

Chapter 12

Climate Change Impact on High-Altitude Ecosystems and Their Impact on Human Communities

Case Study: San Bernardino Mountains and Urban Communities Interface: Historical, Contemporary, and Future

Paul W. Bierman-Lytle

12.1 Introduction

Global Overview of High-Altitude Ecosystems:

Half of the Human Population Depends on Mountains Defined by elevation above sea level (minimum between 300 and 1000 m, depending on latitude), steepness of slope (at least 2° over 25 km, on a 30-arc-second grid), and excluding large plateaus, mountains occupy about one fifth of Earth's terrestrial surface. Twenty percent (1.2 billion) of the world's human population live in mountains or at their edges, and half of the humankind depends in one way or the other on mountain resources (largely water).

Mountains are Characterized by High Biodiversity Because of the compression of climatic life zones with altitude and small-scale habitat diversity caused by different topo-climates, mountain regions are commonly more diverse than lowlands and are thus of prime conservation value. They support about one quarter of terrestrial biodiversity, with nearly half of the world's biodiversity hot spots concentrated in mountains. Geographically fragmented mountains support a high ethno-cultural diversity. For many societies, mountains have spiritual significance, and scenic landscapes and clean air make mountains target regions for recreation and tourism. Thirty-two percent of protected areas are in mountains (9345 mountain protected areas covering about 1.7 million km²).

Mountain Ecosystems are Exceptionally Fragile Mountains are subject to both natural and anthropogenic drivers of change. These range from volcanic and seismic events and flooding to global climate change and the loss of vegetation and soils because of

P. W. Bierman-Lytle (✉)
Sustainable Environment Associates Corporation, Denver, CO, USA
e-mail: p.biermanlytle@pangaeon.com

inappropriate agricultural and forestry practices and extractive industries. Mountain biota are adapted to relatively narrow ranges of temperature (and hence altitude) and precipitation. Because of the sloping terrain and the relatively thin soils, the recovery of mountain ecosystems from disturbances is typically slow or does not occur.

Human Well-Being Depends on Mountain Resources These ecosystems are particularly important for the provision of clean water, and their ecological integrity is key to the safety of settlements and transport routes. They harbor rich biodiversity and contribute substantially to global plant and animal production. All these services depend on slope stability and erosion control provided by a healthy vegetative cover. As “water towers,” mountains supply water to nearly half of the human population, including some regions far from mountains, and mountain agriculture provides subsistence for about half a billion people. Key mountain resources and services include water for hydroelectricity, flood control, mineral resources, timber, and medicinal plants. Mountain populations have evolved a high diversity of cultures, including languages, and traditional agricultural knowledge commonly promotes sustainable production systems. In many mountain areas, tourism is a special form of highland–lowland interaction and forms the backbone of regional as well as national economies.

Defining Mountains by Topography Only The United Nations Environment Program–World Conservation Monitoring Center has adopted criteria based on altitude and slope in combination to represent the world’s mountain environments.¹ Topographical data from the GTOPO30 global digital elevation model (USGS EROS Data Centre 1996) were used to generate slope and local elevation range on a 30-arc-second (about 1 km) grid of the world. These parameters were combined with elevation to arrive at empirically derived definitions of six elevation classes. To reduce projection distortion in the original data set, analysis was based on continental subsets in equidistant conic projection. The global mountain area thus defined is almost 40 million km², or 27% of Earth’s surface. Assuming a lower mountain boundary of 1000 m at the equator and a linear reduction of this boundary to 300 m at 67°N and 55°S reduced the total “mountain” land area by 5.4 million km² or 3.7% of the global land.²

Class 1, elevation >4500 m

Class 2, elevation 3500–4500 m

Class 3, elevation 2500–3500 m (San Bernardino Mountain range)

Class 4, elevation 1500–2500 m and slope ≥ 2 (San Bernardino Mountain range)

Class 5, elevation 1000–1500 m and slope ≥ 5 or local elevation range (7 km radius) > 300 m

Class 6, elevation 300–1000 m and local elevation range (7 km radius) > 300 m outside 23°N to 19°S

Class 7, isolated inner basins and plateaus less than 25 km² in extent that are surrounded by mountains but do not themselves meet criteria 1–6 (this seventh class was introduced in the 2002 revision of the original 2000 system)³

¹ Kapos et al. 2009.

² Millennium Ecosystem Assessment, World Resources Institute (2005b, p. 684).

³ Millennium Ecosystem Assessment, World Resources Institute (2005b, p. 684).

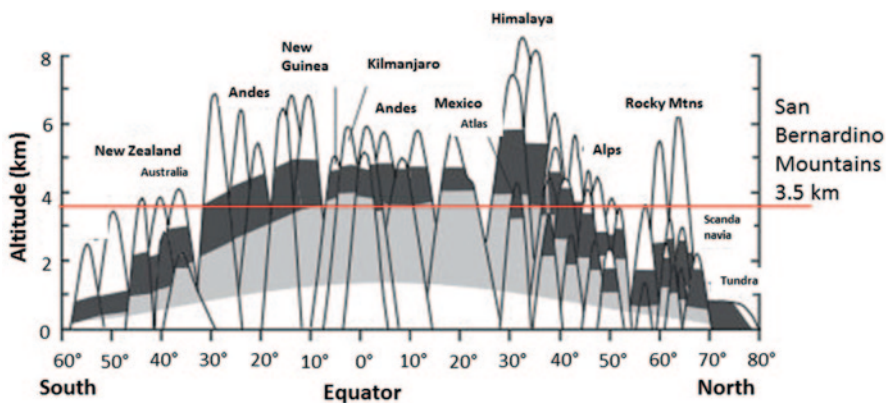


Fig. 12.1 Classic Humboldt Profile of the latitudinal position of altitude belts in mountains across the globe and compression of thermal zones on mountains, altitude for latitude. *Grey* is montane; *black* is alpine; *white* is the nival belt (© Millennium Ecosystem Assessment, World Resources Institute 2005a)

In this global assessment, three belts were distinguished for mountain regions where precipitation regimes allow forest growth. In treeless arid or semiarid regions, analogues to these belts can be defined (see Fig. 12.1).

- *The montane belt* extends from the lower mountain limit to the upper thermal limit of forest (irrespective of whether forest is present or not). This limit has a mean growing season temperature of $6.7 + 0.8^{\circ}\text{C}$ globally, but is closer to 5.5°C near the equator and to 7.5°C near temperate latitudes. Between 40°N and 30°S , this belt covers a range of 2000–3000 m of elevation.
- *The alpine belt* is the treeless region between the natural climatic forest limit and the snow line. The term “alpine” has many meanings, but here it refers strictly to a temperature-driven treeless high-altitude life zone that occurs worldwide and not solely in the European Alps (the term “alp” is of pre-Indo Germanic origin). Some synonyms such as “andean” and “afro-alpine” are in common scientific use. Land cover is dominated by grassland or low-stature shrubland. Outside subpolar regions ($<60^{\circ}\text{N}$, $<50^{\circ}\text{S}$), the alpine belt extends over an elevation range of 800–1200 m, with its lower boundary varying from about 500 to 4000 m above sea level, depending on latitude.
- *The nival belt* is the terrain above the snow line, which is defined as the lowest elevation where snow is commonly present all year round (though not necessarily with full cover). While the lower part of the nival belt is still rich in living organisms, usually very little plant and animal life is found beyond 1000–2000 m above the tree line, although animals and flowering plants can be found up to around 6000 m in some parts of the world (Figs. 12.2, 12.3, and 12.4).⁴

⁴ Millennium Ecosystem Assessment, World Resources Institute (2005b, pp. 684–685).

Fig. 12.2 San Bernardino Mountains. (©Peakbagger 2004)



Fig. 12.3 San Bernardino Mountain range. (©Peakbagger 2004)

12.2 Origins of the San Bernardino Mountain Range Ecosystem

Tectonic plate movement along the San Andreas Fault,⁵ commonly called the Transverse Range, formed the San Bernardino and neighboring mountain ranges approximately 11 million years ago. The mountains are still actively rising, a few millimeter

⁵ The San Andreas Fault is a continental transform fault that extends roughly 810 miles (1300 km) through California in the USA. It forms the tectonic boundary between the Pacific Plate and the North American Plate, and its motion is right-lateral strike slip (horizontal). The fault divides into three segments, each with different characteristics, and a different degree of earthquake risk. Although the most significant (Southern) segment only dates back about 5 million years, the oldest sections were formed by the subduction of a spreading ridge 30 million years ago.

Fig. 12.4 California in the USA. (©Magellan Geographics, Santa Barbara, California, 1992)



per year. The fault runs along the southern base of the San Bernardino Mountains, crosses through the Cajon Pass and continues the Northwest along the northern base of the San Gabriel Mountains. Many local rivers originate in the range, which receives significantly more precipitation than the surrounding desert. The range's unique and varying environment allows it to maintain some of the greatest biodiversity in the state (Fig. 12.5).

The San Bernardino, $34^{\circ}08'N$ $116^{\circ}53'W$, run for approximately 60 miles (97 km) from Cajon Pass in the Northwest—which separates them from the San Gabriel Mountains—to San Geronio Pass, across which lie the San Jacinto Mountains, in the Southeast. The Morongo Valley in the Southeast divides the range from the Little San Bernardino Mountains.⁶ Encompassing roughly 2100 miles² (5439 km²), the mountains lie mostly in San Bernardino County, with a small southern portion reaching into Riverside County. The range divides three major physiographic regions: the highly urbanized Inland Empire to the Southwest, the Coachella Valley in the Southeast, and the Mojave Desert to the North. Most of the range lies within the boundaries of the San Bernardino National Forest.

The San Bernardino Mountains are the highest range south of the Sierra Nevadas, and are also unique in being one of the few transverse ranges in the USA. This huge and rugged country is filled with history, romantic legends, and magnificent scenery, which are many reasons human communities have originated and settled in and around the high-altitude range. Proclaimed a “Forest Reserve” on February 25, 1893, these mountains were redesignated as the San Bernardino National Forest by presidential proclamation in 1925. This vast area is much larger than the State of Rhode Island at 1058 square miles (2740 km²). Within the boundary of the National Forest are 812,633 acres (328,861 ha), of which 198,042 acres (80,145 ha) are state and private lands. The San Geronio Wilderness runs along the southern spine of this mountain range, and consists of 33,898 extremely rugged acres (13,718 ha). The highest

⁶ <http://www.bigbearhistory.org/sbdomtns.htm>.

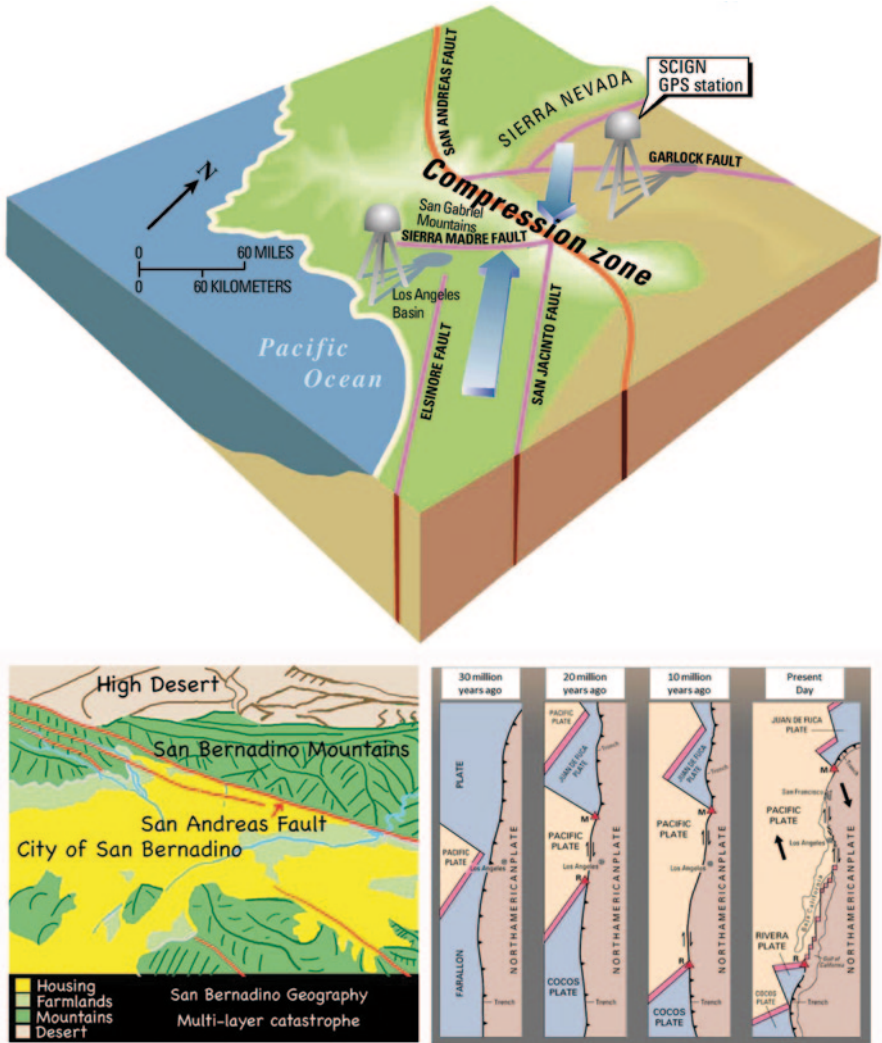


Fig. 12.5 Tectonic plate forming the San Bernadino Mountains—11,000,000 years ago (U.S. Geological Survey 2006)

mountain in Southern California, Mt. San Gorgonio—nicknamed Old Greyback—at 11,502 ft. (3500 m), stands well above several others reaching over 10,000 ft. (3050 m)—Dobbs Peak, Jepson Peak, Charlton Peak, and San Bernadino Peak.

San Bernadino Mountain Ecosystem DNA What is this mountain ecosystem made of and what is its quantitative and qualitative natural capital value?

