Methodology

for Calculating the Ecological Footprint of California

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Authors:
David Moore
Joy Larson
Katsunori Iha
Kyle Gracey
Mathis Wackernagel

Review:
Ryan Van Lenning
Scott Mattoon
Jill Connaway

For further information, please contact:
312 Clay Street, Suite 300
Oakland, CA 94607-3510
USA
Phone: +1.510.839.8879
info@footprintnetwork.org
www.footprintnetwork.org

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Executive Summary

The Ecological Footprint for California, forming part of the California Sustainability Indicators project undertaken by the U.S. Environmental Protection Agency Region 9, represents a significant development in the use of the Ecological Footprint and biocapacity[1] accounts: This is the first Ecological Footprint and biocapacity study of the state of California.

There are two possible ways of determining the Ecological Footprint for sub-national populations, such as at the state level. Because enough data were obtained specific to California, Ecological Footprint analyses could be conducted using both methods.

The first method, a "bottom-up" approach, counts the Ecological Footprint of all of the individual products consumed by the sub-national population and sums these together. Consumption is estimated from production (within the state's boundaries) plus imports minus exports. For example, the amount of potatoes consumed in California is calculated by adding imported potatoes to those grown in California and subtracting the potatoes that are exported. The potato Footprint then estimates how much area is needed to grow this consumed amount of potatoes. For California, the available data for production and biocapacity were largely complete. But trade data were only available in low resolution, which limits the accuracy of consumption assessments using this method.

The second method, a "top-down" approach, starts with the national-level per capita Ecological Footprint. Using data that compare national average consumption and California average consumption, the national Footprint results are adjusted to reflect California's reality. For example, if data indicated that Californians consumed x percent more crop products than the average American, then the crop Footprint for California residents would be assumed to be on average x percent larger than the American average.

Each method offers opportunities for different kinds of analyses. With the bottom-up analysis, Footprint of production (which cannot be accurately obtained with the top-down approach) and biocapacity estimates help determine local demand on biocapacity against local availability of biocapacity. However, this top-down method provides more accuracy for identifying which human activities contribute to the Footprint of consumption. Therefore Global Footprint Network recommends the bottom-up approach for estimating state-level (sub-national) Ecological Footprints for production and biocapacity. But for assessing the Footprint of consumption, the top-down method is more accurate.

The differences in results presented here for components of the consumption Footprint, using top-down and bottom-up method, can be large (most notably grazing land, cropland and forest land). The difference in the estimated consumption Footprints using the two methods is only 5 percent: The total consumption Footprint using the bottom-down analysis added up to 5.9 global hectares per capita, while the top-down approach resulted in 6.2 global hectares per capita.

Although this report contains a brief section on the results of these analyses, more details on the results and what they mean for the state are presented in a separate report (*The Ecological Footprint and Biocapacity of California, 2013 — Global Footprint Network*).

[1] Biocapacity refers to the capacity of land and sea area to provide ecosystem services. In theory, all services are included that compete for space. In practice, because of data constraints, Global Footprint Network's National Footprint Accounts, which are also the basis for the California assessment, only include carbon dioxide emissions in the waste calculation. More data would lead to larger Footprint results.

1. Introduction

1.1 What is the Ecological Footprint?

The **Ecological Footprint** is an accounting tool that measures the amount of biologically productive land and sea area required to produce what a population (or an activity) consumes and to absorb its waste, using prevailing technology and management practice. The Ecological Footprint is compared to available **biocapacity**, that is, the planet's or a region's biological capacity to provide the products and services people demand.

Biologically productive land and sea includes area that 1) supports human demand for food, fiber, timber and space for infrastructure, and 2) absorbs the emitted waste. Current national accounts, as well as this one for California, only include the carbon dioxide emissions from fossil fuel burning in the waste calculations. With better and internationally comparable data sets, other waste streams could be included as well. Biologically productive areas include cropland, grazing land, forest and fishing grounds, and do not include deserts, glaciers and the open ocean.

1.2 Purpose and scope

Growing human population, ever-increasing energy and material use, and waste generation characterize our economic and social systems. However, nature's bioproductive capacity and other services provided by ecosystem processes are finite. The U.S. Environmental Protection Agency, Region 9, is developing a suite of substantive and informative indicators on economy-environment interactions to facilitate decision-making for the long-term benefit of the state. The Ecological Footprint is one of these indicators.

The purpose of this report is to present the methodology used for determining the Ecological Footprint of California. The conceptual and technical challenges associated with two methodologies associated with sub-national Ecological Footprint analyses are explored. This study is the first Ecological Footprint analysis done at the state-level for California; it is a baseline study starting with data already available and determines the Ecological Footprint for one year (2008, the most recent year for which complete datasets are available).

This report accompanies an MS EXCEL file that includes all of the data sources and calculations used to determine the Ecological Footprint and biocapacity of California. A more detailed presentation of the results of these analyses can be found in a separate report (*The Ecological Footprint and Biocapacity of California, 2013 — Global Footprint Network*).

2 Method

Typically, a calculation of the Ecological Footprint with complete source data is only possible at a global or national scale. Ecological Footprint analysis is data-intensive, and production and trade statistics for all of the industries and economic activities captured by the Ecological Footprint methodology are rarely collected at a sub-national le

vel.

However, California, with the largest U.S. state population, has a lot of different industrial, manufacturing, service, and agricultural sectors. As a result, state agencies collect data for a wide variety of economic activities, and many statistics used in the Ecological Footprint methodology that are rarely available at the state level are available within California. In fact, enough data were obtained to conduct Ecological Footprint analysis using two different approaches.

The "***bottom-up***" method counts the Ecological Footprint of all of the individual products consumed by the sub-national population and sums these together. This follows the exact same sequence of calculations as the National Footprint Accounts.

The "***top-down***" method begins with Ecological Footprint results calculated at the national level, using the National Footprint Accounts. It then derives sub-national Footprints by adjusting for consumption differences between the national and the sub-national population. More precisely, it stretches (or shrinks) each component of the national Footprint for the relative differences between the national average consumption in that component and the corresponding consumption of the sub-national population.

2.1 Bottom-up methodology

2.1.1 Bottom-up overview

The bottom-up methodology mirrors the approach of the National Footprint Accounts but instead of using national-level data, it uses input data specific to the sub-national population.

This can be considered a "component" method because the Ecological Footprint of all products consumed by a population are aggregated together: The amount of biological material in products that are consumed (tonnes per year) is divided by the yield of the specific land or sea area (annual tonnes per hectare) from which the biological material was harvested (e.g., paper from forest land, crops from crop land, etc.). It includes the amount of land required to sequester carbon dioxide emissions that are either directly emitted by the population (e.g., in transportation) as well as the carbon dioxide emissions generated in the manufacturing processes that produce the goods consumed by the population.

The number of hectares that result from this aggregation are then converted to global hectares (gha) using yield and equivalence factors (these factors are explained below). The sum of the global hectares needed to support the biocapacity demand of the population gives that population's total Ecological Footprint. The Ecological Footprint values (expressed in gha) can be divided by the size of the population to determine the Ecological Footprint per capita (expressed as per capita gha).

2.1.1.1 Global hectares

In relation to the Ecological Footprint and biocapacity, productivity refers to the amount of biological material useful to humans that is generated in a given area. Average productivity differs between area types, as well as between countries for any given area type. For comparability across area types and countries, Ecological Footprint and biocapacity are expressed in units of world-average bioproductive area, referred to as global hectares (gha); that is, a biologically productive hectare with world average productivity. A global hectare of cropland, for example, would occupy a smaller physical area than the much less productive pasture land, as more physical area of pasture land would be needed to provide the same biocapacity as one hectare of cropland. Because world productivity varies slightly from year to year, the value of a global hectare may change from year to year.

2.1.1.1.1 Yield factors and equivalence factors

Two important type of coefficients, the yield factors (YF) and the equivalence factors (EQF), allow results of Ecological Footprint analysis to be expressed in terms of global hectares (Monfreda et al., 2004; Galli et al., 2007), providing comparability between countries' Ecological Footprints as well as biocapacity values.

The biological productivity of each area type varies geographically; a hectare of cropland in an arid area may produce far fewer crops than a hectare of cropland in a wet area. The use of a **yield factor** accounts for differences between countries in productivity ***of a given area type***. Yield factors capture the difference between domestic/local/regional productivity and world average productivity for usable products within a given area type. They are calculated as the ratio of national average to world average yields and thus vary by country, area type and year. They may reflect natural factors such as differences in precipitation or soil quality, as well as anthropogenic-induced differences such as management practices. Using the yield factor to transform physical land area allows comparison of the same area between different geographic regions.

Not all of the area types have similar biological productivity, either. As mentioned a hectare of cropland produces more biocapacity than a hectare of grazing land, for example. **Equivalence factors** translate the area ***of a specific area type*** available or demanded into units of world average biologically productive area. Equivalence factors are calculated as the ratio of the maximum potential ecological productivity of world average land of a specific area type (e.g., cropland) and the average productivity of all biologically productive lands on Earth. This normalizes the Ecological Footprint calculations into a single unit so that the values for different areas are comparable.

The methodology and calculations for determining yield factors and equivalence factors can be found in Calculation Methodology for the National Footprint Accounts, 2011 Edition (Borucke, 2012).

2.1.1.2 Footprint of consumption, production and trade

The **Footprint of production** is calculated as the sum of the Footprints for all biological renewable materials harvested, for the space for infrastructure areas and for sequestering the CO_2 emissions generated within the defined geographical region. It reflects a direct demand for domestic/local biocapacity, as well as the demand imposed by local CO_2 emissions. In other words, it includes all the area within a region necessary for supporting the harvest of primary products (cropland, pasture land, forest land and fishing grounds), the region's built-up area (roads, factories, cities), and the area needed to absorb all carbon dioxide emissions from fossil fuel burning within the boundaries of the region.

