% of its biocapacity for the amount of food it produces, yet without producing more food for the people who live in the area it will become agriculturally unsustainable in two to three decades.

At the very least, the current profits from agricultural exports could be reinvested back into maintaining the sustainability of the bioregion. The region's investment community could focus more on the green infrastructure in its own backyard. This seems essential if those who live in the bioregion are to develop self-reliant capacities for the renewal of their natural systems.

Closely related to this is our third observation: the ethic of economic growth has continued to strengthen during the past fifty years. For the generation of the Sixties, the connection between economic growth and environmental degradation was never fully articulated or measured. Attention has still not been paid to the physical size of the economy within the larger ecosystem.

Our study underscores how important the methods of impact valuation are in sustainable development. For example, we learned that the amount of arable land available in the area for farm production could be expanded by 1.9 billion acres. If this happened, the number of farmworker jobs could be increased by 252% and the region would increase its net agricultural yield of 11.7 trillion calories by an additional 18.7 trillion food calories per year. This is why we stress the significance of looking both at actual results and measurable potentials as guideposts for what is empirically possible.

Without tools for projecting sustainability into the future, there is no way of accurately determining the scale of economic development and its ecological footprint upon the region — and little sense of value other than market value. This, of course, is not unique to the San Francisco Bay Watershed. The scale for sustainable limits for agriculture seems to be missing nearly everywhere, blurred by the commercial trading of food biomass and bioenergy into and out of the world's bioregions.

This leads to our final observation. People are conditioned to adopt technological, bureaucratic and economic practices without applying them directly to the regional ecology and the communities which support them. We believe that technology could be much more interconnected with the ecology and the ecological culture of the San Francisco Bay Watershed.[18]

Technological applications for biocapacity have enormous possibilities for restoring the life-places in this bioregion. Biocapacity technology is vitally needed for training communities how to estimate and measure sustainable yields and empower them to grow more food. Yet the area's technology firms seem unaware of the need for smart applications in community management of the food systems within their own bioregion (and indeed, in all bioregions across the world).

This was perhaps the most intriguing result in our study. Trends in consumer technology tend to separate communities from their natural habitats and regional cultures, while the market for biocapacity seems to be almost entirely ignored. Both forms of economic misallocation — between the counties of the region and between the area's wealth creators and their surrounding ecology — are unsustainable. Considering the wealth that is generated in this bioregion, a major focus is needed on important factors like the reduction of food loss and waste, the increased availability of arable land and safeguards on the amount of residential population that the environment can support.

The San Francisco Diaspora

The vision of bioregionalism — reinhabiting the place where we live through sustainable practices — is alive but not well. It's getting late in the game now to reestablish an ecology of shared identity while reducing energy and resource consumption. Based on our research, most of the region will exceed

[18] If community members are to restore their own ecologies, the development of design solutions for ecological accounting should not be left to experts. This means creating technology as a planning tool for local communities to accurately determine how many people the bioregion can support, how habitable it will remain, and what kinds of activities should be developed, continued or discontinued. Biocapacity technology for measuring ecologically and socially sustainable patterns needs to be in the hands of community members, planners, elected officials and bioregional associations.

its biocapacity to produce food for its growing population within two or three decades.

Industrial pollution, climate change, sea level rise, invasive species, water diversions and loss of wetlands are threatening enormous swaths of human habitat. Before 2050, the prodigious agricultural production of the San Francisco Bay Watershed will fail to produce sufficient quantities of agriculture for its population due to uncertain rainfall, flooded coasts and inlets, depletion of aquifers, topsoil loss, an export-led business model and a lack of cooperative dialogue among its political subdivisions.

Our study indicates that locally-produced calories have more monetary and ecological value when consumed in the same life-places where they are produced. Yet as long as the San Francisco/Oakland/Hayward MSA continues to import agriculture from elsewhere, the community will be impacted by rising food prices. Importing food into the dense population of the Bay Area will be possible until its food suppliers — foreign, domestic and regional — face their own supply limits for finite energy and raw materials and the breakdown of their own fragile infrastructures.

When the Bay Area becomes too severe a strain on the bioregion itself, the decline will be rapid. The external dependency on food may collapse and the capacity of the entire San Francisco Bay Watershed to sustain itself would be overtaken by extreme costs in food, water, energy and housing.

Why do we exploit our ecosystems instead of restoring them as life-places for habitation? This was the basic question raised in 1968. Now, ironically, San Francisco's 'back to the land' diaspora could turn into a mass evacuation from the region as its resources continue to decline and its self-sufficiency falters. How this existential crisis is addressed in the San Francisco Bay Watershed — and in bioregions everywhere — will determine the ecological future of all life-places and our sustainability as a species. The question then will be, not how sustainable but how inhabitable is my own bioregion?