An early version of the range rose in the Miocene, between 11 and 5 million years ago, but has largely eroded. The range was shaped into its present form during the Pleistocene epoch beginning approximately 2 million years ago, with regional uplift continuing to the present. The rocks that make up the mountains are

much more ancient than the mountains themselves—ranging from 18 million to 1.7 billion years old.⁷

These mountains are shaped by several primary tectonic or fault blocks—the Big Bear block, which forms the large montane plateau that characterizes the northern portions of the range; and the more complex and fractured San Gorgonio, Wilson Creek, and Yucaipa Ridge blocks, which form the rugged and heavily dissected southern parts of the mountains.⁸ Because of their large, steep rise above the surrounding terrain, the San Bernardino Mountains have been subject to great amounts of erosion that have carved out numerous river gorges. Rocks and sediment from the mountains are deposited on the surrounding valley floors as massive alluvial fans.⁹ Regional alluvial deposits can reach the depths of 1000 ft. (300 m) or more, and their permeable soils constitute several major groundwater basins.^{10,11}

The modern landscape of the San Bernardino Mountains is a product of erosional dissection by streams and rivers that are gradually stripping away rock products and carrying them downstream to alluvial basins at the base of the range. The next few million years of earth history will witness a competition between erosional agents that will tend to reduce the elevation of the San Bernardino Mountains and tectonic agents that may continue to increase their elevation.¹²

The San Bernardino Mountains, along with the nearby San Gabriel and San Jacinto ranges, are considered a sky island—a high mountain region whose plants and animals vary dramatically from those in the surrounding semiarid lands. The San Bernardino Mountains in particular comprise the largest forested region in Southern California, and support some 1600 species of plants. Foothill regions are primarily composed of chaparral and evergreen oak woodland communities, with a transition to forests of deciduous oak, yellow pine, Jeffrey pine, incense cedar, and several fir species at elevations above 5000 ft. (1500 m). Deeper within the mountains, perennial streams fed by springs and lakes nourish stands of alders, willows, and cottonwoods.¹³

Roughly 440 species of wildlife inhabit the mountains,¹⁴ including 71 endangered animal species such as the San Bernardino flying squirrel, California spotted owl, mountain yellow-legged frog, southern rubber boa, and Andrew's marbled butterfly, and 85 flora species.¹⁵ The mountains once had an abundant population of California grizzly bear, but hunting eliminated their populations by 1906.¹⁶ Black bears roam

⁷ U.S. Geological Survey (2006).

⁸ Spotila et al. (1998–2006).

⁹ Matti and Morton (2000).

¹⁰ Eckis (1928).

¹¹ Gandhok et al. (1999).

¹² http://geomaps.wr.usgs.gov/archive/scamp/html/scg_trans_sbmt.html, USGS, Southern California Geological Survey, Bailey and Jahns (1954); Dibblee (1982b); Matti and Morton (1993); Matti et al. (1992a, 1992b); Miller (1946); Sadler (1981, 1982); Spotila et al. (1999).

¹³ U.S. Forest Service (2009a).

¹⁴ U.S. Forest Service (2009a).

¹⁵ “Endangered species”. *Mountains Group—San Gorgonio Chapter*. Sierra Club.

¹⁶ “Black Bear Management Plan.” California Department of Fish and Game (1998–2007).

Fig. 12.6 American bald eagle. (© U.S. Department of Agriculture (USDA), 2009)



Fig. 12.7 Coral snake. (© U.S. Department of Agriculture, 2009)



Fig. 12.8 Sub-alpine forest. (© USDA, 2009)



the highlands today, but they are not native to the region: they were imported from the Sierra Nevada by the California Department of Fish and Game in the 1930s, in part to attract tourists to the mountains (Figs. 12.6, 12.7, 12.8, and 12.9).¹⁷

¹⁷ “Black Bear Management Plan”. California Department of Fish and Game (1998–2007).

Fig. 12.9 Black bear. (non-native species) (© USDA, 2009)



12.3 Historical Relationships Between Human Communities and this High-Altitude Ecosystem

12.3.1 *Native Americans: The First People*

Archaeological discoveries in the San Bernardino Valley suggest that humans have populated the region for at least 10,000–12,000 years.¹⁸ Several Native American groups held the lands surrounding the San Bernardinos. Most of these tribes did not have permanent settlements in the mountains, with the possible exception of a few groups of Serrano (Figs. 12.10, and 12.11).¹⁹

The Spanish explorers who first came upon Big Bear Valley named the Native Americans who lived here the “Serranos,” which means mountaineers. The Serranos are thought to be Shoshonean by descent, and they probably gradually migrated to the San Bernardino Mountains from the Wind River country of Wyoming some 3000 years ago. Once in Southern California, the Serranos were not extensive travelers, and their range was within an area marked by the Mojave Desert, San Bernardino Valley, and Mt. San Jacinto. Their summer encampments were spent mostly in the San Bernardino Mountains. Their dwellings were made of poles and tulle grass or brush and had a smoke hole at the top. A center fire pit was only for heating, as all cooking was done outside. The floor was covered with tulle mats, and these and animal skins were used for bedding. Acorn mush was a basic food. It was pounded from nuts gathered in the fall from black oaks near Oak Glen. Pinion nuts were also a favorite, with Big Bear Valley a main source. Other foods were mesquite beans, berries, chia seeds, roots, tubers, bulbs, and sage. Rodents, birds, insects, reptiles, fish, rabbits, and deer were also part of their diet.

¹⁸ “San Bernardino County History.” County of San Bernardino (2008).

¹⁹ Robinson and Harris (2006).



Fig. 12.10 Desert Cahuilla woman and native Serranos. (© Edward S. Curtis, 1926)

Fig. 12.11 Fibrous threads on leaf segments (*Washingtonia filifera*). (© U.S. Forest Service, 2012)



The Serrano women were accomplished pottery makers; their Tizon ware was thin, delicate, and beautifully decorated with free hand patterns in a wide variety of colors. They also made excellent baskets from natural fibers that were decorated with eagle, rattlesnake, sun, moon, and many other designs. The Serranos held the grizzly bear in deep reverence, and thought of these huge animals as great grandfathers. Bear meat was never eaten, nor was bear fur ever worn. Ravaged by smallpox sometime after 1774, the Serrano population had declined to about 100 when the

Fig. 12.12 The mountains are named for the San Bernardino Valley, in turn named by the Spanish in 1810. (© Jeremy Miles, 2007)



1910 census was taken.²⁰ They would have traveled into the mountains in the summer to hunt deer and rabbits, gather acorns, berries, and nuts, and seek refuge from the desert heat.²¹ They established well-traveled trade routes, some of which were later used by Europeans to explore and settle the region. Much of the evidence of their camps and settlements is now gone due to development. The Serrano lived in pit houses and constructed brush shelters during the milder times of the year. They moved from the lower elevations where they resided in the winter months to the higher elevations in the springtime to gather plants. It is still possible to find smooth grinding stones (*manos* or *metates*) and mortar holes in rock, where acorns and seeds were prepared for food. Occasionally visitors find pieces of pottery or arrowheads.

12.3.2 *Pioneers (European/Americans)*

Spanish explorers first came upon the San Bernardino Mountains in the late 1700s, naming the eponymous San Bernardino Valley at its base. European settlement of the region progressed slowly until 1860, when the mountains became the focus of the largest gold rush ever to occur in Southern California. Waves of settlers brought in by the gold rush populated the lowlands around the San Bernardinos, and began to tap the mountains' rich timber and water resources on a large scale by the late nineteenth century.

During the 1600s and 1700s, various Spanish explorers passed through coastal Southern California and claimed the area for Spain. In 1769, the Spanish government began an effort to bring what they called Alta California under their control and introduce Christianity to native peoples through the construction of missions (Figs. 12.12, and 12.13).²²

Beginning in 1851, Mormon colonists began emigrating to the San Bernardino Valley. The Mormons bought and subsequently split up Rancho San Bernardino, and greatly improved the area's agricultural production by bringing in thousands of head of livestock and overhauling the local irrigation network.²³

²⁰ Big Bear Valley Historical Society (2013).

²¹ U.S. Forest Service (2009b).

²² Clugston, Steve. "The Real El Camino: California Missions in Another Light". University of California Riverside.

²³ Guinn (1902).

Fig. 12.13 The Mill Creek valley was the first area of the mountains to be logged. (© J. Cook Fisher, 2007)



12.3.3 *Human Uses of the High-Altitude Ecosystem*

For thousands of years, the Native Americans, one can say, lived “softly” on the ecosystem; indeed, their “footprint” of settlement and use of the mountain resources have all but vanished today. They took what was needed for their survival, food, shelter, materials for clothing, vegetation for making baskets, earth for pottery, feathers for decoration, water for nourishment. They respected and revered certain wildlife, such as the bear and eagle, and would not hunt them. Ironically, today, both are endangered due to European explorers and hunters. So in contrast to the original human communities, the next group of humans entering the ecosystem viewed the natural resources differently. Every aspect of the ecosystem was seen as a resource to make money. In other words, the ecosystem was a bank or reserve for human commerce. And since the ecosystem was seemingly “abundant,” no regard for preservation, restoration, or management was included in the “commercial” ventures. Not until the US government instated the US Department of Agriculture (USDA) Division of Forestry in the early 1900s were portions of the ecosystem protected from human exploitation. The human “commerce” derived from the high-altitude ecosystem included:

- *Agriculture*

In 1880, Frank Elwood Brown designed the first dam in the Big Bear Valley, forming Big Bear Lake—the world’s largest artificial reservoir at the time—to supply water to citrus farms around San Bernardino

- *Fox farming*

The raising of foxes for their magnificent furs dates from the 1890s. The high altitude and dry air eliminated many internal and external pests, while the cool summer nights, seasonal changes, and cold winters were ideal for the fur industry. The pen-raised silver foxes were flighty, nervous, and unpredictable, and required diligent care and feeding. Superior breeding pairs would bring US\$ 2000–3000 and fine pelts would command as much as US\$ 1100. The demise of the fox fur industry was the result of several factors: the increased cost of food, a 20% luxury tax, and Russia and other lend-lease countries dumped shiploads of fur on the world market.²⁴

²⁴ <http://www.bigbearhistory.org/foxfarm.htm>.

- *Mountain Cattle Ranches*
As early as 1857, cattle and sheep were grazing in the San Bernardino Mountains in large numbers. The peak of mountain cattle ranching lasted for about 60 years, from the 1880s until the 1940s.
- *Logging and sawmills*
Around 1845, lumber was needed for sheds and wine kegs for the Los Angeles Vineyard. This was followed by the Mormons who began their settlement of San Bernardino in 1851. One of their vital needs was for lumber. By 1854, six sawmills were producing lumber and shingles. By 1892, one company alone had logged 8000 acres.
- *Mining*
The Holcomb Valley gold rush of 1860 brought hundreds of miners into the area. Digging into the “ecosystem” required huge railroad steam shovels that could dig 1000 yards of gravel a day. The long windrows made by this shovel are still visible today. With this exception, no structures remain at any of these historic mines, and only caved in tunnels, collapsing shafts, and piles of colorful tailings are evidence that they once existed.²⁵
- *Gold rush*
Beginning in 1860, the California gold rush drew hundreds of settlers to the high-altitude mountains. Soon the little communities of Belleville, Union Flat and Clapboard Town had been built. It is estimated that between 1500 and 2000 people were in Holcomb Valley during the peak of the boom in the 1860s.²⁶
- *Dams*
With the arrival of the Southern Pacific in Southern California in 1876, the area boomed as people flocked to the new land. When Frank E. Brown and E. G. Judson established the town site of Redlands in 1879, they looked toward the mountains for additional water for their new agricultural community. The first dam was built in 1884. It was 60 ft. high (18.3 m) and 300 ft. (91.5 m) wide and contained 3304 cubic yards (2526 m³) of rock work and 1600 barrels (191,000 L) of cement. The total cost for labor and materials was US\$ 68,000. At that time, the Bear Valley Dam created the largest man-made lake in the world, and was also considered the eighth wonder of the world because it held! In 1911, J. S. Eastwood built the present multiple-arch dam, which tripled the capacity of the lake to 73,000 acre-feet (af). This dam was 20 ft. (6 m) higher and cost US\$ 138,000 to construct. This 1911 dam was reinforced in 1988 to comply with increased earthquake safety standards at a cost of nearly US\$ 13,000,000!²⁷
- *Recreation resorts*
Recreational development of the mountain range began in the early 1900s, when mountain resorts were built around these new irrigation reservoirs created by dams. Since then, the mountains have been extensively engineered for transportation and water supply purposes. Four major state highways and the

²⁵ <http://www.bigbearhistory.org/mining.htm>.

²⁶ <http://www.bigbearhistory.org/goldrush.htm>.

²⁷ <http://www.bigbearhistory.org/dams.htm>.

California Aqueduct traverse the mountains today; these developments have all had significant impacts on area wildlife and plant communities. Most early tourists arrived by stagecoach, though in time the old Mormon logging road through Waterman Canyon was overhauled, allowing for the passage of automobiles.²⁸

The development of resorts also proliferated on rivers and high mountain valleys. Snow in the San Bernardinos was seen as an obstacle before the 1920s and practically shut down recreation in the winter. However, more and more Southern Californians braved the dangers of winter travel in the mountains, and the mountain resorts became a sought-after winter destination by the 1930s.²⁹ Skiing did not become a popular recreational activity in the mountains until a simple sling lift was built at Big Bear in 1938.³⁰ By 1949, a 3000-ft.-long (910 m) chair lift was built, hugely increasing the amount of skiers the area's resorts could accommodate.

Tourism is the primary economic generator for the area, contributing millions of dollars per year to the county and providing over 2000 full-time and 1000 part-time jobs for approximately 50,000 local residents. The majority of mountain residents commute to the urban cities below each day. The mountain resort towns are host to over 5 million visitors a year.

12.4 Modern Relationships: Mountain Communities, San Bernardino City, and the New Community, Arrowhead Springs

The history of human communities' impact on high-altitude ecosystems is consistent, with the exception of the original Native Americans. It is also one-sided. Humans have, repeatedly and predictably, past and present, taken from the ecosystem, the natural capital,³¹ but return little, if anything that contributes to the ecosystem's sustainability. And, typically, humans conduct this behavior at the peril of losing the ecosystem's value: Exploitation of flora and fauna for food, clothing, and daily living amenities (earthenware, baskets, shelter, utensils); extraction of precious metals for adornment, currency, and products; timber for heat, buildings, transportation, furniture, and other human necessities or luxuries; water for drinking, agriculture, and energy; and enjoyment (to the point of overuse) of the "natural" beauty and climate of these high-altitude ecosystems, in the form of resorts and recreation. Each of these "uses" of mountain ecosystem resources results in the establish-

²⁸ <http://www.bigbearhistory.org/dams.htm>, pp. 34–35.