Some of this production is exported. Populations also rely on imports of goods from other regions. The Ecological Footprint accounts also include the Footprint that is embodied in trade. The **Footprint of imports** is the Ecological Footprint embodied in goods that are imported; the **Footprint of exports** is the Ecological Footprint embodied in goods that are exported.

With the Footprints of production, import and export, one can calculate the most commonly reported type of Ecological Footprint: the **Footprint of consumption**. This Footprint is defined as the area used to support a defined population's consumption. The Footprint of consumption is calculated as a population's Footprint of production (i.e., what they produce within their territory) plus imports minus exports.

For example, if a country grows cotton for export, the embodied Footprint of that cotton product is not included in that country's Footprint of consumption; rather, it is included in the Footprint of consumption of the country that imports the cotton and uses it to manufacture T-shirts. However, this embodied Footprint *is* included in the exporting country's Footprint of production.

2.1.1.3 Primary and derived products

"**Primary products**" are the raw goods that are either consumed or used to make other (derived) products. For example, timber would be a primary product that is harvested from forest land. Timber can be used to manufacture a number of derived products like furniture and paper. These kinds of manufactured goods are considered to be "**derived products**" that are made from primary products.

2.1.1.4 Biocapacity

The Ecological Footprint measures a population's demand for biocapacity — that is, the area needed to renew biological materials, provide for infrastructure space and to absorb emitted waste. In the present calculations, the only waste stream that is included is carbon dioxide from burning fossil fuel. Current accounts distinguish five area uses. The Ecological Footprint distinguishes six area uses, since forest products and carbon sequestration both compete for the same biocapacity category (forest land).

An **ecological (or biocapacity) deficit** occurs when the Footprint of a population exceeds the biocapacity of the area available to that population. Conversely, an ecological reserve exists when the biocapacity of a region exceeds its population's Footprint. Biocapacity can be calculated for any geographic area and scale — for instance a farm, a region, or the world as a whole. Most common is to compare a population's consumption Footprint with the biocapacity of the territory it inhabits. If there is a regional or national ecological deficit, it means that the region is importing biocapacity through trade, using the global commons (for instance, when emitting carbon dioxide into the atmosphere that is not sequestered by the territory), or liquidating regional ecological assets. The latter possibility is called "overshoot." Overshoot means that local harvest exceeds local regeneration. Global overshoot occurs when humanity's demand on nature exceeds the biosphere's biocapacity. Such overshoot leads to a depletion of Earth's life-supporting natural capital and a buildup of waste such as carbon dioxide in the atmosphere. In contrast to the national or regional ecological deficit that can occur without overshooting local ecosystems, global ecological deficits inevitably are identical with overshoot, since those global deficits cannot be compensated for by trade.

Ecological Footprint Accounts are specifically designed to yield conservative estimates of global overshoot as Ecological Footprint values are, when in doubt, consistently underestimated, while biocapacity estimates are, when in doubt, overestimated. For instance, human demand, as reported by the Ecological Footprint, is underestimated because of the exclusion of freshwater consumption, soil erosion, greenhouse gas emissions other than carbon dioxide, biological wastes, as well as impacts for which no regenerative capacity exists (e.g., pollution in terms of waste generation, toxicity, eutrophication, etc.). In turn, the biosphere's supply is overestimated as land degradation, groundwater depletion, climate change and the long-term sustainability of resource extraction is not taken into account. Gaps between Ecological Footprint and biocapacity are likely larger than the calculations imply. These limitations also demonstrate how the Ecological Footprint is not a complete measure of environmental impact, let alone sustainability.

2.1.2 Area types

2.1.2.1 Cropland

Cropland consists of the area required to grow all crop products, including all crops for human consumption, livestock feeds, fish meals, oil crops and rubber. It is the most productive of the area types included in the Ecological Footprint Accounts.

Worldwide in 2008 there were 1.53 billion hectares designated as cropland[2] (FAO ResourceSTAT Statistical Database 2011). The Ecological Footprint methodology calculates the Footprint of cropland using data on production, import and export of primary and derived agricultural products. The Footprint of each crop type is calculated as the area of cropland that would be required to produce the harvested quantity at world-average yields.

Cropland biocapacity represents the combined productivity of all land devoted to growing crops. As an actively managed area type, cropland has yields of harvest equal to yields of growth by definition and thus it is not possible for the Footprint of production of cropland (as currently computed) to exceed biocapacity within any given geographic area (Kitzes et al., 2009).

Crop trade data for California

Because of differences in the data categories of crop data reported at the global level (UN FAO data) and at the state level (California Department of Food and Agriculture), production and trade flow components of the National Footprint Account (NFA) methodology were modified for this Footprint analysis of California. But the calculations were the same. Hence the NFA calculations for cropland Footprint were replicated using production and land cover data specific to crops produced in the state.

The source data for imports and exports of crop products in the National Footprint Accounts calculate the cropland Footprint according to trade flows (imports and exports) of 413 crop products. The average Footprint intensity (gha per annual tonne) of each individual crop product is multiplied by the weight of each crop product imported/exported, and the resulting Footprint values are added up to determine the total Footprint of imports and Footprint of exports. For California, data at this resolution were not available; a single aggregate group “All Crop Products” was used. It was assumed that this single category includes all of the crop products that are reported in the FAO dataset. The yield (and, by extension, Footprint intensity) for this single category was calculated as the weighted average yield across all produced U.S. crop items.

The sources for state-level data specific to California that were used in this bottom-up analysis are listed in Appendix A.

[2] In the Ecological Footprint, “cropland” is defined to match the FAO land use category “Arable land and Permanent crops” – FAO code 6620.

2.1.2.2 *Grazing land*

The grazing land Footprint measures the area of grassland used (apart from and in addition to crop feeds) to support livestock. Grazing land comprises all grasslands used to provide feed for animals, including cultivated pastures as well as wild grasslands and prairies. In 2008, there were 3.37 billion hectares of land worldwide classified as grazing land[3] (FAO ResourceSTAT Statistical Database 2011).

In contrast to cropland, when calculating the grazing land Footprint the yield represents average above-ground net primary productivity (NPP) for grassland and does not reflect harvest or rangeland management practices. Since the yield of grazing land represents the amount of above-ground primary production available in a year, and there are no significant prior stocks to draw down, overshoot is not physically possible over extended periods of time for this area type. For this reason, a country's grazing land Footprint of production cannot exceed its biocapacity in the National Footprint Accounts. In the event that the grazing land Footprint of production (based on calculated feed requirements) is larger than the available biocapacity (based on NPP and grazing land area), the Footprint of production is set equal to the available biocapacity.

Grazing land trade data for California

There were similar data limitations in the grazing land Footprint that were encountered in the cropland Footprint. For imports the National Footprint Accounts calculate the grazing land Footprint of imports according to trade flows of 163 animal products. Product-specific intensities are used to determine the embodied Footprint associated with each product. For California, data at this resolution for animal products were not available, and a single aggregate group was used. Due to the inability to disaggregate the imports, the weighted average Ecological Footprint intensity (Footprint of production per ton) of California produced livestock was applied to this single category of grazing land imports.

2.1.2.3 *Fishing grounds*

The fishing grounds Footprint is calculated based on the annual primary production required to sustain a harvested aquatic species, using estimates of the maximum sustainable catch for a variety of fish species. These sustainable catch estimates are converted into an equivalent mass of primary production based on the various species' trophic levels (based on the work of Pauly and Christensen, 1995). This estimate of maximum harvestable primary production is then divided among the continental shelf areas of the world. Fish caught and used in aquaculture feed mixes are included.

There were no alterations to the fishing grounds Footprint calculations for this study, although in addition to using data specific to California, the area of California's continental shelf was separated from the total area for the United States.

2.1.2.4 *Forest land*

Forests accommodate both the forest Footprint as well as the carbon Footprint. The forest product Footprint measures the annual harvest of fuel wood and timber to supply forest products. The carbon Footprint represents the area needed to sequester emitted carbon dioxide from fossil fuel burning.

[3] In the Ecological Footprint, "grazing land" is defined to match the FAO land use category 'Permanent meadows and pastures' – FAO code 6655.

Worldwide in 2008 there were 4.04 billion hectares of forests in the world (FAO ResourceSTAT Statistical Database 2011).[4] The yield used for forests is the net annual increment (NAI) of merchantable timber per hectare. Timber productivity data from the UNEC and FAO Forest Resource Assessment and the FAO Global Fiber Supply are utilized to calculate the world average yield of 1.81 m^3 of harvestable wood per hectare per year (UNECE and FAO 2000; FAO 1998).

Forest land trade data for California

The National Footprint Accounts calculate the forest product Footprint according to the production quantities of 13 primary timber products and three wood fuel products. Trade flows include 30 timber products and three wood fuel products. For California, data at this resolution were not available, and a single aggregate group was used ("All products"). Due to the inability to disaggregate, it was assumed that all of the traded forest products were primary products: The yield (and, by extension, Footprint intensity) for this group was considered to be the same yield of 1.81 m^3 of harvestable wood per hectare per year for primary products (e.g., saw logs, veneer logs, roundwood).

2.1.2.5 Carbon Footprint and carbon sequestration land

The land needed to sequester carbon dioxide emissions from fossil fuel use, the carbon Footprint — sometimes referred to as "carbon uptake land" within the Ecological Footprint literature — is the only area type included in the current national Ecological Footprint methodology that is exclusively dedicated to tracking a waste product: carbon dioxide from fossil fuel burning.[5] It shares forest biocapacity with the forest product Footprint. The accounts do not explicitly allocate how much of the forest biocapacity is dedicated to which use.

Carbon dioxide is released into the atmosphere from a variety of sources, including human activities such as burning fossil fuels and certain land use practices, as well as natural events such as forest fires, volcanoes and respiration by animals and microbes. Only carbon dioxide emissions from human activities are included in the carbon component of the Ecological Footprint, and the only greenhouse gas that is included in the current Ecological Footprint calculations is carbon dioxide.