Still, if there's any area that can break down the barriers between people and their land-place, integrating the human community with the ecological community, it's the Bay Area — the spot where modern bioregionalism began and remains a vital part of the cultural memory. Community members are the very organisms that depend on environmental resources for support. Now we must learn how to restore this dynamic balance. The issue is not if we have the will to do this, but how soon can it be done?

Action

How do we conceive of a bioregion as a self-organizing system when its constituent parts are divided by political boundaries? How do we make collective decisions in line with the region's natural boundaries? How do we take action to align our natural boundaries with our political boundaries?

The tools for changing this imbalance are at hand. More and more, we recognize that the natural resources of an area do not exist in isolation. To live self-sufficiently and self-reliantly within the boundaries of a bioregion requires bringing people, communities, natural sciences and technology together with their life-places.

Much progress has been made in the San Francisco Bay Watershed through educational and advisory organizations for the management of bioregional resources. Some of these agencies include:

American Farmland Trust
Association of Bay Area Governments
Bay Area Open Space Council
California State Coastal Conservancy
Community Alliance with Family Farmers
Global Food Initiative
Greenbelt Alliance
Sustainable Agriculture Education
UC Davis Agricultural Sustainability Institute
UC Sustainable Agriculture Research and Education Program

Still, bioregionalism lacks a critical mass. It is vital that these groups are joined by others and start making collective decisions for the dynamic balance of the bioregion. The intent is not to create a new bureau of land management. We propose a new bioregional partnership among regional planners, environmental planners, civil and environmental engineers, elected officials, businesses, technology companies and community activists.

To this end, we suggest a bioregional association which meets regularly within the counties of the San Francisco Bay Watershed. This group could begin its discussion with questions like these:

- What does it mean to live in a natural life-support system according to what is available in that place?
- How do we change our behavior to reestablish balance with our life-supporting systems and enrich the life of our own place?
- How do we develop the sustainability of the San Francisco Bay Watershed as a unique 'life-place'?
- Could resource management be better organized for the people living within this bioregional district?
- Can the San Francisco Bay Bioregion restore and maintain its habitats to maintain their quality of life?
- How do we plan for this kind of continuity?
- What kinds of policies would be effective in increasing agricultural sustainability for the people of this bioregion?
- Can we physically measure the regional economic system relative to the ecosystem that sustains it?
- How can we know if — and for how long — the life-sustaining capacity of the area will serve both present and future generations?
- How might biocapacity research be made useful for policymakers?

Meanwhile, the bioregional association would develop strategies and a timeline for implementing solutions. This report suggests a handful of important leverage points that could make a dramatic difference in the long-term agricultural vitality of the area. There is a small window now for facing the extensive risk of food decline and recognizing the potential of biocapacity research to renew our food production and distribution methods.

We see the possibility of developing advocacy and a constituency for:

- reducing food loss and waste of food
- increasing the arable land available for farming
- decreasing residential population growth

- raising the ratio between locally-produced and locally-consumed food
- reorienting agricultural production from exports to the needs of the region's population
- increasing the number of farmworker jobs
- protecting soil fertility
- recycling waste as nutrients
- maintaining biodiversity
- ensuring the nutritional value of agriculture

Here's an example of how a bioregional association could be instrumental. Our data shows that the San Francisco Bay MSA with little agricultural land tends to have much less food loss and waste than the other counties, while farm conservancy measures in the agricultural districts have far greater potential than in the MSA. At the same time, with a moderately-sized population and the highest amount of arable land available in the bioregion, San Joaquin County has the capacity to feed 3/4 of the region's population. In addition, based on the 1.9 million total potential acres of arable land, more than 200,000 new jobs for farmworkers could be created across the bioregion, beyond the 95,082 farmworker jobs which now exist.

Seemingly unrelated factors like these could be woven together through intra-county negotiations, bringing all interests to the table and leveraging new solutions for the management of food biocapacity. At present, there are few political means of unifying the region's diverse interests for land-use planning, ecological restoration and sustainability. But this new bioregional association could hold discussions for cooperative policies or legislation based on the strengths and weaknesses of the various counties. It would be able to influence self-regulating, self-reliant agreements and programs among county jurisdictions which are not generally engaged in power-sharing.

In the long-term, many other issues could be integrated into a larger bioregional agenda. This study has focused on the biocapacity of agriculture. There is plenty of scope for other essential plans and policies within the bioregion, including water, energy, waste recycling, forestry, tourism, cultural heritage, industry, public utilities, infrastructure and logistics. Yet agricultural sustainability is still the place to start getting back to the land.