²⁹ http://en.wikipedia.org/wiki/San_Bernardino_Mountains#cite_note-53.

³⁰ http://en.wikipedia.org/wiki/San_Bernardino_Mountains#cite_note-54.

³¹ "Natural capital is the land, air, water, living organisms, and all formations of the Earth's biosphere that provide us with ecosystem goods and services imperative for survival and well-being. Furthermore, it is the basis for all human economic activity." International Institute for Sustainable Development (IISD), Winnipeg, Manitoba, Canada (2010).

ment of permanent human settlements. Humans, above all other living organisms, exhibit a propensity to dominate whatever resources we encounter, including our own species (i.e., Native Americans). Natural and human capital, it appears, is for our unrestricted use, manipulation, enjoyment whenever, wherever, and however we choose. This “DNA” makeup of human populations, most behavioral ecologists conclude, is exactly the reason we humans have evolved as “masters” of all species. Yet, it could also be our demise, or at least, the diminution of our quality of life, though most current societies do not recognize this path or conclusion. The exploitive trends remain the same, and the appreciation or understanding of the values natural capital contribute continues to be a very low priority. One major factor that may encourage humans to begin acknowledging high-altitude ecosystems value is climate change. The impacts on both natural capital and human communities will be real, tangible, and monetizable.

12.5 The “Elephant in the Room”: Climate Change and its Impact on High-Altitude Ecosystems and the Resulting Impact on Human Communities

The San Bernardino Mountains, the “sky island” as it is classified, is a perfect case study for climate change impacts on the ecosystem and on the human communities that depend on it. The approach taken in this case study follows the outline below³²:

- Phase 1: identify and quantify the ecosystem service value, or “natural capital.”
- Phase 2: identify existing human community value that results from ecosystem service value.
- Phase 3: identify climate change impacts, positive and negative, on both ecosystem service value and human community value
- Phase 4: identify paths forward to reduce negative impacts and/or how human communities must adapt to climate change impacts.

12.5.1 Phase 1: Identify and Quantify the Ecosystem Service Value, or “Natural Capital”

Ecosystem service value, or “natural capital,” includes:

- *Food.* This includes the vast range of food products derived from plants, animals, and microbes.
- *Fiber.* Materials included here are wood, jute, cotton, hemp, silk, and wool.
- *Fuel.* Wood, dung, and other biological materials serve as sources of energy.

³² Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 9).

- *Genetic resources.* These include the genes and genetic information used for animal and plant breeding and biotechnology.
- *Biochemicals, natural medicines, and pharmaceuticals.* Many medicines, biocides, food additives such as alginates, and biological materials are derived from ecosystems.
- *Ornamental resources.* Animal and plant products, such as skins, shells, and flowers, are used as ornaments, and whole plants are used for landscaping and ornaments.
- *Freshwater.* People obtain freshwater from ecosystems and thus the supply of freshwater can be considered a provisioning service. Freshwater in rivers is also a source of energy. Because water is required for other life to exist, it could also be considered a supporting service.

12.5.1.1 Regulating Services

These are the benefits obtained from the regulation of ecosystem processes, including:

- *Air quality regulation.* Ecosystems both contribute chemicals to and extract chemicals from the atmosphere, influencing many aspects of air quality.
- *Climate regulation.* Ecosystems influence climate both locally and globally. At a local scale, for example, changes in land cover can affect both temperature and precipitation. At the global scale, ecosystems play an important role in climate by either sequestering or emitting greenhouse gases.
- *Water regulation.* The timing and magnitude of runoff, flooding, and aquifer recharge can be strongly influenced by changes in land cover, including, in particular, alterations that change the water storage potential of the system, such as the conversion of wetlands or the replacement of forests with croplands or croplands with urban areas.
- *Erosion regulation.* Vegetative cover plays an important role in soil retention and the prevention of landslides.
- *Water purification and waste treatment.* Ecosystems can not only be a source of impurities (for instance, in freshwater) but also can help filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems and can assimilate and detoxify compounds through soil and subsoil processes.
- *Disease regulation.* Changes in ecosystems can directly change the abundance of human pathogens, such as cholera, and can alter the abundance of disease vectors, such as mosquitoes.
- *Pest regulation.* Ecosystem changes affect the prevalence of crop and livestock pests and diseases.
- *Pollination.* Ecosystem changes affect the distribution, abundance, and effectiveness of pollinators.
- *Natural hazard regulation.* The presence of coastal ecosystems such as mangroves and coral reefs can reduce the damage caused by hurricanes or large waves.

12.5.1.2 Cultural Services

These are the nonmaterial benefits people obtain from ecosystems through spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences, including:

- *Cultural diversity.* The diversity of ecosystems is one factor influencing the diversity of cultures. For example, high-altitude ecosystems often impact how people respond to their environments; i.e., food, shelter, ornament, agriculture versus nomadic lifestyle, resulting in cultural and heritage roots.
- *Spiritual and religious values.* Many religions attach spiritual and religious values to ecosystems or their components.
- *Knowledge systems* (traditional and formal). Ecosystems influence the types of knowledge systems developed by different cultures. Seasonal patterns in the environment, such as animal and bird migrations, flowering of plants, and uses of plants and minerals for health become knowledge passed down from generation to generation.
- *Educational values.* Ecosystems and their components and processes provide the basis for both formal and informal education in many societies. Learning how the world works through one's environment has always advanced primitive communities to more informed civilizations.
- *Inspiration.* Ecosystems provide a rich source of inspiration for art, folklore, national symbols, architecture, and advertising.
- *Aesthetic values.* Many people find beauty or aesthetic value in various aspects of ecosystems, as reflected in the support for parks, scenic drives, and the selection of housing locations.
- *Social relations.* Ecosystems influence the types of social relations that are established in particular cultures. Fishing societies, for example, differ in many respects in their social relations from nomadic herding or agricultural societies.
- *Sense of place.* Many people value the "sense of place" that is associated with recognized features of their environment, including aspects of the ecosystem.
- *Cultural heritage values.* Many societies place high value on the maintenance of either historically important landscapes ("cultural landscapes") or culturally significant species.
- *Recreation and ecotourism.* People often choose where to spend their leisure time based in part on the characteristics of the natural or cultivated landscapes in a particular area.

12.5.1.3 Supporting Services

Supporting services are those that are necessary for the production of all other ecosystem services. They differ from provisioning, regulating, and cultural services in that their impacts on people are often indirect or occur over a very long time, whereas changes in the other categories have relatively direct and short-term impacts on people. (Some services, like erosion regulation, can be categorized as both

a supporting and a regulating service, depending on the timescale and immediacy of their impact on people.)

These services include:

- *Soil formation*. Because many provisioning services depend on soil fertility, the rate of soil formation influences human well-being in many ways.
- *Photosynthesis*. Photosynthesis produces oxygen necessary for most living organisms.
- *Primary production*. The assimilation or accumulation of energy and nutrients by organisms.
- *Nutrient cycling*. Approximately, 20 nutrients essential for life, including nitrogen and phosphorus, cycle through ecosystems and are maintained at different concentrations in different parts of ecosystems.
- *Water cycling*. Water cycles through ecosystems and is essential for living organisms.

Ecosystem services are the benefits people obtain from ecosystems. These include *provisioning services* such as food, water, timber, and fiber; *regulating services* that affect climate, floods, disease, wastes, and water quality; *cultural services* that provide recreational, aesthetic, and spiritual benefits; and *supporting services* such as soil formation, photosynthesis, and nutrient cycling (see Fig. 12.14). The human species, while buffered against environmental changes by culture and technology, is fundamentally dependent on the flow of ecosystem services.³³

12.5.1.4 San Bernardino High-Altitude Ecosystem Services Value

Estimated ecosystem services value (ESV)=US\$ 290 billion covering 637,000 ha (1,574,400 acres)

Values include:

- Mixed forest
- Urban green
- Open water and streams
- Wetlands
- Habitat refugium
- Recreation
- Aesthetic and amenity
- Water regulation and supply
- Climate and atmospheric regulation

No values could be estimated for:

- Food and raw materials
- Soil retention and formation
- Waste assimilation

³³ Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 9).

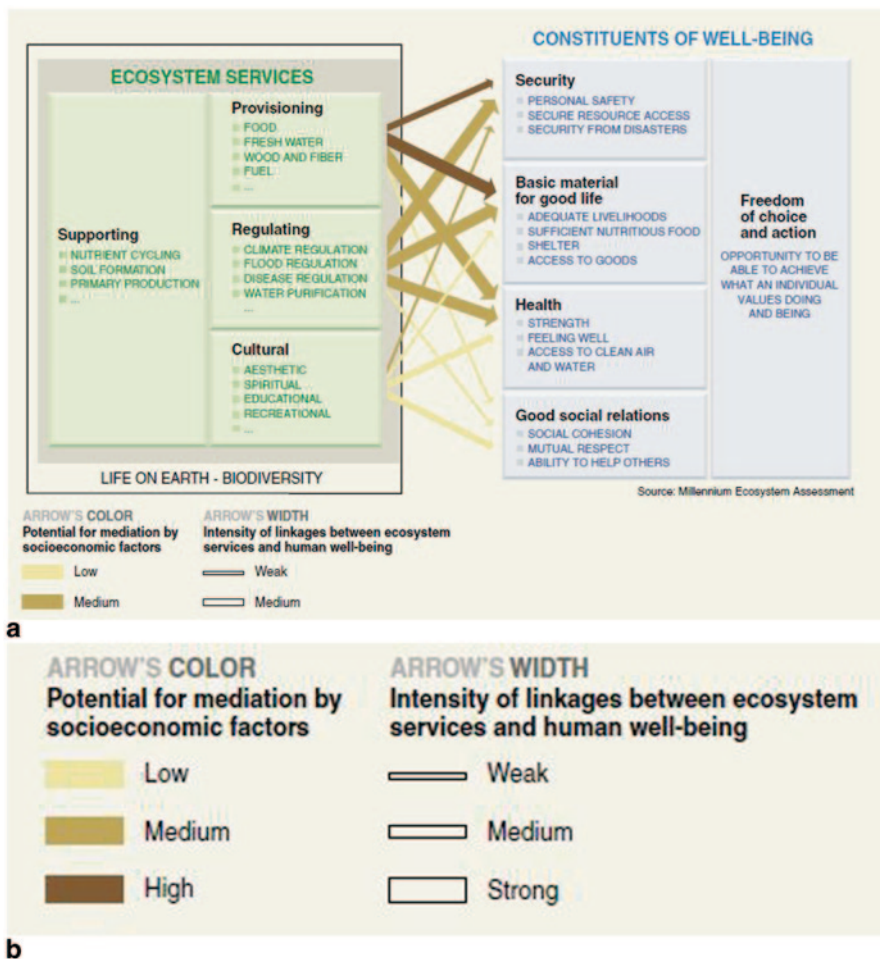


Fig. 12.14 © Millennium Ecosystem Assessment, World Resources Institute (2005a, b)

The ESV was derived from the following methodology developed by Troy and Wilson.³⁴

12.5.1.5 Spatially Explicit Ecosystem Value Transfer

Value transfer involves the adaptation of existing valuation information to new policy contexts where valuation data are absent or limited. For ESVs, this involves searching the literature for valuation studies on ecosystem services associated with ecological resource types present at the policy site. Value estimates are then

³⁴ Troy and Wilson (2006, pp. 435–449).

transferred from the original study site to the policy site. Value transfer has become an increasingly practical way to inform decisions when primary data collection is not feasible due to budget and time constraints, or when expected payoffs to original research are small. As such, the transfer method is now seen as an important tool for environmental policy makers since it can be used to relatively quickly estimate the economic values associated with a particular landscape for less time and expense than a new primary study.

The approach developed by Troy and Wilson forms the foundation of the Natural Assets Information System™, a decision support system framework developed by Spatial Informatics Group, Limited Liability Company (LLC) (<http://www.sig-gis.com>). The framework, which builds upon the value transfer methodology, is implemented in three case studies and consists of seven core steps: (1) spatial designation of the study extent; (2) establishment of a land cover typology whose classes predict significant differences in the flow and value of ecosystem services; (3) meta-analysis of peer-reviewed valuation literature to link per unit area coefficients to available cover types; (4) mapping land cover and associated ecosystem service flows; (5) calculation of total ESV and breakdown by cover class; (6) tabulation and summary of ESVs by relevant management geographies, and (7) scenario or historic change analysis.

Step 1: Study Area Definition

Study area definition is an essential but often underappreciated first step, since small boundary adjustments can have large impacts on final ESV estimates. While the client's desired target area for study may correspond neatly with administrative or political boundaries those may or may not correspond with relevant biogeophysical boundaries.

Step 2: Typology Development

The development of a land cover typology starts with a preliminary survey of available geographic information system (GIS) data at the site to determine the basic land cover types present. This is followed by a preliminary review of economic studies (see step 3) to determine whether ecosystem service value coefficients have been documented for these cover types in a relatively similar context.

Step 3: Literature Search and Analysis

The collected empirical studies, preferably from a similar context, are read and analyzed to extract valuation coefficients for ecosystem services associated with each cover class in the typology. The information includes the ecosystem service and cover type valued, valuation method, year of study, and per hectare value estimates, among other attributes.

There are three broad categories of valuation studies that exist in the field today:

1. Peer-reviewed journal articles, books and book chapters, proceedings, and technical reports that use conventional environmental economic valuation techniques and are restricted to an analysis of social and economic values. These are the most desirable studies.
2. Non-peer-reviewed publications that include PhD dissertations, technical reports, and proceedings, as well as public raw data.
3. Secondary analysis (e.g., meta-analysis) of peer-reviewed and/or non-peer-reviewed studies that use conventional or nonconventional valuation methods.

Step 4: Mapping

Map creation involves GIS overlay analysis and geo-processing to combine input layers from diverse sources to derive the final land cover map.