Many different ecosystem types have the capacity for long-term storage of carbon dioxide, including the area types considered in the Ecological Footprint Accounts such as cropland or grassland. However, since most terrestrial carbon uptake in the biosphere occurs in forests, and to avoid overestimations, carbon uptake land is assumed to be forest land in the Ecological Footprint methodology. For this reason, it is considered to be a subcategory of forest land. Therefore, forest for timber and fuelwood is not separated from forest for carbon uptake. Global Footprint Network has not yet identified reliable global data sets on how much of the forest areas are dedicated to long-term carbon uptake. Hence, the National Footprint Accounts (and State Footprint Accounts by extension) do not distinguish which portion of forest land is dedicated to forest products and how much is permanently set aside to provide carbon uptake services. The carbon component of the Ecological Footprint includes carbon dioxide emissions from direct fossil fuel combustion as well as the

[4] In the Ecological Footprint, "forest" is defined to match the FAO land use category 'Forest Area' – FAO code 6661. Due to data limitation, current accounts do not distinguish between forests for forest products, for long-term carbon uptake, or for biodiversity reserves.
[5] Today, the term "carbon footprint" is widely used as shorthand for the amount of anthropogenic greenhouse gas emissions. In the Ecological Footprint methodology however, it translates this amount of anthropogenic carbon dioxide into the amount of biologically productive area required to sequester carbon dioxide emissions. (See Galli et al. (2012) for additional information.)

carbon dioxide emissions embodied in traded commodities. Emissions that are embodied in traded commodities are considered to be carbon dioxide emissions that are emitted in one place to manufacture commodities that are consumed by the end user elsewhere (See Appendix B for more detail).

For this study, similar to fishing grounds, there were no alterations to the carbon Footprint calculations for California. However, the source data for trade into and out of the state use categories for commodities and product groupings different from the list of commodities in the UN database used for the NFA accounts, and these commodities had to be manually mapped to the corresponding embodied energy to determine the embodied Footprint.

2.1.2.6 Built-up land

The built-up land Footprint is calculated based on the area of land covered by human infrastructure: transportation, housing, industrial structures and reservoirs for hydroelectric power generation. In 2008, the built-up land area of the world was approximately 170 million hectares. The Ecological Footprint methodology assumes that built-up land occupies what would previously have been cropland. This assumption is based on the observation that human settlements are generally situated in fertile areas with the potential for supporting high-yielding cropland (Wackernagel et al., 2002).

For lack of a comprehensive global dataset on hydroelectric reservoirs, the Ecological Footprint methodology assumes these to cover areas in proportion to their rated generating capacity. Built-up land always has a biocapacity equal to its Footprint since both quantities capture the amount of bioproductivity lost to encroachment by physical infrastructure.

Also, for simplicity reasons, no trade adjustment is calculated, even though in reality some of California's infrastructure is used by the outside world (such as hotels, airports, ports, almond processing facilities), and California's demand uses infrastructure in the rest of the world (such as roads, hotels, airports, or factories).

2.1.2.7 Adjustments to NFA methodology for California — unmeasured consumption

Although in this study California has been treated as an independent country, there are two major areas in which this assumption does not hold, both relating to cross-border movement of goods and services. First, federal government expenditures related to the country as a whole (e.g., defense) and specific government transfers of goods into California will not be tracked. Second, goods which are transported by businesses into the state without an actual sale taking place will also likely be excluded from the analysis.

In order to rectify this, the national per capita Ecological Footprint associated with government and business consumption (from the national CLUM described below) were added to the per capita California Ecological Footprint that was calculated using the bottom-up method. There is a potential for double counting that could arise from government purchases that are made within the state (and therefore show up in the consumption statistics already). However, it was assumed that purchases by government within California are minimal compared to those purchases that are made outside the state (e.g., federal government) but still contribute to services provided to Californians. It is believed that this potential for double counting will be negligible compared to the overall Footprint.

2.2 Top-down methodology

In contrast to the bottom-up methodology that results in Ecological Footprint values disaggregated by only area type, it is possible to further identify which human activities contribute to a population's Ecological

Footprint. This is done by using economic data in combination with expenditure patterns to allocate the Ecological Footprint to industrial sectors' final demand and produce a Consumption Land Use Matrix (CLUM). A CLUM is a presentation of an Ecological Footprint as a matrix with area types as columns and consumption categories as rows. These consumption categories generally fall under the classifications of food, housing, transportation, goods and services; higher resolution CLUMs further subdivide these categories (explained in more detail below with an example in Table 1).

Specific to California, one of the challenges of the bottom-up analysis was tracking trade into and out of the state. California is reliant on imports to meet its Ecological Footprint, and since the trade data for California were of a low resolution (i.e., trade data aggregated into one single product category for cropland, grazing land and forest land result in Footprint of consumption values that are not as precise as those produced with NFA source data), it was important to verify that the estimates for the Footprint of consumption as calculated from production and estimations of trade flows reflect the actual demand.

The general process for this top-down analysis follows an input-output based national CLUM (Global Footprint Network, 2009) that is scaled up/down according to the consumption patterns (e.g., based on average expenditures) of the sub-national population. It follows three basic stages: Resource input, Production, and Consumption.

2.2.1 Resource input and production

There are two key datasets for national CLUM analysis: The national-level Ecological Footprint and economic input-output (I-O) tables. I-O tables show the flow of monetary resources through a country's economy. They depict inter-industry relations of an economy, showing how the output of one industry is an input to each other industry. This allows one to trace the effects on total economic output through changes in the final demand for the production from individual industrial sectors (examples of industrial sectors are agriculture, mining, textiles, chemical and rubber manufacturing, construction, transport, communication, etc.).

Furthermore, Multi-Regional Input-Output (MRIO) tables allow one to trace inter-country flows of money and the associated Ecological Footprint in trade, and it is around an MRIO dataset that Global Footprint Network's national CLUMs are built (Ewing, et. al., 2012). This MRIO analysis is based upon a model provided by the Global Trade Analysis Project (GTAP), which details the monetary flows between industrial sectors within and between regions. Global Footprint Network extends this model by making an initial allocation of the Ecological Footprint of production by area type component to the industrial sectors which first place these demands (e.g., the forest land Ecological Footprint is allocated to the forestry sector).

Starting with the NFA for the United States, the Footprint of production and the Footprint of imports are entered into the I-O table for the USA. These Footprint values are allocated to the various industrial sectors for the "input" into the economy. The Ecological Footprint is then assumed to flow through the global economy in proportion to the monetary flows. In this way, the total embodied Ecological Footprint associated with final consumption can be estimated. This output is separated into domestic consumption and production for export.

2.2.2 Consumption Land Use Matrix (CLUM)

The final consumption from various industrial sectors is translated into specific consumption categories (as defined by the United Nations Classification of Individual Consumption According to Purpose: COICOP[6]) of goods and services used by consumers. When these consumption categories are presented as the amount of

[6] http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=5

embodied Footprint of each of the six area types (cropland, grazing land, forest land, fishing grounds, built-up land and carbon), then the resulting consumption category against area type matrix is termed a Consumption Land Use Matrix, or CLUM. In addition to the categories of household consumption, CLUMs show the Ecological Footprint per area type of gross fixed capital formation and government expenditure (described below). A CLUM is unique to the economic system of a country, and can often highlight surprising findings that reveal important underlying features of a nation's consumption and its demand on ecological systems.

These CLUMs are also highly useful for determining the Ecological Footprint of (sub-national) regions. By using relative expenditure and price data between the national and the sub-national region, each category within the CLUM can be scaled to the regional level. The top-down method in determining the California Ecological Footprint uses this approach. Such an approach more completely captures the full supply-chain Ecological Footprint of consumption, though it does not provide data on the Ecological Footprint of production or biocapacity.

Household consumption, gross fixed capital formation and government expenditure

Within the CLUM, there are two broad classifications for final demand:

- Short-lived consumption goods that are paid for by **households**. They fall under the broad categories of Food, Shelter, Transportation, Goods and Services. These categories and their sub-categories usually follow the ones defined by COICOP.
- Short-lived consumption goods that are paid for by the government (for governing, public schools, police, etc.).
- Long-lived goods, which are called gross fixed capital formation.

Gross fixed capital formation (GFCF) accounts for household investment (e.g., new housing), investment by firms (e.g., new factories and machinery), or investment by government (e.g., transport infrastructure). The supply chains for GFCF are complicated and state-level trade statistics may not capture all transfers of capital. Because national IO tables contain all purchases made by businesses and governments within an economy (described in the Resource input and Production section above), all investments in capital are tracked. For a simplified example, if a company bought all the parts to construct a new factory outside California's borders and then shipped them into California to build the factory, it would not show up in the trade statistics, which may only track sales across state borders. But it would show up as expenditure within that industry in the IO table.

Government expenditure relates to the ongoing consumption associated with the functions of the government. Federal government expenditures related to the country as a whole (e.g. defense) and specific government transfers of goods into California will not be tracked in California-specific statistics.

Because data for GFCF and federal government expenditures either do not show up or are incomplete in the California-specific data sources used in the bottom-up analysis described above, the per capita Ecological Footprint values for GFCF and government expenditures from CLUM for the United States were added to the results of the bottom-up analysis for the state of California.

2.2.3 Scaling the national CLUM to California

The CLUM for the United States was scaled to California consumption patterns using supplemental data sources specific to California.

Household expenditure data for California were derived from the U.S. Census Bureau's Consumer Expenditure Survey. The total expenditure by families surveyed by the Census Bureau in California was divided by the total number of people in those families. This was then compared against the full-sample expenditure (across the entire U.S.) divided by the full-sample number of individuals.

Price data were taken from the Cost Of Living Index (COLI) from ACCRA[7], which gives relative prices across metropolitan areas compared to the U.S. average. California prices as a whole were assumed to be a population weighted average of the prices in 12 major metropolitan areas in California included in COLI.

Finally, since carbon emissions directly emitted by households (i.e., emissions from direct fuel combustion for heating and transport) were not included within the industrial flows that are used to calculate the CLUM, they are added to the CLUM after scaling takes place. These data were taken directly from the California Greenhouse Gas Inventory described in Appendix A.

[7] http://www.coli.org/

3 Results

3.1 California's Ecological Footprint and biocapacity

The average Ecological Footprint of the citizens of California is larger than the available biocapacity within the state's borders; in 2008 (the most recent year for which complete datasets were available), the available biocapacity in California made up only 16 percent of the total Ecological Footprint.

Grazing land and fishing grounds within the state produce enough biocapacity to meet the average Ecological Footprint of products from those land uses. However, cropland and grazing land biocapacity within the state boundaries of California are less than the Footprints, and California makes up for these differences with trade. The largest deficit is with carbon sequestration. In 2008, the carbon Footprint made up 72 percent of California's total Ecological Footprint.[8]

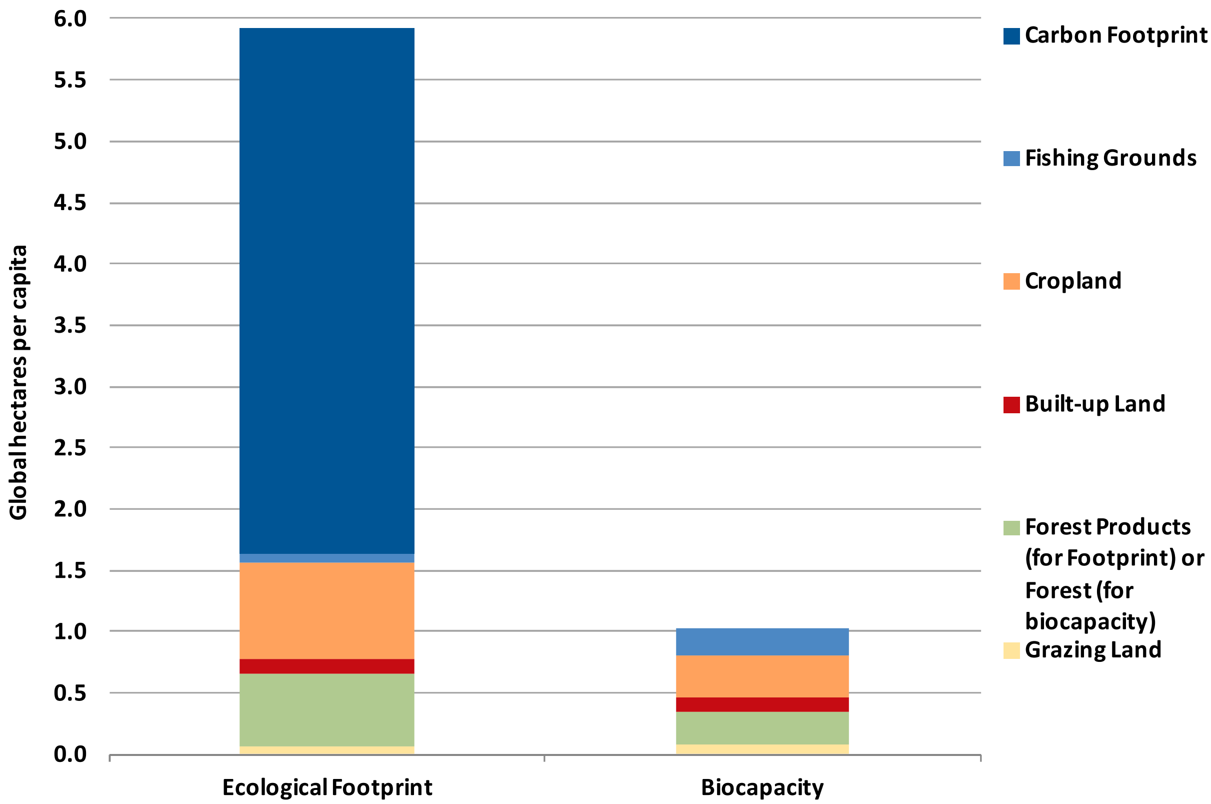

Figure 1 - California's Ecological Footprint and biocapacity, by area type, 2008. *These are the results of the bottom-up analysis. The difference between the Ecological Footprint and biocapacity is referred to as ecological deficit. Note that the forest and carbon component in the Footprint are counted against the forest component in biocapacity.*

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[8] Footprint calculations do not imply that the climate challenge can be resolved by providing more biocapacity for carbon sequestration. Rather, they point out that the demand for biocapacity outstrips availability. A large carbon Footprint without the corresponding forest biocapacity to sequester indicates that a) there will be carbon accumulation in the atmosphere, and b) there is no sufficient local substitute available to replace fossil fuel with biomass energy, should that become necessary.

3.1.1 California compared to the United States

In 2008, the United States had the eighth largest per capita Ecological Footprint in the world, at 7.2 gha per capita. The California State Footprint Accounts show California to have a smaller per capita Footprint: 5.9 gha. This Ecological Footprint would rank California as having the world's 15th largest Ecological Footprint per person, about equal to the Irish or Swedish average. The breakdown of the area types in the United States and California Ecological Footprints are shown in Figures 2 and 3.

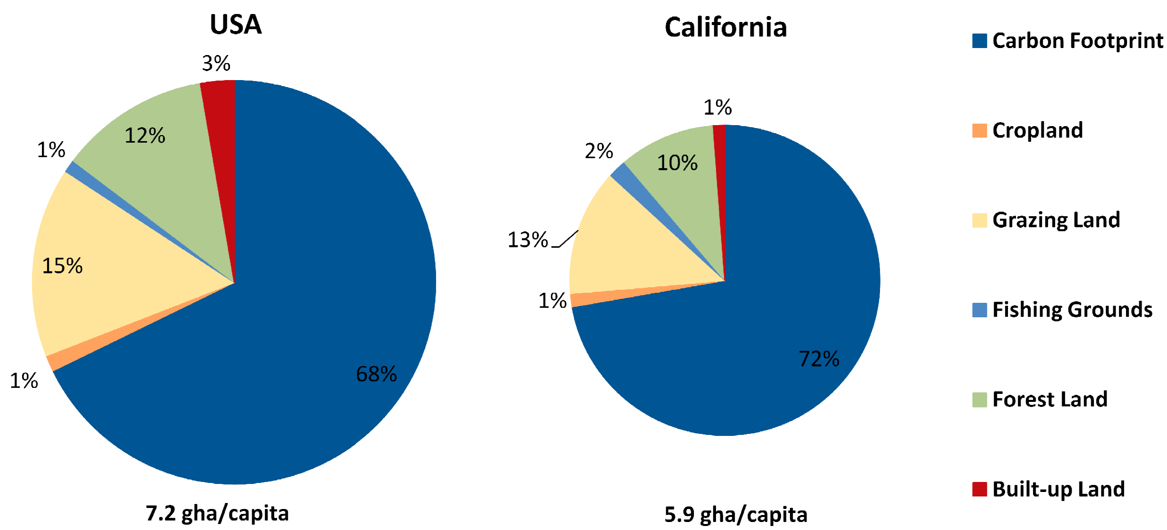

Figure 2 - The Ecological Footprint of the United States of America and California by area type as a portion of the Ecological Footprint, 2008. *(Bottom-up analysis results.)*

Most of the difference between the national average and Californian per capita Ecological Footprint can be explained by a lower amount of carbon dioxide emissions per person in California; the carbon component of California's Ecological Footprint (its carbon Footprint) is 0.6 gha per person lower than the United States average.

However, surprising results, such as that California consumes 35 percent less agricultural and fish products (in gha), may be due to state level trade data which are of a lower resolution (e.g., trade data are aggregated into a single product category) than the national-level datasets (which have many products categories).

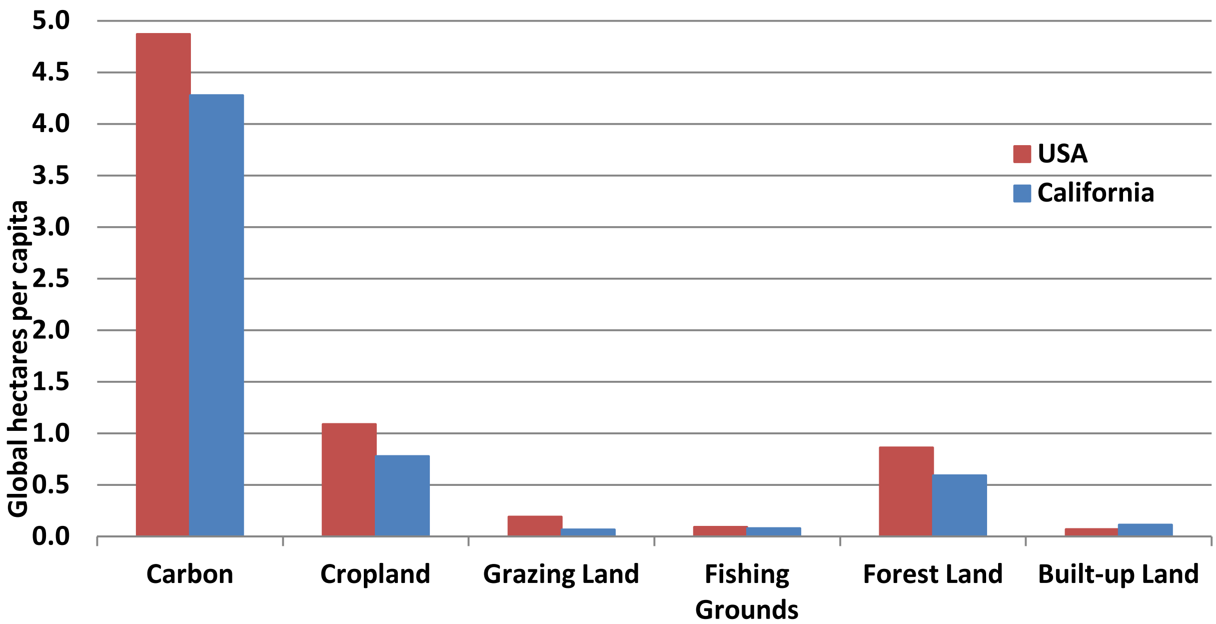

Figure 3 - The Ecological Footprint of the United States and California by area type, per capita, 2008.