Step 5: Total Value Calculation

Once each mapping unit is assigned a cover type, it can then be assigned a value multiplier from the economic literature, allowing ecosystem service values to be summed and cross-tabulated by service and land cover type. The total ecosystem service value flow of a given cover type is then calculated by adding up the individual, non-substitutable ecosystem service values associated with that cover type and multiplying by area as given below.

$$V(ES_i) = \sum_{k=1}^n A(LU_i) \times V(ES_{ki})$$

where $A(LU_i)$ = area of land use/cover type (i) and $V(ES_{ki})$ = annual value per unit area for ecosystem service type (k) generated by land use/cover type (i).

Step 6: Geographic Summaries

In the fifth step, land cover areas and ESVs are summarized by a geographical aggregation unit. While ESVs can be mapped by the original minimum mapping unit (e.g., a land cover pixel), for large map extents with small minimum mapping units (pixels are frequently 30 m on a side or smaller), patterns may be visually imperceptible and so geographic aggregation is often warranted. Moreover, managers may be interested in visually displaying the value of ecosystem services by some geographical unit with management significance, such as town, county, or watershed.

Step 7: Scenario Analysis

Finally, scenario or historic change analysis can be conducted by changing the inputs in steps 4 and 5. For future scenario analysis, this involves changing the land cover input to reflect a proposed management alternative and for historic change analysis it involves quantifying and valuing land cover changes in the past.

12.5.2 Phase 2: Identify Existing Human Community Value that Results from Ecosystem Service Value

Human communities situated in the San Bernardino Mountains, total 20 communities, consisting of approximately 54,500 resident population, increasing up to 440,000 in tourist peak seasons,³⁵ with a net economic value of approximately US\$ 9.37 billion:

High-altitude human communities “value”:

Residential property	US\$ 1.9 billion
Commercial property	US\$ 1.0 billion
Institutional (schools)	US\$ 0.57 billion
Manufacturing	US\$ 0.25 billion
Public services (fire, police)	US\$ 0.35 billion
Healthcare facilities/services	US\$ 0.05 billion
Tourism	US\$ 0.75 billion
Infrastructure (roads, bridges, dams, utilities, sewage, man-made landscaping, street lighting, etc.)	US\$ 4.5 billion
Total	US\$ 9.37 billion

12.5.2.1 Human Communities in High-Altitude Ecosystem of San Bernardino Mountains

1. Lake Arrowhead: elevation of 5174 ft. (1577 m), population=12,424
 - i. The racial makeup of Lake Arrowhead was 10,729 (86.4%) White (73.0% non-Hispanic White)³⁶, 95 (0.8%) African American, 93 (0.7%) Native American, 152 (1.2%) Asian, 33 (0.3%) Pacific Islander, 847 (6.8%) from other races, and 475 (3.8%) from two or more races. Hispanic or Latino of any race were 2709 persons (21.8%).
2. Big Bear City: elevation of 6772 ft. (2064 m), population=12,304
 - i. The racial makeup of Big Bear City was 10,252 (83.3%) White (75.8% non-Hispanic White)³⁷, 83 (0.7%) African American, 202 (1.6%) Native

³⁵ Robinson and Harris (2006, p. 1).

³⁶ http://en.wikipedia.org/wiki/Lake_Arrowhead,_California#cite_note-12.

³⁷ http://en.wikipedia.org/wiki/Big_Bear_City,_California#cite_note-3.

American, 103 (0.8%) Asian, 31 (0.3%) Pacific Islander, 1089 (8.9%) from other races, and 544 (4.4%) from two or more races. Hispanic or Latino of any race were 2323 persons (18.9%)

3. Crestline: elevation of 4613 ft. (1406 m), population=10,770
4. Big Bear Lake: elevation of 6752 ft. (2,058 m), population=5112
 - i. The racial makeup of Big Bear Lake was 4204 (83.8%) White (73.3% non-Hispanic White)³⁸, 22 (0.4%) African American, 48 (1.0%) Native American, 78 (1.6%) Asian, 10 (0.2%) Pacific Islander, 491 (9.8%) from other races, and 166 (3.3%) from two or more races. Hispanic or Latino of any race were 1076 persons (21.4%).
5. Running Springs: elevation of 6109 ft. (1862 m), population=4862
 - i. The racial makeup of Running Springs was 4325 (89.0%) White, 23 (0.5%) African American, 47 (1.0%) Native American, 50 (1.0%) Asian, 6 (0.1%) Pacific Islander, 146 (3.0%) from other races, and 265 (5.5%) from two or more races. Hispanic or Latino of any race were 695 persons (14.3%).
6. Blue Jay: elevation of 5203 ft. (1586 m), population=2314
7. Sugarloaf: elevation of 7096 ft. (2163 m), population=1816
 - i. The racial makeup was 61.9% White, 1.2% African American, 2.3% Native American, 1.0% Asian, 0.1% Pacific Islander, 3.6% from other races, and 6.3% from two or more races. Hispanic or Latino of any race were 27.9% of the population.
8. Forest Falls: elevation of 5341 ft. (1628 m), population=943
9. Green Valley Lake: elevation of 7200 ft. (2195 m), population=800
10. Arrowbear Lake: elevation of 6086 ft. (1855 m), population=736
11. Lytle Creek: elevation of 3800 ft. (1200 m), population=701
 - i. The racial makeup of Lytle Creek was 606 (86.4%) White, 6 (0.9%) African American, 7 (1.0%) Native American, 23 (3.3%) Asian, 0 (0.0%) Pacific Islander, 25 (3.6%) from other races, and 34 (4.9%) from two or more races. Hispanic or Latino of any race were 98 persons (14.0%).
12. Cedar Glen: elevation of 5403 ft. (1647 m), population=552, demographics: The racial makeup of the CDP was 86.6% White, <0.1% African American, <0.1% Native American, 9.2% Asian, 4.2% Pacific Islander, <0.1% from other races, and <0.1% from two or more races. Hispanic or Latino of any race were <0.1% of the population.³⁹
13. Rimforest: elevation of 5741 ft. (1750 m), population less than 100
14. Skyforest: elevation of 5741 ft. (1750 m), population less than 100

³⁸ http://en.wikipedia.org/wiki/Big_Bear_Lake,_California#cite_note-8.

³⁹ http://en.wikipedia.org/wiki/Cedar_Glen,_California#cite_note-3.

15. Crest Park: elevation of 5630 ft. (1720 m), population less than 100
16. Twin Peaks: elevation of 5777 ft. (1761 m), population less than 100
17. Mountain Home Village: 3691 ft. (1125 m)
18. Angelus Oaks: elevation of 5800 ft. (1800 m), population=535
19. Fawnskin: elevation of 6827 feet (2081 m). population: artist colony less than 100
20. Arrowhead Springs: elevation of 2059–3000 ft. (1145 m), population=6

Total resident population: approximately 54,500

Total tourism population: 400,000–500,000 annually

Communities at the base of the San Bernardino Mountains which depend primarily on the high-altitude ecosystem water supply have a combined population of approximately 2,100,000,⁴⁰ providing over 700,000 jobs, and generating approximately US\$ 70.9 billion in revenue:

- Manufacturing shipments: US\$ 18.9 billion
- Wholesales: US\$ 27.6 billion
- Retail sales: US\$ 21.7 billion
- Hospitality and food services: US\$ 2.7 billion

Total=US\$ 70.9 billion

These urban communities cover an area of approximately 20,057 square miles (51,944 km²) or 12.8 million acres (5.2 million ha).

12.5.3 Phase 3: Identify Climate Change Impacts, Positive and Negative, on Both Ecosystem Service Value and Human Community Value

The balance of scientific evidence suggests that there will be a significant net harmful impact on ecosystem services worldwide if global mean surface temperature increases more than 2 °C above preindustrial levels or at rates greater than 0.2 °C per decade (*medium certainty*). There is a wide band of uncertainty in the amount of warming that would result from any stabilized greenhouse gas concentration, but based on the Intergovernmental Panel on Climate Change (IPCC) projections this would require an eventual carbon dioxide (CO₂) stabilization level of less than 450 parts per million CO₂ (*medium certainty*).⁴¹

Climate change in our case study, the San Bernardino high-altitude ecosystem and human communities that depend on it, will trigger impacts on the ecosystem services described in detail on pp. 14–16, Step 1: Regulating Services, Cultural Services, and Supporting Services.

⁴⁰ U.S. Department of Commerce (2012).

⁴¹ Millennium Ecosystem Assessment, World Resources Institute (2005a, p. 31).

Much of the data assembled for the section topics below are from *Climate Change-Related Impacts on the San Diego Region by 2050*. This study considers the regional impacts due to climate change that can be expected by 2050 if current trends continue. The range of impacts presented in this study is based on projections of climate change using three climate models⁴² and two emission scenarios drawn from those used by the IPCC.⁴³ A number of analytical models were developed and used for this study to provide quantitative estimates of the impacts where possible. For example, temperature data from the IPCC scenarios were applied to regional ecosystem models to provide information on the migration patterns of species trying to adapt to higher temperatures. These temperature data were also used to extrapolate forecasts of peak electricity demand in the region, which will be exacerbated by higher temperatures as well as the faster inland population growth where the country is hottest.⁴⁴

For some impacts, the study has relied on a literature review and summary of the latest research in the topic of interest. For example, the increased likelihood of regional wildfires as well as the relationship of heat stress illnesses and fatalities due to rising temperatures has been based on these expert reviews. Similarly, the long-term supply issues associated with external water deliveries from the Sacramento River Delta and the Colorado River have been based on the conclusions from outside research. These water supply conclusions have been combined with an analytical extrapolation of regional water demand to develop an overall supply and demand analysis for this study.⁴⁵

A. Climate change on ecosystem service value (ESV):

1. A changing climate will add to the stress on ecological systems in ways that may create feedback cycles with significant consequences. For example, as the amount of rainfall occurring within (and between) years changes, the effects of fragmentation on native species may be even more intense. Also, the current fire regime is changing rapidly and many species will not be able to adapt fast enough, which can lead to the extinction of native plants and animals. There is evidence pointing to nitrogen deposition as being one of the factors contributing to the recent changes of fire regimes in Southern California. Although more research is needed in this area, nitrogen deposition may contribute to greater fuel loads by facilitating the proliferation of invasive grasses and thus altering the fire cycle in the region (Allen et al. 2003). With climate change, the “climatic envelopes”⁴⁶ that species need will move due to increasing temperatures and

⁴² The three models are: the National Center for Atmospheric Research’s Parallel Climate Model (PCM), the National Oceanic and Atmospheric Administration’s Geophysical Fluids Dynamics Laboratory (GFDL) version 2.1, and the French Centre National de Recherches Météorologiques (CNRM).

⁴³ The IPCC’s Special Report on Emissions Scenarios (SRES) A2 and B1 scenarios.

⁴⁴ Messner et al. (2005, p. 1).

⁴⁵ Messner et al. (2005, p. 1).

⁴⁶ Locations where the temperature, moisture, and other environmental conditions are suitable for persistence of species.

more frequent fires. For many species, a changing climate is not the problem *per se*. The problem is the rapid rate of climate change: the envelope will shift faster than species are able to follow. For other species, the envelope may shift to areas already converted to human land use. To put the rate of temperature change for species survival into context, a 1–5° (0.56–2.8°) increase by 2050 predicted by the three climate change models is 10–50 times faster than the temperature changes (2°, or 1.1° per 1000 years) that occur when ice ages recede.⁴⁷

2. California climate projections indicate forest ecosystems will be substantially affected by temperature rise and indirect climate change effects (Cayan et al. 2008a). Extended drought can stress individual trees, increase their susceptibility to insect attack and result in widespread forest decline. For example, it is thought that lowered water tables from drought and excessive groundwater pumping is causing coast Live Oaks in the Descanso area to die out as experts cannot isolate a disease or insect causing their ruin. The projected warmer winter temperatures may indirectly increase insect survival and populations, including pest species such as bark beetles that girdle and kill the trees. Forest-dependent fish and wildlife species may be lost as a result of reduced forest habitat and other indirect effect of climate change, such as drought, increased nonnative grasslands, and wildfire. Latitudinal and/or elevation range shifts in the distribution of plant and animal populations in response to climate change could be severely constrained in the county as a result of population growth and development, habitat degradation by nonnative grasses, unsuitable soils or other physical limitations (Parmesan 2006). Southern California Shrublands The results of the Center for Conservation Biology (CCB) modeling showed that southern California shrublands, in response to rising temperatures and reduced precipitation, each vegetation type moves to higher elevations where conditions are cooler and there is greater precipitation. The suitable environmental conditions for coastal sage scrub were predicted to decrease between 10 and 100% under altered climate conditions, with the greatest reductions at higher temperatures and extremes in precipitation. Chaparral responded in a similar manner as coastal sage scrub, although higher percentages of suitable habitat remain at the elevated temperatures with current or reduced levels of precipitation. Projected increases in nonnative grasses and fire frequency also may substantially reduce the range and extent of future shrublands.

Plant and animal species will each differ in their sensitivity to a changing climate, but the fact that they depend on each other increases the overall effects. The CCB models predicting suitable habitat for the Quino Checkerspot butterfly and California Gnatcatcher, when in association with plant species, were compared with predictions from models that included only climate variables and did not consider species associations. It was found that when vegetation, shrub, or host plant species were included in the animal models, potential habitat for the butterfly and songbird were reduced by 68–100% relative to the climate-only models under altered climate conditions.⁴⁸

⁴⁷ Messner et al. (2005, p. 24).

⁴⁸ Messner et al. (2005, pp. 24–25).