3.1.1.1 Biocapacity

California's per capita biocapacity is much less than that of the United States: 1.0 gha, compared to 3.9 gha. The contribution of each area type is shown in Figure 4. This discrepancy is mostly due to the high population density in California and the aridity of much of its landscapes.

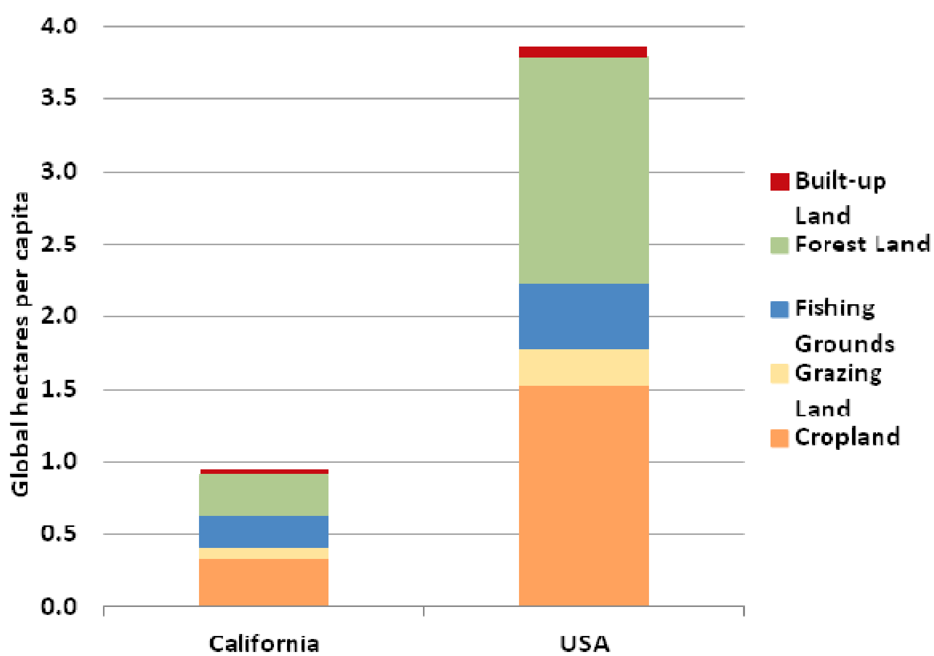

Figure 4 - Biocapacity of California and the United States by area type, per capita, 2008.

This is highlighted when looking at available biocapacity per unit of land area. The average biocapacity density in the United States is about 1.2 global hectares per hectare. This means each hectare of surface of the United States (including all areas, even those that do not contribute to biocapacity such as deserts) is on average worth 1.2 global hectares. In contrast, the biocapacity density of California is slightly lower, only about 0.9 global hectares per hectare.

3.2 California CLUM

Table 1 shows the Consumption Land Use Matrix (CLUM) for California. In this table, top level row categories are highlighted in grey: Food, Housing, Personal Transportation, Goods and Services. Each top-level category is further broken down into sub-categories given by COICOP classifications.

Two categories of particular interest are "Electricity, gas and other fuels" under Housing, and "Operation of personal transport equipment" under Personal Transportation.

These categories include direct emissions from households due to fossil fuel combustion (e.g., gasoline for transportation and natural gas for heating) which are not passed through the IO analysis. These direct emissions are converted into global hectares (gha) in supplemental analysis and then added to the CLUM.

The columns list each area type and the total, with each cell referring to the Ecological Footprint for a certain area type resulting from final purchases falling within each consumption category. For example, the forest land Footprint associated with recreational equipment is 0.11 gha per capita.

The Ecological Footprint of households makes up 72 percent of California's Ecological Footprint, with Government and Gross Fixed Capital making up the remaining 8 percent and 20 percent respectively. Looking at the consumption categories for household consumption, Personal Transportation has the largest Footprint (30 percent of household consumption), and not surprisingly most of this is carbon (Figure 5 below). We can see in the CLUM (Table 1) that most of the Footprint of Personal Transport is from operation of personal vehicles.

A more detailed presentation of the results of these analyses is published in a separate report (*The Ecological Footprint and Biocapacity of California, 2013 – Global Footprint Network*).

Table 1 - California's Consumption Land Use Matrix, 2008. The results as presented may not sum exactly due to rounding.

Consumption category	Crop-land	Grazing land	Forest products	Fishing grounds	Built-up land	Carbon Footprint	TOTAL
Food	0.58	0.08	0.01	0.05	0.00	0.15	0.88
Food	0.48	0.06	0.01	0.04	0.00	0.12	0.71
Non-alcoholic beverages	0.04	0.01	0.00	0.00	0.00	0.01	0.06
Alcoholic beverages	0.06	0.01	0.00	0.01	0.00	0.02	0.11
Housing	0.01	0.00	0.11	0.00	0.00	0.64	0.77
Actual rentals for housing	0.00	0.00	0.00	0.00	0.00	0.04	0.04
Imputed rentals for housing	0.00	0.00	0.00	0.00	0.00	0.10	0.11
Maintenance and repair of the dwelling	0.00	0.00	0.09	0.00	0.00	0.06	0.16
Water supply and miscellaneous dwelling services	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Electricity, gas and other fuels	0.00	0.00	0.01	0.00	0.00	0.40	0.41
Service for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Personal Transportation	0.06	0.01	0.04	0.01	0.01	1.17	1.30
Purchase of vehicles	0.01	0.00	0.01	0.00	0.00	0.05	0.07
Operation of personal transport equipment	0.05	0.01	0.03	0.01	0.01	0.83	0.92
Transport services	0.00	0.00	0.00	0.00	0.00	0.30	0.30
Goods	0.14	0.06	0.18	0.01	0.01	0.44	0.84
Clothing	0.04	0.03	0.01	0.00	0.00	0.07	0.16
Footwear	0.01	0.00	0.00	0.00	0.00	0.01	0.02
Furniture, furnishings, carpets etc.	0.01	0.01	0.01	0.00	0.00	0.03	0.05
Household textiles	0.01	0.00	0.00	0.00	0.00	0.01	0.02
Household appliances	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Glassware, tableware & household utensils	0.00	0.00	0.00	0.00	0.00	0.10	0.10
Tools and equipment for house & garden	0.00	0.00	0.02	0.00	0.00	0.01	0.03
Medical products, appliances & equipment	0.00	0.00	0.00	0.00	0.00	0.02	0.03
Telephone & telefax equipment	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Audio-visual, photo & info. Processing equipment	0.00	0.00	0.01	0.00	0.00	0.04	0.05
Other major durables for recreation & culture	0.00	0.00	0.00	0.00	0.00	0.05	0.06
Other recreational equipment etc.	0.02	0.01	0.11	0.00	0.00	0.05	0.19
Newspapers, books & stationery	0.00	0.00	0.01	0.00	0.00	0.01	0.02
Goods for household maintenance	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Tobacco	0.05	0.01	0.00	0.00	0.00	0.02	0.09
Services	0.15	0.02	0.09	0.02	0.02	0.39	0.69
Out-patient services	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Hospital services	0.00	0.00	0.00	0.00	0.00	0.03	0.04
Postal services	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Telephone & telefax services	0.00	0.00	0.00	0.00	0.00	0.01	0.01
Recreational & cultural services	0.02	0.00	0.00	0.00	0.00	0.00	0.03
Package holidays	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Education	0.01	0.00	0.01	0.00	0.00	0.08	0.11
Catering services	0.06	0.01	0.01	0.01	0.00	0.01	0.11
Accommodation services	0.01	0.00	0.00	0.00	0.00	0.00	0.01
Personal care	0.01	0.00	0.01	0.00	0.00	0.05	0.07
Personal effects nec	0.01	0.00	0.04	0.00	0.00	0.02	0.07
Social protection	0.01	0.00	0.01	0.00	0.00	0.07	0.10
Insurance	0.01	0.00	0.00	0.00	0.00	0.04	0.05
Financial services nec	0.00	0.00	0.00	0.00	0.00	0.03	0.03
Other services nec	0.00	0.00	0.00	0.00	0.00	0.01	0.02
Sub-total Household Consumption	0.95	0.17	0.44	0.09	0.05	2.80	4.49
Government	0.05	0.01	0.03	0.00	0.01	0.38	0.47
Gross Fixed Capital Formation	0.08	0.01	0.38	0.00	0.02	0.74	1.23
Total	**1.08**	**0.19**	**0.84**	**0.09**	**0.07**	**3.91**	**6.18**

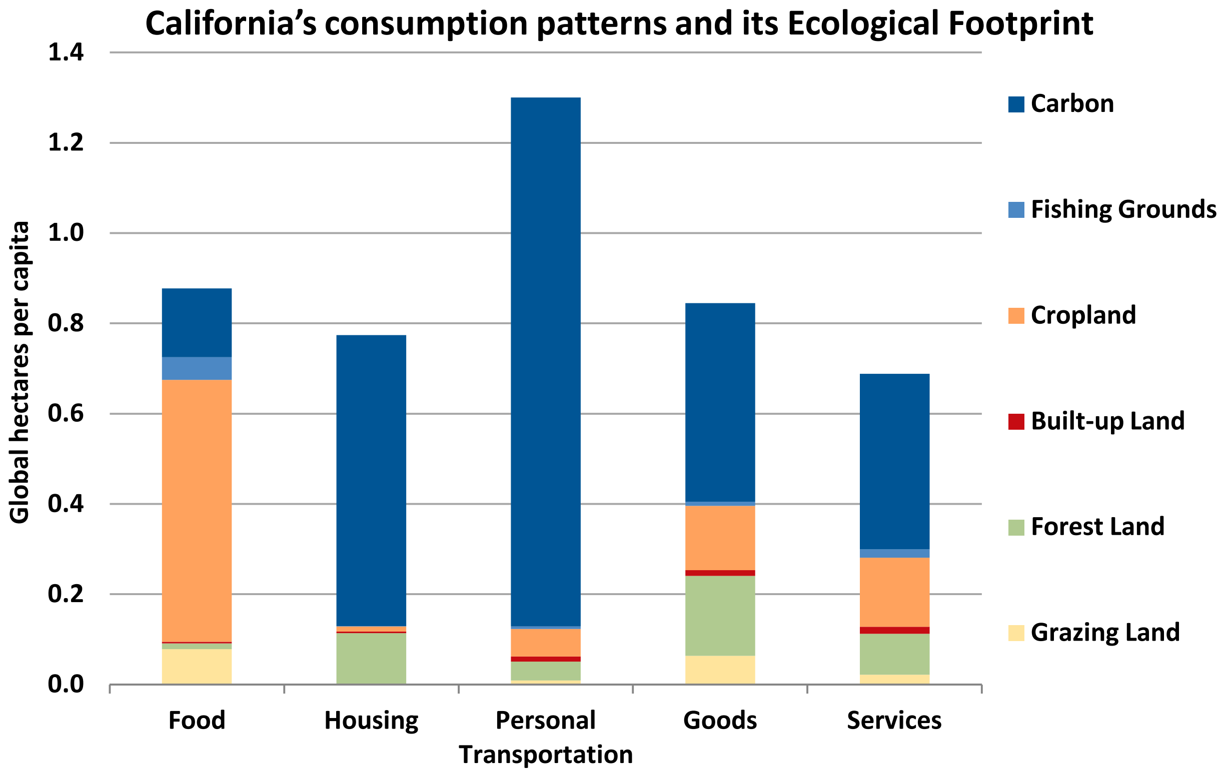

Figure 5 - California's Ecological Footprint by consumption category for consumables paid for by household, per capita, 2008. *(Top-down analysis results.)*

3.3 Comparing the bottom-up and top-down methodologies

Comparing the results obtained with the bottom-up methodology to results obtained with the top-down approach provides substantial validation of the results described above. Typically, top-down and bottom-up estimates differ by 10–15 percent at a national level, which is a function of the different ways that trade is estimated. For the estimate of California's Ecological Footprint, the results from these two methodologies differ by only 5 percent.

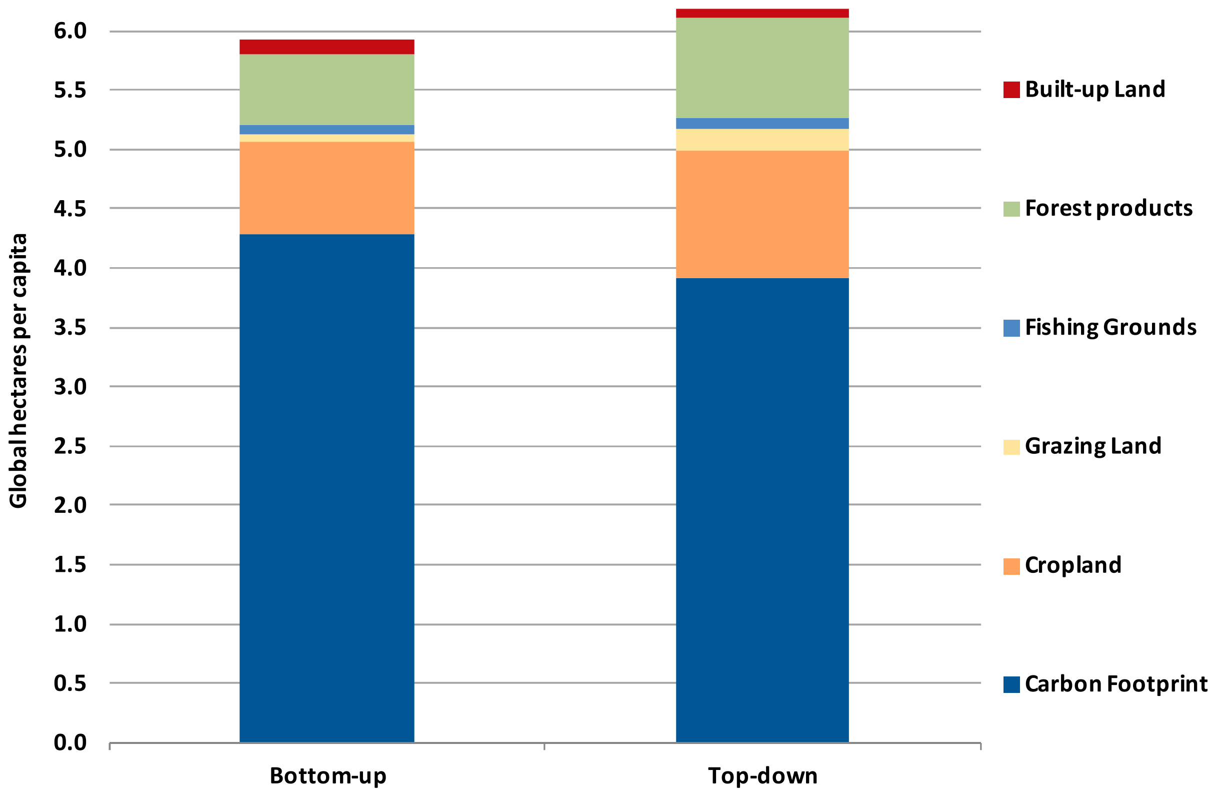

Figure 6 – California's Footprint: Comparison of per capita results from bottom-up and top-down methodologies, 2008.

Using the top-down approach the estimation for California's per capita Ecological Footprint was 6.18 gha. The similarity of the results of these two methodologies indicates that a relatively high level of confidence in the bottom-up California State Footprint Accounts can be assumed. Since a California CLUM was derived in this analysis, these results could also be used as a starting point for sector-level analysis of California's Ecological Footprint.

However, as Figure 6 shows, there are differences in the individual area types. The largest percentage difference is in grazing land, but there are large differences in cropland and forest land as well (Table 2 below). These large differences are most likely the result of low resolution trade data.

Because the trade data used in the bottom-up analysis for these area types were aggregated into single product categories ("All Crop Products" for crop products instead of the 413 separate crop products used in the NFA, "All products" for forest land products instead of 30 forest products used in the NFA, and "Animals Live" instead of the 157 products used in the NFA), the level of precision for the relative Footprint intensity (gha per annual tonne) of traded products is compromised.

Consider cropland, where different crops have different yields (and by extension, different Footprint intensities). The Footprint of imports and exports is influenced by the specific combinations of products that are traded and their relative intensities. Examples of crop products with low world average yields are vanilla (0.09 t/ha per year) and cashews (0.22 t/ha per year), compared to products with high world average yields like mushrooms and truffles (280 t/ha per year) and sugar cane (59 t/ha per year). Without a large number of crop products in the trade data; when all crops are grouped into one broad category these differences in yields are not captured, and the Footprint intensity of traded items loses precision. The impact of these differences in yield on the Footprint of consumption is most notable in countries/regions/populations that are large importers or exporters.

For example, if California imports more crops of a higher intensity, the cropland Footprint as calculated with the bottom-up analysis would be higher (and might be closer to the cropland Footprint as calculated using the top-down approach).

Table 2 - Differences in the California consumption Footprint per person calculated via the bottom-up vs. the top-down approach by area type, 2008.

Area type	Bottom-up	Top-down	Difference (gha/capita)	Difference (between methodologies)
Carbon Footprint	4.28	3.91	0.37	9%
Cropland	0.78	1.08	-0.30	-39%
Grazing Land	0.07	0.19	0.12	-169%
Fishing Grounds	0.08	0.09	-0.01	-14%
Forest Products	0.59	0.84	-0.25	-42%
Built-up Land	0.12	0.07	0.05	42%
Total	**5.92**	**6.18**	**-0.26**	**-4%**

3.3.1 Conclusion

Despite these differences between the two methodologies for each individual land use, overall the total Ecological Footprint values are close. When estimating the Footprint of consumption, due to the weakness in trade data used in the bottom-up analysis described throughout this report and the lack of data that show federal government expenditures, using the top-down methodology likely produces more precise results.

However, the bottom-up methodology is useful for determining the Footprint of production and available biocapacity. In-depth comparisons of these two values (by area type) would shed light on the use of resources within the state of California and link final demands for economic productivity and household consumption to the provisioning services of ecosystems within the state.

4 Recommendations and future analysis

4.1 Economic productivity and biocapacity

Although California has a large economy and benefits in the short-term from increases in crop prices, it is still reliant on imports. This exposes the state economy to long-term risk when global resource prices increase. Global resource prices include the cost of oil, seeds and all of the inputs to California's agricultural system. Based on data availability, some things can be monitored to assess this vulnerability:

- Evaluate Footprint of Production vs. GDP.
- Evaluate the costs of inputs like water and fossil fuel compared to Footprint production.
- To what extent are we losing ecological capital needed to maintain high productivity (ground water, soil, etc.)?

4.2 Sector-level analysis

Specific to the bottom-up Ecological Footprint analysis, there were two areas where further analysis could have been done but were beyond the scope and budget for this project:

- Identification of sources for trade data of higher resolution (e.g., including many more product categories).
- Further investigation into the grazing land calculation for the state, namely identifying data sources for imports of crop residues and examining feed mixes for livestock that produce dairy (and meat).
- Adjustments for the California carbon intensity of production. Now, the carbon intensity of energy production (used for exports) was taken from the National Footprint Account for the Unites States. This could be improved and made more specific to California.

Specific to the top-down IO-based analysis, closer examination of the CLUM results can highlight which activities contribute most to the Ecological Footprint, and these pressure points can be traced to the respective industrial sector(s) that provide goods and services used in these activities.