3. Extinction of fauna species⁴⁹
 - i. Fauna species at risk: San Bernardino flying squirrel, California Spotted Owl, Mountain yellow-legged frog, Southern Rubber Boa, and Andrew's marbled butterfly.⁵⁰
4. Extinction of flora species and emergence of new, climate-adapted species⁵¹
 - i. Flora species are listed as^{52,53}:
 1. *Sensitive plant list*: There are more than 85 species of sensitive plants.⁵⁴ They include Colville's Dwarf-Abronia, Parish's Rock-cress, Yellow Owl's Clover, Abram's Live-Forever, Parish's Alumroot, Fuzzy Rat-Tails, Lemon Lily, Baldwin Lake Linanthus, Purple Mimulus, Windows Phacelia and Pine-Green Gentian.
 2. *Watch list*: Bear Valley Woolypod of the pea family, Woolly Sunflower, Humboldt Lily, Laguna Mountains Jewel Flower, a member of the mustard family and Lemmon's *Syntrichopappus*, a variety of sunflower. Watch list plants are those that need to be observed to make certain they are not threatened or endangered.
 3. *Federally threatened list*: Three plants in the San Bernardino Mountains are on the federal threatened species list, according to the National Parks Service. They include Bear Valley Sandwort, a member of the pink family; Ashy-Grey Paintbrush, part of the figwort family; and Kennedy's Buckwheat which is, of course, a member of the buckwheat family. These plants are considered dangerously close to extinction unless protected from human activity and repopulated. *Federally endangered list*: Endangered plant species are on the verge of extinction and consequently require extraordinary management and guidance on federal lands as well as a recovery plan. Three plants in the San Bernardino Mountains are on the federal endangered species list. They include San Bernardino Mountains bladderpod and Slender-Petaled Mustard, both of the mustard family, and Bird-footed Checkerbloom, a member of the mallow family.
5. *Temperature change*: Mountains are likely to warm 4.5–5.5°F. The occurrence of “extreme heat days,” days when temperatures exceed 95°F, is expected to increase substantially. Mountain areas will see extreme hot days increase by 4.5–6 times the current number. The biggest surprise from the more detailed modeling is that the coasts and mountains are warming a lot faster than anyone suspected.

⁴⁹ Currently, there are approximately 440 species of fauna. U.S. Forest Service (2009a).

⁵⁰ “Endangered Species”. *Mountains Group-San Gorgonio Chapter*. Sierra Club.

⁵¹ Currently, there are 1600 species of flora. Grinnell (1908).

⁵² Douglas Hawk, eHOW, Demand Media Inc., September 22, 2011.

⁵³ US Fish & Wildlife Service, US Department of the Interior, March 27, 2013.

⁵⁴ U.S. Department of Agriculture, Forest Service (2010).

The tops of nearby mountains like the San Bernardinos, which currently have ski areas like Big Bear, will warm faster than any other place in the Los Angeles area. The coasts, too, will be far warmer than had previously been expected.⁵⁵

6. *Rainfall change*: Precipitation in the region will retain its Mediterranean pattern, with winters receiving the bulk of the year's rainfall, and summers being dry. Models lack consensus on whether it will be drier or wetter overall, but because of warming and effectively earlier summer conditions, there is evidence that the area's landscape will fall into hydrological deficit (drought) more often than it has historically.⁵⁶ *Drought*: One important aspect of all of the climate model projected simulations is that the high degree of variability of annual precipitation that the region has historically experienced will prevail during the next five decades. This suggests that the region will remain highly vulnerable to drought.⁵⁷
7. *Snowfall change*: By 2050, the San Bernardino mountains may see a reduction in snowfall up to 42% of their annual averages. If immediate efforts are made to substantively reduce emissions through mitigation, mid-century loss of snow will be limited to 31%. However, if emissions are not curbed, the mountains will lose 66% of their snowfall by the end of the century, compared with present day.
8. *Water resource change*: The effects of climate change on water demand are likely to reflect both warming and drying trends. Climate-change projections for the southwestern USA indicate that by 2050, runoff and ground water could decline by an average of about 7 in./year over the entire Southwest (Seager et al. 2007; Milly et al. 2005). As noted earlier, elevated greenhouse gas levels are expected to produce temperature increases of 1.5–4.5°F (0.8–2.5°C) over Southern California by the mid-twenty-first century. More frequent and drier (20% drier) drought years are also projected by the early twenty-first century, assuming increased ENSO⁵⁸ intensity. The model results shows droughts becoming 50% more common during the 2000–2049 period than during the 1950–1999 period.⁵⁹ Drought and soil moisture retention will negatively impact water levels in:
 - i. Lakes/dams
 - ii. Reservoirs/dams
 - iii. Streams
 - iv. Wells
9. *Wildfire change*: The frequency of fire incidents and their devastating impacts on the residents of the region has increased in direct proportion to human population growth since the vast majority of ignitions are caused by human

⁵⁵ http://green.blogs.nytimes.com/2012/07/05/district-by-district-climate-change-in-los-angeles/?_r=0, Kaufman (2013).

⁵⁶ Messner et al. (2005, p. 38).

⁵⁷ Messner et al. (2005, p. 14).

⁵⁸ El Nino/Southern Oscillation (ENSO).

⁵⁹ Messner et al. (2005, p. 21).



Fig. 12.15 Firefighting and aftermath of wildfires in San Bernardino Mountains (© USDA 2012)

activities. It is likely that the changes in climate due to the warming of the region will increase the frequency and intensity of fires even more, making the region more vulnerable to devastating fires. Extended drought conditions forecasted by climate models in the coming decades are expected to increase the likelihood of large wildfires. A past study of the western USA has shown (Westerling et al. 2006) that large wildfire frequency and longer wildfire durations increased in the mid-1980s when there was a marked increase in spring temperatures, a decrease in summer precipitation, drier vegetation and longer fire seasons. A more recent study (Spracklen et al. 2008) explores these relationships to 2050 using temperature and precipitation data from a global climate model (GISS).⁶⁰ This study suggests that 42% more California Coastal Shrub acreage will burn in the decade around 2050 as compared to present trends and that overall, 54% more acreage in the western USA will burn compared to present (Fig. 12.15).⁶¹

B. Climate change on human communities will have the following impacts:

1. *Population shifts*

1. As the region's population grows, it will also become older. Approximately, one quarter of the region's current population is baby boomers, the large cohort born between 1946 and 1964. Their presence helps increase the median age in the region from 33.7 years in 2004 to 39 years in 2030, an increase of 16%. Dynamic changes in the region's age structure will continue to occur from 2030 and 2050, albeit at a slower pace than seen in the 2030 forecast. Between 2030 and 2050, the number of people age 65 and older is estimated to increase by 35%, compared to an increase of 14% for the overall population. Age groups under 18, and between 18 and 64, will grow more slowly—at around 10% each. By 2050, almost one quarter of the region's residents (over 1,000,000) will be age 65 and older, with over half being older than age 41. The aging population of the region will be more vulnerable to the public health impacts of climate change, including increased heat waves and air pollution.⁶²

⁶⁰ Goddard Institute for Space Studies (GISS).

⁶¹ Messner et al. (2005, p. 22).

⁶² Messner et al. (2005, p. 2).

2. Scenario 1: Climate change impacts may result in human migration away from the mountains to more convenient, reliable, cheaper, safer, and less risk amenities. Human population decrease in ecosystem region will benefit the restoration of ecosystem services, even if these services are new due to climate change, since man-made exploitation or “footprint” on the ecosystem would decrease. For example, fewer automobiles from tourism would reduce air and noise pollution, fewer tourists and residents in mountain communities would result in reduced consumption of fossil fuels, water, reduced solid waste and sewage. Wildlife species would begin to recover, flora species may expand with less interference from human exploitation
3. Scenario 2: Climate change impacts may result in increased human populations in the mountains. For example, lower elevation communities and urban cities will increase in size creating urban congestion, air and noise pollution, restrictions on water and energy consumption, minimal private land, crowded residential neighborhoods, crowded schools, congested traffic, and minimal “natural” environments. Consequently, many people will seek refuge from urban congestion in the mountains, despite the risks, costs, and inconveniences. They will adjust their lifestyles to the ecosystem impacts from climate change. The lifestyle adaptation will outweigh the negative alternatives of living in lower elevations. Access to water, fresher and cooler air, protected natural forests, quieter environment, and less congestion will be worth it.
4. Tourism
 1. Decrease in tourism may occur due to cost of transportation fuel, traffic congestion, and poor economy.
 2. Increase in tourism may occur due to desire to seek healthier environment (clean air, cooler temperatures, closeness to “nature,” recreation, and “get-away” from urban congestion, noise, and pollution.
2. *Public health shifts*: There are many potential public health issues that are likely to affect the region in 2050, both directly and indirectly. Projections of a growing and aging population with changing ethnic profiles suggest a larger number of people will be vulnerable to environmental health risks, and the projections for climate change indicate more stressful conditions facing vulnerable populations. Specific impacts include: (1) increased heat waves, creating a significant risk of adverse health effects and heat-related mortality; (2) increased exposure to air pollution resulting in adverse health effects, including exacerbation of asthma and other respiratory diseases, cardiac effects, and mortality; (3) increasing incidence of wildfire, which will contribute to direct injuries and mortality as well as indirect health effects of air pollution; and (4) increases in the levels of exposure to vector-borne or infectious diseases—potential increases in West Nile Virus and hantavirus will require particular attention and increased medical resources to address. All of the above impacts have a magnified effect on an aging population base and will therefore require increased efforts and resources to effectively manage.⁶³

⁶³ Messner et al. (2005, pp. 41–42).

1. *Extreme heat*: Heat waves have claimed more lives over the past 15 years than all other declared disaster events combined in California, and heat waves are expected to increase in frequency, magnitude and duration in the region over the next 50 years. Public health risks around extreme heat are not equal; certain individuals, populations, and communities are at greater risk than others. A recent analysis of temperatures during summers with no heat waves (1999–2003) found a 3% increase in deaths in any given day for a 10°F (5.6°C) increase in temperature (including humidity; Basu et al. unpublished.). Factors that should be considered when identifying community-level risk include the incidence of relatively high percentages of: children under 5 years of age and elderly people 65 and over; chronically ill persons (especially those suffering cardiovascular or respiratory conditions); and socially isolated individuals. In 2050, there will be one million seniors 65 years and older in the region, roughly equal to nearly one quarter of the region's total population. The aging population of the region will likely face more mortality events associated with an increase in temperature due to climate change.⁶⁴
2. *Disease*: Climate change could increase the risk of certain vector-borne diseases, while decreasing the risk of others. The occurrence of vector-borne disease is influenced by a variety of factors. Prevailing temperature influences the rate of development of larvae of some vectors, as well as the rate of development of the infectious agent in the vector. Humidity and rainfall patterns affect both the composition and abundance of arthropod vectors (mosquitoes, fleas, ticks, etc.), as well as animal hosts (Lang 2004).⁶⁵ Behavior patterns of hosts, such as indoor living, and vector preferences for particular hosts and periods of peak activity, also influence transmission opportunities. The region will experience increased public health risks from mosquito-transmitted West Nile Virus (Dudley et al. 2009) assuming more intense El Niño cycles (Anyamba et al. 2006) and rodent-transmitted hantavirus (Yates et al. 2002), and higher temperatures predicted for the region could facilitate the local establishment of tropical vector-borne diseases such as malaria and dengue fever, while reducing public health risks from the endemic mosquito-transmitted diseases Western Equine Encephalitis and St. Louis Encephalitis (Gubler et al. 2001). Climate warming effects on the geographic and altitudinal ranges and population densities of rodent hosts and flea vectors will alter the distribution of high-risk areas for plague (*Yersinia pestis*) in the region (Lang 1996; 2004).⁶⁶ Predicted future increased residential development and recreational activities within the unincorporated areas of the region due to population growth, which will increase the potential for contact between humans and wildlife disease hosts and vectors, may result in higher public health risks from diseases transmitted by rodents and rabbits such as tularemia, plague, and hantavirus (Smith 1992).⁶⁷

⁶⁴ Messner et al. (2005, pp. 26–27).

⁶⁵ www.ove.org/Journal%20PDF/December%202004/5Lang%2003-44.pdf.

⁶⁶ www.ove.org/Journal%20PDF/December%202004/5Lang%2003-44.pdf.

⁶⁷ Smith and Mendelsohn (2006).

3. *Economic shifts*

1. Tourism will still represent main source of revenue for mountain communities
2. The cost of water will be adversely affected both by increases in the costs of water imports and increases in demand, anticipated as a result of climate change. Currently, the cost of supplying additional water to the region—which can be inferred from the cost of new desalination and reclamation projects—is between US\$ 600 and 1800/acre-ft., depending on the water source. This cost may rise significantly by 2050 as less expensive ways to increase water supply are exhausted. Continued growth in Los Angeles, Arizona, Las Vegas, and the Central Valley is likely to increase competition for the same imported water supplies, with the potential to drive up prices as purchase agreements are renegotiated in the future. Aggressive actions to plan for future water supplies as they vary with climate change and to curb demand through conservation measures will have significant economic benefits as well as overall improvements in the reliability of water deliveries to the public.⁶⁸
3. The cost of the 2007 wildfires in the region was estimated at nearly US\$ 2 billion for losses in residential and commercial properties (Nash *in press*). In addition to the direct costs, many private firms and public agencies are forced to shut down during a large-scale wildfire event. A complete three-day shutdown costs roughly US\$ 1.5 billion.⁶⁹ Therefore, one extra large-scale wildfire due to climate change can have a major impact on the economy due to productivity losses.
4. Californians experience the worst air quality in the nation, resulting in yearly economic costs of approximately US\$ 71 billion (US\$ 36–136 billion), with about US\$ 2.2 billion (US\$ 1.5–2.8 billion) associated with hospitalizations and medical treatment of illnesses related to air pollution exposure.⁷⁰ Deteriorating air quality from increases in ambient ozone levels as well as possible increases of particulate matter (PM) levels in some scenarios will push these costs even higher. Local and regional emission mitigation activities will be essential in reducing these costs and improving regional public health.

4. *Pollution shifts*

1. Air quality: An increase in hot, sunny days due to climate change causing increased population exposure to ground-level ozone has been projected for the region in the year 2050. In addition to potential increases in ozone levels, there will be increased stress from extreme heat days, coupled with an increase in the number of vulnerable people present within the region. These changes are likely to present a significant public health and economic impact.⁷¹ Wildfires can be a significant contributor to air pollution in both urban and rural areas, and have the potential to significantly impact public health through particulates and volatile organic compounds in smoke plumes.

⁶⁸ Messner et al. (2005, p. 40).

⁶⁹ Messner et al. (2005, p. 40).

⁷⁰ Messner et al. (2005, p. 42).

⁷¹ Messner et al. (2005, p. 28).

Wildfire smoke contains numerous primary and secondary pollutants, including particulates, polycyclic aromatic hydrocarbons, carbon monoxide, aldehydes, organic compounds, gases, and inorganic materials with toxicological hazard potentials (Künzli et al. 2006). Future land use and climate change will exacerbate the risk of wildfires as a result of the alteration of fire regimes in the county. Fires also create secondary effects on morbidity as the result of increased air particulates that can worsen lung disease and other respiratory conditions. People most at risk of experiencing adverse effects related to wildfires are children and individuals with existing cardiopulmonary disease, and that risk seems to increase with advancing age.⁷²

5. *Infrastructure shifts*: increase stress on infrastructure

1. Electricity: The forecast shows a dramatic increase of 60–75% in peak electricity demand by 2050, an increase of more than 2500 MW from present levels. The differences between the models account for roughly 7% of the total, or approximately 400 MW. The “base case” on the graph shows what peak demand would be if temperatures did not increase (i.e., demand based on population growth alone).

Annual consumption trends for electricity: There is a nominal difference in the forecasts based on the model and scenario. This means that assumptions about electricity consumption in the forecasting model are primarily population-dependent and only marginally temperature-dependent for estimating annual electric consumption. Overall annual electricity consumption is expected to increase of 60–62% by 2050 compared to current demand. Rising temperatures account for approximately 2% of the increase in consumption.⁷³ Demand for electricity is projected to increase significantly by 2050. That increase will be largely driven by population increases, augmented by increased average and peak temperatures, especially in inland areas where population growth rates are highest. The main climate impact on electricity demand and associated supply issues will be the increased need for summer cooling. Overall, peak demand for electricity and annual electricity consumption will rise dramatically in the region by 2050. Annual electricity consumption is expected to increase more than 60%. That will push consumption from the current level of approximately 20,000 gigawatt-hours (GWh) to more than 32,000 GWh in 2050. While population growth is an important contributor to increased demand, warmer temperatures are expected to push total energy consumption up to 2% points above the population-driven change by 2050. Similarly, peak electric demand is expected to increase by over 70%, from approximately 3700 MW to as much as 6400 MW in 2050. Increased average and peak temperatures (i.e., climate-driven changes) are projected to account for approximately 7% of the total increase in peak demand.⁷⁴

⁷² Messner et al. (2005, pp. 29–30).

⁷³ Messner et al. (2005, p. 34).

⁷⁴ Messner et al. (2005, pp. 42–43).

2. Fossil fuels (natural gas, transportation fuel) and renewable energy (solar electricity, solar hot water, wind electricity, geothermal): remote mountain communities may discover that renewable energy sources, plus energy conservation, will be more reliable and less expensive.
 - a. Extreme temperature events and impact on system reliability: Peak demand will be even more challenging to deal with under future climate scenarios because of the increased frequency of extreme heat events. To avoid reliability problems and increased outages, the electric utility will need to make additional investments and customers will need to modify consumption patterns in order to reduce peak summer electricity demand. In general terms, the analysis of the climate models and extreme temperature events shows that there will be a three-month expansion of higher-temperature events as well as an increased frequency of events. In other words, the period when high-temperature days are most frequent, currently between June and September, will expand to May through November. Early November will “feel” like September currently does.
 - b. Decreased summertime generation capacity: Summertime, when demand is highest, is also the time when operating efficiency is lower and line losses increase—both due to temperature effects. This will result in further need for utilities to purchase or build additional power supplies. Further, transmission line congestion is worst during times of peak demand, which will exacerbate delivery problems unless utility investments keep pace with these effects.
 - c. Thermal generator efficiency: The efficiency of thermal power generators, including fossil fuel as well as nuclear-fired units, goes down when air temperature goes up. Higher outdoor air temperatures reduce the efficiency and capacity rating of natural gas and oil units by reducing the ratio of high and low temperatures in the power cycle.
 - d. Wind generation: The availability of wind power may also be affected by climate change, although projected climate impacts on wind are highly uncertain at this time. Further research in this area is needed because changes in wind resources are not currently modeled in the global climate scenarios. The US Climate Science Program predicted that overall wind-power generation would decrease in the mountain areas of the West, but could increase in California (US Climate Change Science Program 2007).⁷⁵ New research could provide more specificity with regard to both the location of impacts on wind resources and the timing of those effects, so that utilities may consider wind’s impact on generation in the context of both installed capacity and imported energy.
 - e. Transmission line losses: Transmission line losses may increase as a result of climate change, although there is a need for further research in this area. One study quantified temperature impacts on electricity transmission line losses, noting that “electric transmission lines have greater resistance in warmer temperatures, and thus climate change will result in

⁷⁵ Available at: www.ornl.gov/sci/sap_4.5/energy_impacts/sap4_5final_rvwdrft.pdf.

increased line losses (Feenstra et al. 1998).⁷⁶ A separate concern is line sag. As demand increases during hot weather, transmission line conductor temperatures increase, which causes the lines to stretch and sag. If a line sags into an object such as a tree, the current can be discharged to the ground, causing a short circuit that could initiate a major power outage. However, it is conductor temperature (a function of load) that is the main cause of sagging power lines. Currently, there are insufficient data to conclude that ambient temperature increases of a few degrees would have a significant impact on line sag.⁷⁷

3. Potable water: Economic value of water resources will increase, resulting in tighter controls and regulations over water acquisition, storage, and distribution. Prioritization of water will be established: food (agriculture irrigation), drinking (potable water), human services (healthcare), recreation (pools), aesthetics (fountains). Seawater desalination will be considered an option to reduce potable water demand from high-altitude water resources, but will increase regional power demand. Other regional options such as recycling and local groundwater are less energy intensive, 400 and 570 kWh/af, respectively, according to a Pacific Institute study, *Energy Down the Drain* (Cohen et al. 2004). That study concluded that satisfying future growth in water demand in the region via conservation would reduce the overall energy intensity of the water supply by 13%. In comparison, satisfying growth in water demand via recycling would reduce overall energy intensity by only 4%, while using seawater desalination to satisfy growth would increase overall energy intensity by 5%. This emphasizes the overall energy savings of conservation versus other regional alternatives. The energy savings will also result in less overall GHG emissions from the utility sources providing the power.⁷⁸
4. Greywater: Reuse and harvesting of greywater will be maximized for agriculture irrigation, firefighting, landscape irrigation, flushing toilets, as an example.

Due to critically dry conditions during 2007 and 2008, the government of California has declared a statewide drought. Local agencies have developed a drought management plan that targets 10–40% reductions in customer consumption, depending on the level of drought intensity. One of the adopted initiatives under this program is the “20 gallon challenge,” which calls for a variety of end user voluntary conservation steps. This challenge targets 10% reductions in consumption (roughly 20 gallons per person) in the current drought. Current evidence suggests that a much smaller reduction is being achieved despite public advertising and awareness campaigns. Successfully achieving the higher reduction figures (40% or more) will rely on mandatory control measures, which will become increasingly necessary if voluntary measures have limited effectiveness.⁷⁹

⁷⁶ Stern et al. (1998).

⁷⁷ Messner et al. (2005, pp. 35–36).

⁷⁸ Messner et al. (2005, p. 35).

⁷⁹ Messner et al. (2005, p. 39).

5. Wastewater: Sewage, or “blackwater,” will be processed from primary, secondary, and tertiary treatments so that it produces useful “greywater.” In some instances, it may even be processed into potable water through UV, ozone, and carbon filtration.
6. Ecosystem exploitation shifts: As a result of growing population, the future demand on ecosystem services will increase significantly. There will be a shift in public policy and consumer behavior (voluntarily or regulated) to optimize key ecosystem services as noted earlier: (a) regulating services, (b) cultural services, and (c) supporting services. Greater respect will shift human community attitudes towards conservation and restoration of ecosystem services.
7. Natural capital investment shifts: As a result of behavioral attitude changes where human communities recognize ecosystem services (but, if not, government policy will regulate behavior), capital investments will be targeted at comprehensive and effective programs that preserve, conserve, restore, and sustain ecosystem services.

12.5.4 Phase 4: Identify Paths Forward to Reduce Negative Impacts and/or How Human Communities Must Adapt to Climate Change Impacts

1. Policy shifts: Public decision makers and agencies must keep moving in a common direction on understanding the climate forecasts for the region, which in turn should facilitate better joint planning. For example, fire protection agencies, utility planners, and public health planners should have a common understanding of temperature increase expected for the region. Likewise, water agencies and fire prevention agencies should have a uniform understanding about the likelihood of droughts and precipitation patterns. Land use planning agencies will have to deal with the combined challenges of sea level rise in coastal areas, increasing fragmentation of ecosystems, as well as mitigation measures to address local emissions that could require increasing future population centers around transportation corridors.⁸⁰
2. Behavioral shifts: Human behavior must change. A few examples:

Agriculture

- Remove production subsidies that have adverse economic, social, and environmental effects.
- Investment in, and diffusion of, agricultural science and technology that can sustain the necessary increase of food supply without harmful tradeoffs involving excessive use of water, nutrients, or pesticides.
- Encourage new innovations in food production, including hydroponics, aeroponics, aquaculture, vertical farming; i.e., soil-less agriculture.

⁸⁰ Messner et al. (2005, p. 36).

- Encourage locally grown produce to reduce transportation costs and pollution. Refer to USGBC's (United States Green Building Council) Leadership in Energy and Environmental Design (LEED)-rating system, as an example.

Water

- Establish and enforce fees for ecosystem services provided by watersheds.
- Increase transparency of information regarding water management and improved representation of marginalized stakeholders.
- Establish water markets that incorporate bioregional context; i.e., balance water resources taken from one bioregion and consumed in another.
- Review options to dams and levees for flood control by evaluating ecosystem services solutions.
- Invest in science and technology to increase the efficiency of water use in agriculture (see above).
- Follow "green" building rating systems that address water conservation guidelines in buildings and man-made landscapes.
- Promote the use of "greywater" to replace potable water uses, such as irrigation and flushing toilets.

Forestry

- Enforce sustainable forest management practices in financial institutions, trade rules, global environment programs, and global security decision making.
- Support initiatives for sustainable use of forest products. Refer to "green" building rating systems for guidelines.⁸¹
- Reform forest governance and development of country-led, strategically focused national forest programs negotiated by stakeholders.

The millennium ecosystem assessment report outlines six major sectors that are necessary to address the viability of ecosystem services long term.⁸²

- Institutions and governance: Changes in institutional and environmental governance frameworks are sometimes required in order to create the enabling conditions for effective management of ecosystems, while in other cases existing institutions could meet these needs but face significant barriers.
 - a. Integration of ecosystem management goals within other sectors and within broader development planning frameworks.
 - b. Increased coordination among multilateral environmental agreements and between environmental agreements and other international economic and social institutions.
 - c. Increased transparency and accountability of government and private-sector performance in decisions that affect ecosystems, including through greater involvement of concerned stakeholders in decision making.
 - d. Development of institutions that devolve (or centralize) decision making to meet management needs while ensuring effective coordination across scales.

⁸¹ USGBC LEED, ESTIDAMA, QSAS, GREEN STAR, BREEAM are a few of the green building rating programs worldwide.

⁸² Millennium Ecosystem Assessment, World Resources Institute (2005a, pp. 93–100).

- e. Development of institutions to regulate interactions between markets and ecosystems.
- f. Development of institutional frameworks that promote a shift from highly sectoral resource management approaches to more integrated approaches.
- Economics and incentives: Economic and financial interventions provide powerful instruments to regulate the use of ecosystem goods and services.
 - a. Elimination of subsidies that promote excessive use of ecosystem services (and, where possible, transfer of these subsidies to payments for nonmarketed ecosystem services)
 - b. Greater use of economic instruments and market-based approaches in the management of ecosystem services:
 1. Taxes or user fees for activities with “external” costs
 2. Creation of markets, including through cap-and-trade systems.
 3. Payment for ecosystem services.
 4. Mechanisms to enable consumer preferences to be expressed through markets.
- Social and behavioral responses: Social and behavioral responses—including population policy; public education; empowerment of communities, women, and youth; and civil society actions—can be instrumental in responding to ecosystem degradation.
 - a. Measures to reduce aggregate consumption of unsustainably managed ecosystem services
 - b. Communication and education
 - c. Empowerment of groups particularly dependent on ecosystem services or affected by their degradation, including women, indigenous people, and young people
- Technological responses: Given the growing demands for ecosystem services and other increased pressures on ecosystems, the development and diffusion of technologies designed to increase the efficiency of resource use or reduce the impacts of drivers such as climate change and nutrient loading are essential.
 - a. Promotion of technologies that increase crop yields without any harmful impacts related to water, nutrient, and pesticide use
 - b. Restoration of ecosystem services
 - c. Promotion of technologies to increase energy efficiency and reduce greenhouse gas emissions
- Knowledge and cognitive responses: Effective management of ecosystems is constrained both by a lack of knowledge and information concerning different aspects of ecosystems and by the failure to use adequately the information that does exist in support of management decisions.
 - a. Incorporate both the market and nonmarket values of ecosystems in resource management and investment decisions

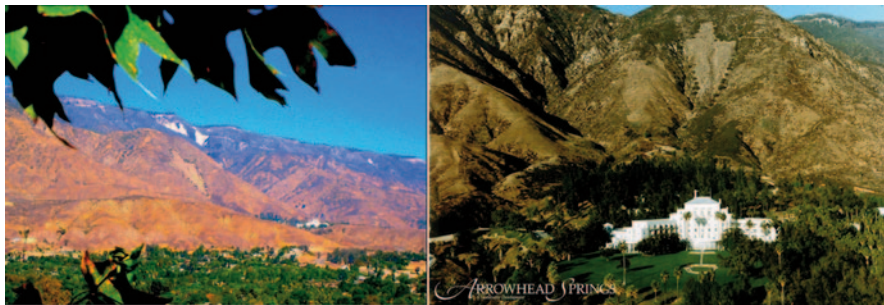


Fig. 12.16 Arrowhead Springs seen from the City of San Bernardino. (©Paul Bierman-Lytle, 2005)

- b. Use of all relevant forms of knowledge and information in assessments and decision-making, including traditional and practitioners' knowledge
 - c. Enhance and sustain human and institutional capacity for assessing the consequences of ecosystem change for human well-being and acting on such assessments
- Design of effective decision-making processes: Decisions affecting ecosystems and their services can be improved by changing the processes used to reach those decisions.
 - a. Use the best available information, including considerations of the value of both marketed and nonmarketed ecosystem services.
 - b. Ensure transparency and the effective and informed participation of important stakeholders.
 - c. Recognize that not all values at stake can be quantified, and thus quantification can provide a false objectivity in decision processes that have significant subjective elements.
 - d. Strive for efficiency, but not at the expense of effectiveness.
 - e. Consider equity and vulnerability in terms of the distribution of costs and benefits.
 - f. Ensure accountability and provide for regular monitoring and evaluation.
 - g. Consider cumulative and cross-scale effects and, in particular, assess trade-offs across different ecosystem services (Fig. 12.16).