4.3 Replication with other states

The top-down methodology described here could be applied to other U.S. states with little additional work. There will be some restrictions on states with low populations, since the Census Bureau is not allowed to identify consumer habits of small groups. However, this is not an issue for most states.

The bottom-up methodology, as noted above, is highly dependent upon agricultural and trade statistics. Many states appear to have agricultural data sources for production similar to those used for this project; however, inter-state trade statistics are less available. States that have a lot of trade through their borders but aren't necessarily large final consumers will be especially difficult to measure accurately.

However, Footprint of production and biocapacity estimates (which cannot be obtained with the top-down method) are of great importance in determining sustainability of production, and this analysis appears to be more feasible across states. The recommended approach to state Ecological Footprint analysis is therefore to estimate biocapacity and Footprint of production using a bottom-up approach, but to estimate consumption using the top-down approach.

4.4 Economic implications

This report documents the biocapacity situation for California. The next question would be to explore: What does this situation (and trends in this situation) mean for California's economic and social health? How significant are the economic risks of running at the current biocapacity deficit, particularly considering that the world as a whole is running in ecological overshoot?

Appendix A: Comparison of California and standard NFA data sources

Subject	CA Data Source	CA Data Classification	NFA Data Source	NFA Data Classification
CO_2 emissions	California EPA. Air Resources Board, Greenhouse Gas Inventory	2006 IPCC Guidelines	International Energy Agency	IEA sector
Embodied CO_2 in traded commodities	U.S. Census Bureau, Commodity Flow Survey	Standard Classification of Transported Goods (SCTG)	United Nations COMTRADE, International Merchandise Trade Statistics	Standard International Trade Classification (SITC)
Crop and livestock production	California Department of Food and Agriculture, Agriculture Resource Directory	No codes given. Manual matching based on names	Food and Agriculture Organization, FAOSTAT	FAO codes (Harmonized System [HS+] codes also available)
Crop and livestock exports	Agricultural Issues Center, UC Davis	No codes given. Manual matching based on names	Food and Agriculture Organization, FAOSTAT	FAO codes (Harmonized System [HS+] codes also available)
Crop and livestock imports	Surface Transportation Board, U.S. Department of Transportation, Carload Waybill Sample	Standard Transportation Commodity Code (STCC)	Food and Agriculture Organization, FAOSTAT	FAO codes (Harmonized System [HS+] codes also available)
Fish production	U.S. National Oceanic and Atmospheric Administration U.S. Fisheries, Department of Science and Technology, Annual Commercial Landing Statistics.	No codes given. Manual matching based on common names	Food and Agriculture Organization Fisheries and Aquaculture, FishSTAT	No classification used. Matching based on scientific nomenclature
Fish trade	National Oceanic and Atmospheric Administration Fisheries. Department of Science and Technology. Annual Trade Data.	No codes given. Manual matching based on common names	Food and Agriculture Organization Fisheries and Aquaculture, FishSTAT	No classification used. Matching based on common group names
Forest product production	California Forestry Association. California Timber Harvest Statistics	No codes since only total volumes used	Food and Agriculture Organization, FAOSTAT	FAO codes

Additional data related to the estimation of biocapacity for California include the following:

Land cover data (direct links are within the spreadsheet)

- Area of cropland is taken from the CDFA Agricultural Resource Directory
- Areas of grazing land and forest land are taken from the University of California, Division of Agricultural and Natural Resources

- Area of continental shelf is taken as the U.S. continental shelf area multiplied by the ratio of the length of California coastline to the length of the U.S. coastline, as reported by the National Oceanic and Atmospheric Administration
- Area of inland lakes is taken from the U.S. Census Bureau
- Area of infrastructure is determined by combining Global Land Cover raster data with the California boundaries taken from the U.S. Census Bureau

Yield data (direct links are within the spreadsheet)

- Crop yields are calculated from data taken from the CDFA Agricultural Resource Directory
- Grassland yields are taken from the Global Land Cover Facility: Global Inventory Modeling and Mapping Studies (GIMMS). The data used are the Normalized Differenced Vegetation Index, combined with the California boundaries taken from the U.S. Census Bureau. This index is also used by the Plant Growth Index
- Forest yields (Net Annual Increment) are taken from the California Department of Forestry and Fire Protection: Fire and Resource Assessment Program
- California's marine yields are assumed to be the same as for the United States as a whole. This portion could potentially be refined by using marine Net Primary Production maps and combining with a California continental shelf boundary file, should one be found.

Appendix B: Equations used in bottom-up methodology

The following provides more detail and some equations used in both the National Footprint Accounts (NFA) and the California State Footprint Account (SFA). This section is taken from the Calculation Methodology for the National Footprint Accounts, 2011 Edition (Borucke, et. al., 2012).

Areas where there are major differences between the NFA and SFA are marked by a →.

The indented bullets following each equation are references to examples of how the equation is used in the SFA workbook; these are examples and are not comprehensive lists of all of the worksheets in the workbook where the equations/concepts are used. More explanation of the layout and presentation of information in the SFA workbook are in Appendix C.

Footprint of production

For a given nation, the Ecological Footprint of production, EF_P, represents direct demand for domestic/local biocapacity and is calculated as:

$$EF_P = \sum_i \frac{P_i}{Y_{N,i}} \cdot YF_{N,i} \cdot EQF_i = \sum_i \frac{P_i}{Y_{W,i}} \cdot EQF_i \qquad \text{(Equation 1)}$$

where P is the amount of each primary product i that is harvested (or carbon dioxide emitted) in the nation; $Y_{N,i}$ is the annual national average yield per hectare for the production of commodity i (or its carbon uptake capacity in cases where P is CO_2); $YF_{N,i}$ is the country-specific yield factor for the production of each product i; $Y_{W,i}$ is the average world yield for commodity i; and EQF_i is the equivalence factor for the area type producing products i.

The equivalence of the second and third terms in Equation 1 arises from the definition of $YF_{N,i}$ as the ratio: $Y_{N,i}/Y_{W,i}$. It is this last simplification that is used in the NFA calculations.

- ❖ SFA workbook locations: crop_efp, fish_marine_efp, fish_inland_efp, forest_efp (columns labeled 'EF_P')

Yield factors

Yield factors (YFs) account for countries' differing levels of productivity for particular area types.[9] YFs are country-specific and vary by area type and year. They may reflect natural factors such as differences in precipitation or soil quality, as well as anthropogenic differences such as management practices.

The YF is the ratio of national average to world average yields. It is calculated in terms of the annual availability of usable products. For any area type L, a country's yield factor YF_L, is given by

[9] For example, the average hectare of pasture in New Zealand produces more grass than a world average hectare of pasture land. Thus, in terms of productivity, one hectare of grassland in New Zealand is equivalent to more than one world average grazing land hectare; it is potentially capable of supporting more meat production.

$$YF_L = \frac{\sum_{i \in U} A_{W,i}}{\sum_{i \in U} A_{N,i}} \qquad \text{(Equation 2)}$$

where U is the set of all usable primary products that a given area type yields, and $A_{W,i}$ and $A_{N,i}$ are the areas necessary to furnish that country's annually available amount of product i at world and national yields, respectively. These areas are calculated as

$$A_{N,i} = \frac{P_i}{Y_{N,i}} \text{ and } A_{W,i} = \frac{P_i}{Y_{W,i}} \qquad \text{(Equation 3)}$$

where P_i is the total national annual growth of product i, and $Y_{N,i}$ and $Y_{W,i}$ are national and world yields for the same product, respectively. Thus $A_{N,i}$ is always the area that produces a given product i within a given country, while $A_{W,i}$ gives the equivalent area of world-average land yielding the same product i.

- ❖ SFA workbook location: yf_crop (column titled 'Yield factor')

With the exception of cropland, all area types included in the California State Footprint Accounts provide only a single primary product i, such as wood from forest land or grass from grazing land. For these area types, the equation for the YF simplifies to

$$YF_L = \frac{Y_{N,i}}{Y_{W,i}} \qquad \text{(Equation 4)}$$

Due to the difficulty of assigning a yield to built-up land, the YF for this area type is assumed to be the same as that for cropland (in other words urban areas are assumed to be built on or near productive agricultural lands). For lack of detailed global datasets, areas inundated by hydroelectric reservoirs are presumed to have previously had world average productivity. All inland waters are assigned a YF of one, due to the lack of a comprehensive global dataset on freshwater ecosystem productivities. The full set of Yield Factors for California is shown in Table 1, which are derived from the data sources listed at the end of Appendix A.

Table A. - Yield factors specific to the California State Footprint Accounts for 2008

Area Type	Yield Factor (world hectares per hectare)
Cropland and built-up land	1.57
Forest	0.49
Grazing Land	0.76
Marine	1.34
Inland Water	1.00

- ❖ SFA workbook location: yf (column titled 'Yield factor')

Equivalence factors

In order to combine the Ecological Footprint or biocapacity of different land-use types, a second coefficient is necessary (Galli et al., 2007). Equivalence factors (EQFs) convert the areas of different area types, at their respective world average productivities, into their equivalent areas at global average bioproductivity across all area types. EQFs vary by area type as well as by year.

The rationale behind EQF calculation is to weight different land areas in terms of their inherent capacity to produce human-useful biological resources. The weighting criterion is not the actual quantity of biomass produced, but what each hectare would be able to inherently deliver.

As an approximation of inherent capacity, EQFs are currently calculated using suitability indexes from the Global Agro-Ecological Zones model combined with data on the actual areas of cropland, forest land and grazing land area from FAOSTAT (FAO and IIASA, 2000; FAO ResourceSTAT Statistical Database 2008). The GAEZ model divides all land globally into five categories, based on the maximum yield from rain-fed agriculture and minimal agricultural inputs. All land is assigned a quantitative suitability index from among the following:

- Very Suitable (VS) – 0.9
- Suitable (S) – 0.7
- Moderately Suitable (MS) – 0.5
- Marginally Suitable (mS) – 0.3
- Not Suitable (NS) – 0.1

The calculation of the EQFs assumes that within each country the most suitable land available will be planted to cropland, after which the most suitable remaining land will be under forest land, and the least suitable land will be devoted to grazing land. The EQFs are calculated as the ratio of the world average suitability index for a given area type to the average suitability index for all area types.