12.5.5 Case Study: Arrowhead Springs

The current “business-as-usual” trend of human communities who reside in the high-altitude ecosystem and those communities at lower elevations that depend on ecosystem services does not bode well for the social and behavioral adaptation that is needed to prepare for climate change impacts. However, pressure on regional and local policies and regulations to address ecosystem services protection and

Fig. 12.17 One-thousand nine-hundred and sixteen-acre (775.4 ha) site boundaries. (© Paul Bierman-Lytle, 2005)



restoration is mounting. Examples include tougher building codes that target water and energy conservation, real estate development requirements that must ensure water supply for 25 years, use of drought-resistant plant species, CO₂ emission controls, and wider use of “greywater.” “Sustainable development” and “green” buildings are strategies commonly accepted as desirable, and often incorporated in city planning and building guidelines and codes.

One case study exemplifies a positive shift in attitudes toward ecosystem services. Situated in the San Bernardino high-altitude ecosystem, the Arrowhead Springs community plans to be a prototype sustainable development that demonstrates how human communities can contribute to ecosystem sustainability while improving human lifestyle, culture, and increasing economic vitality (Fig. 12.17).

Arrowhead Springs encompasses 1916 acres (775.4 ha). The community has proposed the following development guidelines and objectives.

- Prepare the necessary framework for the community to be 100% off the grid. In other words, establish design guidelines for all buildings, existing and new, to be self-reliant, self-sufficient with regard to energy, potable water, solid waste conversion, on-site transportation, communications, and security. With the exception of food independence, all utilities and infrastructure should seek an “ecosystems,” or “system of systems,” approach to being interdependent and independent from external resources.
- Dedicate land area for a ground-mounted solar farm with capacity to provide 100% of the community’s electricity requirements. Maximize renewable energy sources: solar, wind, hydroelectric, biofuels, and geothermal. Electricity demand for the project will require installation of a 10-MW solar electric farm, covering approximately 50 acres (20 ha) if ground-mounted. If installed over parking lots, land area could be reduced, but cost of the solar array would increase (Figs. 12.18, and 12.19).



Fig. 12.18 Ground-mounted solar photo-voltaic panels. (© University of Washington Bothell, 2013)

Fig. 12.19 Solar PV shades parking lot in Las Vegas. (©Solar Done Right, 2013). *PV* photovoltaic



- All existing and new buildings will be high-performance, integrating “deep” energy and water system solutions that are plugged into a “smart grid” integrated utility and infrastructure. Reduce water consumption and reconstitute and reuse all water resources for maximum value.
- Establish an extensive remote sensing management program that monitors the health of biodiversity, flora and fauna, on the property, so that forecasting of the ecosystem services can be observed and adapted to. Consistently and proactively manage, monitor, assess all natural capital assets on an enduring basis; and adapt human response and development to all dynamic shifts encountered or predicted (Figs. 12.20, 12.21, and 12.22).
- Incorporate commercial development activities such that each complements the ecosystem services. For example, wellness spa resorts can feature the natural mineral springs and geothermal waters as traditionally used. Hot springs, steam caves, mud baths, and spring water have historically made the site a destination for Native Americans, tourists and Hollywood celebrities in the 1940s to 1960s. The US Navy, during World War II (WWII), converted the spa resort into a hospital and recovery center (Fig. 12.23).

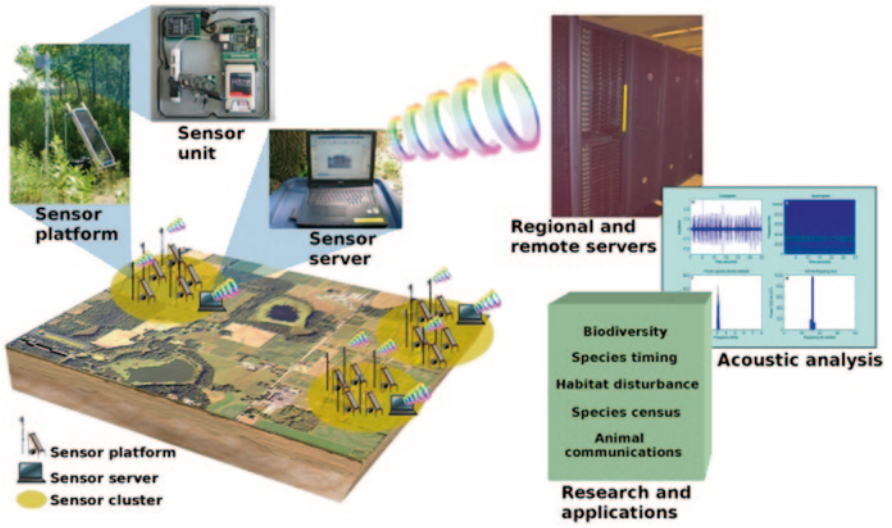


Fig. 12.20 © Remote Environmental Assessment Laboratory 2008

Fig. 12.21 Student prepares a wireless remote sensor. (© Kathy Szlavetz 2007)



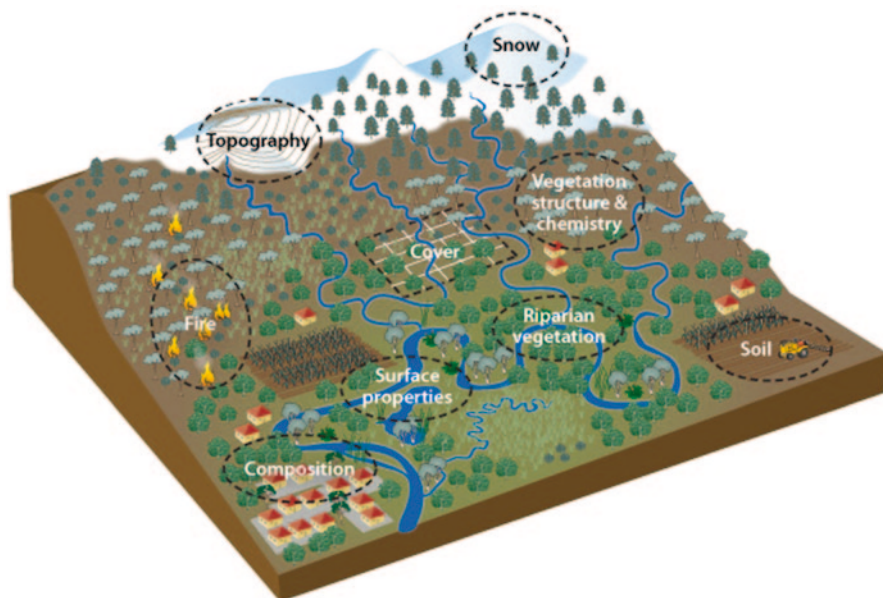


Fig. 12.22 © Remote Environmental Assessment Laboratory 2008



Fig. 12.23 Arrowhead Springs historic spa (1940s) and today. (© Arrowhead Springs 2012)

- An adventure sports park for recreation, training, and coaching is proposed for the property. Some 150 sports, including 50 on land, 50 in water, and 50 in the air, will optimize the mountainous terrain and high elevations. Promoting health and fitness, this new type of “theme” park encourages sustainable use of the natural landscapes, creates a minimal built footprint, while establishing a strong revenue source for the community. Prove that sustainability solutions are profitable, so that more communities will adopt models of sustainable development (Fig. 12.24).
- Optimize carbon sequestration through insightful land management (Fig. 12.25)



Fig. 12.24 Activities include biking, animal tracking, and bird watching. (© Arrowhead Springs 2005)

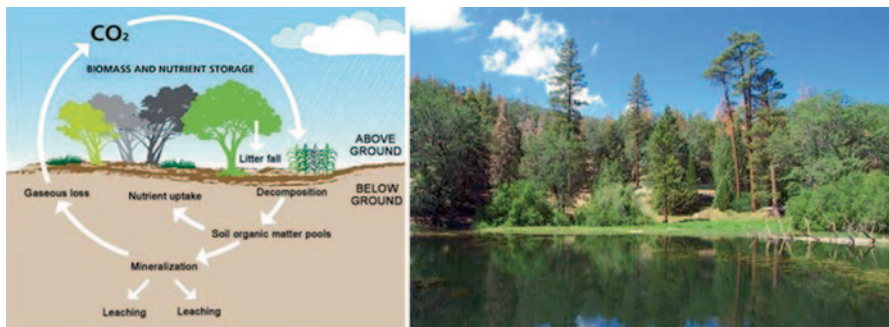


Fig. 12.25 San Bernardino Mountain forests provide significant carbon sequestration. (© Arrowhead Springs 2009)

- Integrate and embed natural capital in all economic enterprises that result in a balance or nurturing of natural capital assets versus exploitation.⁸³
- Natural capital declaration: The natural capital declaration (NCD) is a financed initiative through which financial institutions commit to:
 - Understand the impacts and dependencies of financial institutions on natural capital (directly and through customers) which can translate into material risks or opportunities;
 - Embed natural capital considerations in financial products and services;
 - Work towards a global consensus on integrated reporting and disclosure;
 - Work towards a global consensus for the integration of natural capital in private sector accounting and decision making (Fig. 12.26).

12.5.5.1 Integrated Intelligent Infrastructure Authority

One of the key commercial innovations at Arrowhead Springs is the formation of a comprehensive integrated utility management company. The mission of this company is to maximize efficiencies of all utilities and infrastructure using “intelligent” telecommunications, sensors, and monitoring. This management company will operate

⁸³ Natural Capital Declaration (2012).



Fig. 12.26 Commercial ventures include hydroponic and aquaculture food production, ecological sewage treatment (©TerraSave 2012), solar/hybrid powered transportation. (©Arrowhead Springs 2012)

out of a state-of-the-art Central Command and Communications Control Center (C5) where site-wide ecosystem services and human community services interface.

The C5 manages all Arrowhead Springs property utilities (on-site and “at gate”), infrastructure, and 1444 acres (580 ha) of non-buildable land. Assets include:

1. Existing ecosystem assets and services, including adjacent land areas
 - a. Flora
 - b. Fauna
 - c. Natural springs and wells
 - d. Geothermal springs
 - e. Minerals
2. Climate monitoring (precipitation, temperature)
3. Air quality
4. Noise pollution
5. Wildfire prevention
6. Existing sewage treatment plant
7. Existing man-made lakes and reservoirs
8. Existing fiber optics
9. Existing telephone/telecom services
10. Existing roads, surfaced and non-surfaced
11. Existing landscaping and irrigation network
12. Existing fire controls
13. Existing maintenance equipment and buildings

In addition, Arrowhead Springs plans to establish Arrowhead Springs Development Association (ASDA), a nonprofit company. This nonprofit organization establishes the fee tariff structure for all infrastructure used by on-site tenants, including:

14. Electricity
15. Geothermal energy for hot water, heating, and A/C
16. Spring water/potable water
17. Grey water used for irrigation and fire controls
18. Sewage/wastewater treatment plant on-site
19. Solid waste management: removal and conversion to electricity on-site

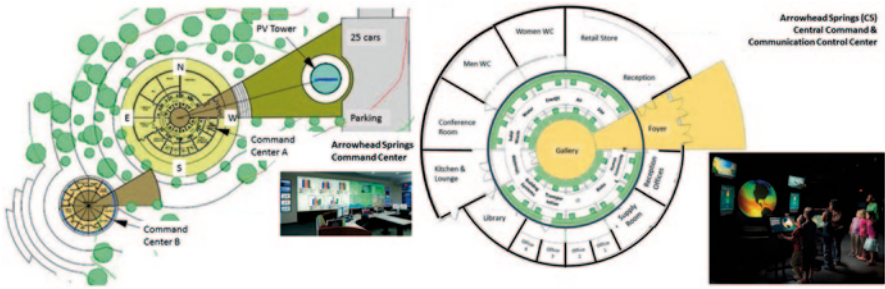


Fig. 12.27 Arrowhead Springs Central Command and Communications Control Center (C5). (© Paul Bierman-Lytle 2005)

Fig. 12.28 Arrowhead Springs master plan layout of commercial center. (© Paul Bierman-Lytle 2005)



- 20. Recycling center
- 21. On-site and off-site eco-transportation: bus service to/from airports, regional hotels, metro train station; on-site vehicles (lease or purchase), including golf carts, segways, multiple passenger trams/buses, limousine, electric bike program, etc.
- 22. Landscaping and irrigation and maintenance
- 23. Streets, paved, and unpaved
- 24. Parking and parking structures
- 25. Street lighting
- 26. Security lighting
- 27. Security (on-site police and celebrity guard protection services)
- 28. Fire Protection (on-site fire station)
- 29. Wildlife habitat management and control (Figs. 12.27, and 12.28)

12.5.5.2 Integrated Intelligent Infrastructure Methodology

As Albert Einstein stated “we cannot solve our problems with the same thinking we used when we created them,” the developers and planners of Arrowhead Springs

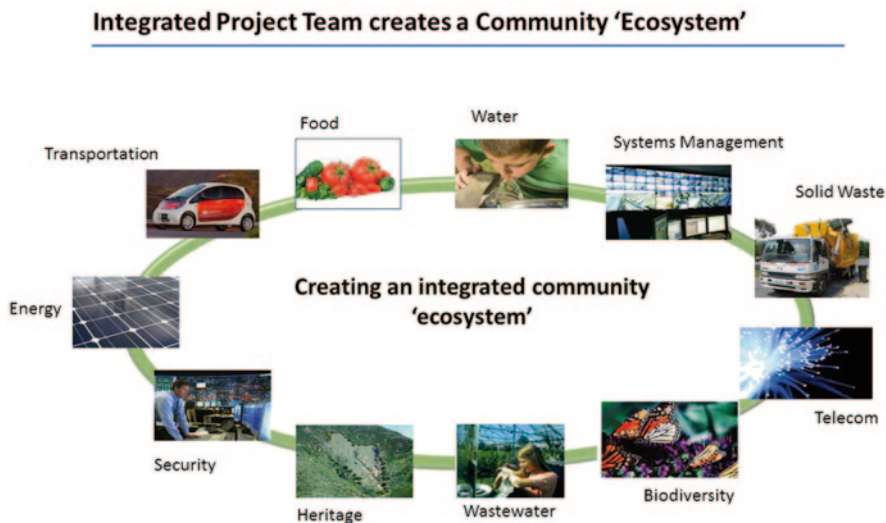


Fig. 12.29 Creating an integrated community “ecosystem.” (© Paul Bierman-Lytle 2009)

embraced a different approach when creating the master plan. It begins with understanding the “carrying capacity” or “sustainable capability” that the ecosystem services can provide a human community. Once the ecosystem services have been assessed, based on site research including biology, remote sensing, geology, forestry, biophilia, and a host of other natural and environmental sciences, the development team now has a baseline from which to align human development (real estate development) with ecosystem services. The second phase is to begin assessing the built environment as a complementary “ecosystem service,” where all parts are integrated and interdependent (Figs. 12.29, and 12.30).

Starting from the “carrying capacity” of a site’s ecosystem services and moving up through design phases is a completely different approach than conventional real estate development (top down) where the planners/architects create a vision of the development, including roads, buildings, and infrastructure *before* they actually know what the ecosystem services can support. The “community as an ecosystem” approach, on the other hand, acknowledges that all human development will benefit from an integrated, interdependent approach. Efficiencies are maximized: energy, water, solid waste, transportation, food production, security, and communications (Figs. 12.31, and 12.32).

At the “macro-level,” all systems (utilities, infrastructure, and buildings) are identified and assembled based on what the ecosystem services offer. At the “micro-level,” each of these systems, or components, identify appropriate technology or design solutions. Each of these parts is then tested through simulation to determine how effective they fit into the community ecosystem and how they respond or impact ecosystem services (Fig. 12.33).

The final step of the simulation analysis of the proposed technology and design solution options is to run a financial model to ensure that the “ecosystem”

Identifying Community Ecosystem Components that Establish Interdependencies

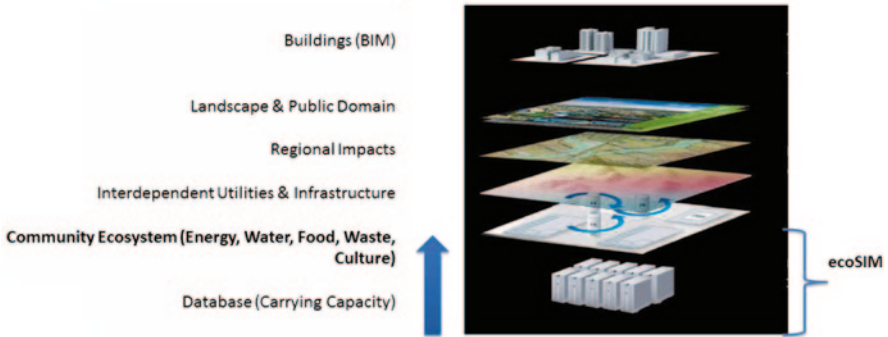


Fig. 12.30 Bottom-up phases of a community ecosystem. (© Paul Bierman-Lytle 2009)

Simulation – Systems Integration @ Macro-level

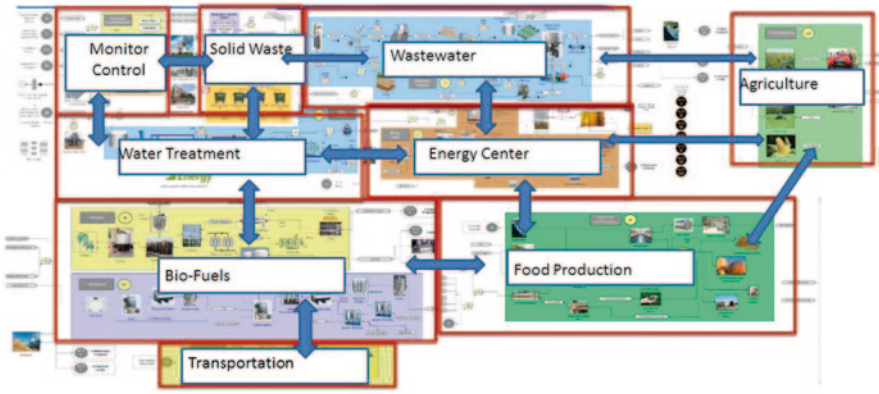


Fig. 12.31 Macro-level simulation of the community infrastructure. (© Paul Bierman-Lytle 2009)

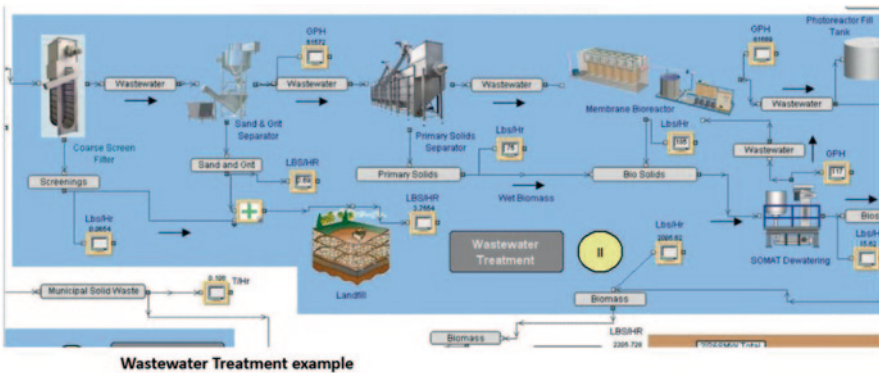


Fig. 12.32 Micro-level simulation of systems. (© Paul Bierman-Lytle, Lee Gary 2009)

Financial modeling of ecosystem components must be constant, dynamic and integrated or results will be 'siload'

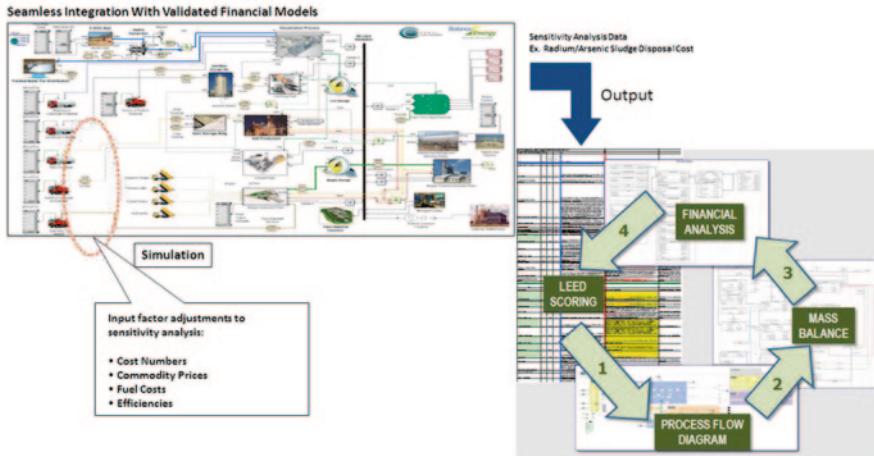


Fig. 12.33 Financial modeling of the community systems. (© Paul Bierman-Lytle, Lee Gary 2009)

Fig. 12.34 Simulation modeling of the community “ecosystem.” (© Paul Bierman-Lytle 2009)

**Simulation of a Community prior to Construction:
Modeling must be a constant interplay between buildings and
infrastructure in order to achieve optimization of systems**



components are economically aligned with the financial objectives of the stakeholders. If not, then the process of micro-level analysis repeats itself testing new alternative solutions until a successful financial model is achieved (Fig. 12.34).

Simulation modeling of the entire “community ecosystem” is critical in order to ensure that all ecosystem components are fully integrated and that synergies with the ecosystem services of the natural environment are optimized. Individual buildings, in turn, must “plug-in” effectively to the overall community “ecosystem,” otherwise the buildings become a liability and constraint on the system (Figs. 12.35, and 12.36).

Now that the community ecosystem and ecosystem services of the natural environment have been fully integrated, the development can now be effectively monitored each hour, each day of the year. Each component of the community ecosystem and the natural ecosystem services can be reviewed continuously to ensure maximum efficiency and synergy. Adaptations to climate or human activities can be more effectively engaged under this approach (Figs. 12.37, and 12.38).

Simulation of Community ‘Plug-in’ Buildings (new and retrofit) prior to Construction

Each building must ‘fit’ into the ‘ecosystem’

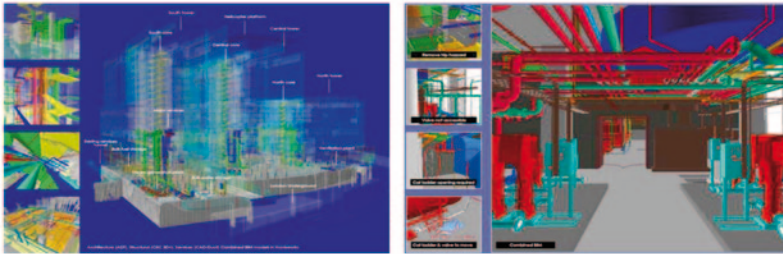
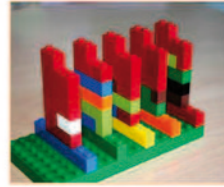


Fig. 12.35 Simulation of community “plug-in” buildings. (© Paul Bierman-Lytle 2009)

Real-time Monitoring a Community of Buildings

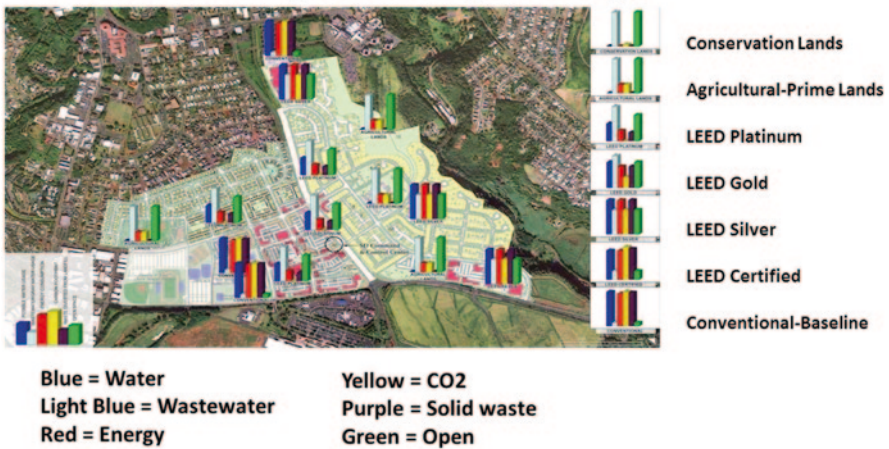


Fig. 12.36 Real-time monitoring of the community. (© Paul Bierman-Lytle 2009)

12.6 Conclusion: What New Paths can We Take? What are Our Options in the Coming Decades?

Human communities must shift from “business as usual” to “mitigation,” including economic, cultural, and behavioral shifts. This shift is not an option. Communities must learn to adapt, to change, to modify their lifestyles, habits, and behaviors. If not, the result will be a reduction in quality and quantity of ecosystem services which all human communities depend. More real estate developers must follow examples like Arrowhead Springs, taking the lead to build sustainable communities based on

Arrowhead Springs C5: Central Communications Command & Control Center

Utility & Infrastructure Management:

1. Water
2. Energy
3. Waste Streams
4. Food
5. Transportation
6. Telecommunications
7. Biodiversity/Biophilia
8. Security
9. Disaster Preparedness
10. Climate Change



Fig. 12.37 Central Communications Command and Control Center. (© Paul Bierman-Lytle 2009)

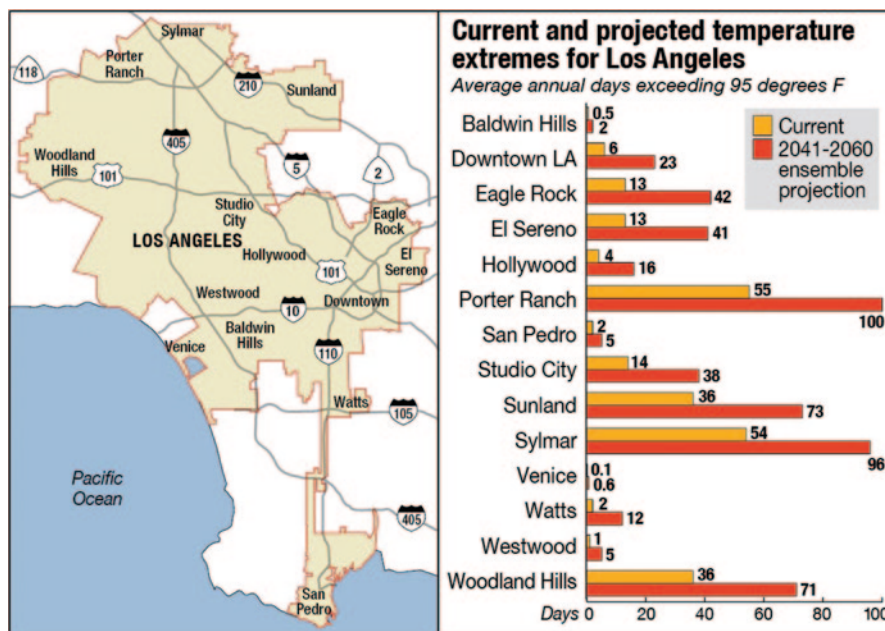


Fig. 12.38 Observed greenhouse gas concentrations in the atmosphere are shown above. The “Climate Change in the Los Angeles Region” project considers climate impacts on both a “business-as-usual” scenario and a “mitigation” scenario. (© C-Change, LA, 2013)

these critical attitude shifts that recognize the full potential of ecosystem services. If approached like Arrowhead Springs, positive engagement of ecosystem services can increase profits by optimization of efficiencies throughout a community's commerce. Healthier, productive, and enjoyable lifestyles will also emerge as human communities acknowledge that ecosystem services are integral to human life.

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