For the reasons detailed above, the EQF for built-up land is set equal to that for cropland, except if there is clear evidence that built-up land does not sit on cropland. EQF for the carbon Footprint (or carbon uptake land) is set equal to that of forest land since carbon sequestration is assumed to draw on forest area. The EQF for hydroelectric reservoir area is set equal to one, reflecting the assumption that hydroelectric reservoirs flood world average land. The EQF for marine area is calculated such that the amount of calories of salmon that can be produced by a single global hectare of marine area will be equal to the amount of calories of beef produced by a single global hectare of pasture. This is based on the assumption that a calorie from animal protein from land and from sea would be considered to be of equivalent resource value to people. The EQF for inland water is set equal to that of marine area.

Table 2 shows the EQFs for the area types in the 2011 California State Footprint Accounts, data year 2008.

Table B. - Equivalence factors used in the California State Footprint Accounts for 2008

Area Type	Equivalence Factor (global hectares per hectare)
Cropland	2.51
Forest	1.26
Grazing Land	0.46
Marine & Inland Water	0.37
Built-up Land	2.51

Cropland's EQF of 2.51 indicates that world-average cropland productivity was more than double the average productivity for all bioproductive area combined. This same year, grazing land had an EQF of 0.46, showing that grazing land was, on average, 46 per cent as productive as the world-average bioproductive hectare.

- ❖ SFA workbook location: eqf. Note that the actual calculation of EQFs is done outside of the SFA template.

Footprint of consumption

All manufacturing processes rely to some degree on the use of biocapacity to provide material inputs and remove wastes at various points in the production chain. Thus all products carry with them an embodied Footprint, and international trade flows can be seen as flows of embodied demand for biocapacity.

In order to keep track of both the direct and indirect biocapacity needed to support people's consumption patterns, the California State Footprint Accounts use a consumer-based approach; for each area type, the Ecological Footprint of consumption (EF_C) is thus calculated as

$$EF_C = EF_P + EF_I - EF_E \qquad \text{(Equation 5)}$$

where EF_P is the Ecological Footprint of production and EF_I and EF_E are the Footprints embodied in imported and exported commodity flows, respectively. For each traded product, EF_I and EF_E are calculated as in Equation 1, with Production P being the amount of product imported or exported, respectively.

The Ecological Footprint Accounts calculate the Footprint of apparent consumption, as data on stock changes for various commodities are generally not available. One of the advantages of calculating Ecological Footprints at the national level is that this is the level of aggregation at which detailed and consistent production and trade data are most readily available.

- ❖ SFA workbook locations: ef_carbon, ef_crop, ef_grazing, ef_fish, ef_forest, ef_built (columns titled 'EF_C').

Extraction rates [derived products]

A variety of derived products are also tracked in the NFA, for which production yields (Y_W) have to be calculated before implementation of Equation 1. Primary and derived goods are related by product specific extraction rates. The extraction rate for a derived product, $EXTR_D$, is used to calculate its effective yield as follows:

$$Y_{W,D} = Y_{P,D} \cdot EXTR_D \qquad \text{(Equation 6)}$$

where $Y_{W,D}$ and $Y_{W,P}$ are the world-average yield for the derived and the primary product, respectively.

- ❖ SFA workbook locations: crop_trade_yield_w, crop_yield_n, crop_yield_w, forest_yield_n, forest_yield_w (columns titled 'Yield')

Often $EXTR_D$ is simply the mass ratio of derived product to primary input required. This ratio is known as the technical conversion factor (FAO, 2000) for the derived product, denoted as TCF_D below. There are a few cases where multiple derived products are created simultaneously from the same primary product. For example, soybean oil and soybean cake are both extracted simultaneously from the same primary product, in this case soybean. In this situation, summing the primary product equivalents of the derived products would lead to double counting. To resolve this problem, the Ecological Footprint of the primary product must be shared between the simultaneously derived goods. The generalized formula for the extraction rate for a derived good D is

$$EXTR_D = \frac{TCF_D}{FAF_D} \qquad \text{(Equation 7)}$$

where FAF_D is the Footprint allocation factor.

- ❖ SFA workbook locations: constant_forest_extr,

This allocates the Footprint of a primary product between simultaneously derived goods according to the TCF-weighted prices. The prices of derived goods represent their relative contributions to the incentive for the harvest of the primary product. The equation for the Footprint allocation factor of a derived product is

$$FAF_D = \frac{TCF_D \cdot V_D}{\sum TCF_i \cdot V_i} \qquad \text{(Equation 8)}$$

where V_i is the market price of each simultaneous derived product. For a production chain with only one derived product, then, FAF_D is 1 and the extraction rate is equal to the technical conversion factor. Note that calculations done with market prices are separate from the SFA workbook.

Biocapacity

For a given country, the biocapacity BC is calculated as follows:

$$BC = \sum_i A_{N,i} \cdot YF_{N,i} \cdot EQF_i \qquad \text{(Equation 9)}$$

where $A_{N,i}$ is the bioproductive area that is available for the production of each product *i* at the country level, $YF_{N,i}$ is the country-specific yield factor for the land producing products *i,* and EQF_i is the equivalence factor for the area type producing each product *i*.

- ❖ SFA workbook locations: biocap (column titled 'Biocapacity')

Total demand for pasture grass [grazing land]

The total demand for pasture grass, P_{GR}, is the amount of biomass required by livestock after cropped feeds are accounted for, following the formula:

$$P_{GR} = TFR - F_{Mkt} - F_{Crop} - F_{Res} \quad \text{(Equation 10)}$$

where *TFR* is the calculated total feed requirement, and F_{Mkt}, F_{Crop} and F_{Res} are the amounts of feed available from general marketed crops, crops grown specifically for fodder, and crop residues, respectively.

- ❖ SFA workbook locations: feed_demand_n (this worksheet has all of the variables for P_{GR} and references feed_mix_w to calculate the variables)

Within the National Footprint Accounts, the assumption is made that since the yield of grazing land represents the amount of above-ground primary production available in a year, and there are no significant prior stocks to draw down, overshoot in grazing land is not physically possible over extended periods of time. For this reason, a country's grazing land Footprint of production is prevented from exceeding local grazing land biocapacity.

The grazing land calculation is the most complex in the National Footprint Accounts and significant improvements have taken place over the past seven years, including total feed requirement updates, inclusion of fish and animal products used as livestock feed and inclusion of livestock food aid (see Gracey et al. 2012 for further details).

→ The main point of divergence of the California State Account from the National Footprint Accounts relates to a lack of detailed data on the use of crop feed for animals produced within the state. Hence, no balancing equations were made to determine the quantity of grass feed actually used by livestock. Instead, the estimate was just based on the average global grass demand per animal (of each species). This is a weakness of the bottom-up analysis due to the difficulty of quantifying imports of feed ingredients for dairy and other confined animal feeding operations.

Primary production requirement [fishing grounds]

The fishing grounds Footprint is calculated based on the annual primary production required to sustain a harvested aquatic species. This primary production requirement, denoted *PPR*, is the mass ratio of harvested fish to annual primary production needed to sustain that species, based on its average trophic level. Equation 11 provides the formula used to calculate *PPR*. It is based on the work of Pauly and Christensen (1995).

$$PPR = CC \cdot DR \cdot \left(\frac{1}{TE}\right)^{(TL-1)}$$ (Equation 11)

where CC is the carbon content of wet-weight fish biomass, DR is the discard rate for bycatch, TE is the transfer efficiency of biomass between trophic levels, and TL is the trophic level of the fish species in question.

In the California State Footprint Accounts, DR is assigned the global average value of 1.27 for all fish species, meaning that for every ton of fish harvested, 0.27 tonnes of bycatch are also harvested (Pauly and Christensen 1995). This bycatch rate is applied as a constant coefficient in the PPR equation, reflecting the assumption that the trophic level of the bycatch is the same as that of the primary catch species. These approximations are employed for lack of higher resolution data on bycatch. TE is assumed to be 0.1 for all fish, meaning that 10 percent of biomass is transferred between successive trophic levels (Pauly and Christensen, 1995).

- ❖ SFA workbook locations: fish_group_yield_n, fish_group_yield_w, fish_feed_group_yield_n, fish_feed_group_yield_w (columns titled 'PPR')

Sustainable harvestable primary production requirement [fishing grounds]

The estimate of annually available primary production used to calculate marine yields is based on estimates of the sustainable annual harvests of 19 different aquatic species groups (Gulland, 1971). These quantities are converted to primary production equivalents using Equation 11, and the sum of these is taken to be the total primary production requirement that global fisheries may sustainably harvest. Thus the total sustainably harvestable primary production requirement, PP_S, is calculated as

$$PP_S = \sum \left(Q_{S,i} \cdot PPR_i \right)$$ (Equation 12)

where $Q_{S,i}$ is the estimated sustainable catch for species group i, and PPR_i is the primary production requirement corresponding to the average trophic level of species group i.

- ❖ SFA workbook location: cnst_fish (column titled 'Available Primary Productivity')

This total harvestable primary production requirement is allocated across the continental shelf areas of the world to produce biocapacity estimates. Thus the world-average marine yield Y_M, in terms of PPR, is given by

$$Y_M = \frac{PP_S}{A_{CS}}$$ (Equation 13)

where PP_S is the global sustainable harvest from Equation 12, and A_{CS} is the global total continental shelf area.

- ❖ SFA workbook location: fish_group_yield_w (column titled 'Effective Yield W)

Significant improvements have taken place over the past seven years in the calculation of the fishing grounds section of the National Footprint Accounts: revision of many fish extraction rates, inclusion of aquaculture production and inclusion of crops used in aquafeeds (see Gracey et al. 2012 for further details on such improvements).

Carbon Sequestration Land of Production from CO_2 emissions

Analogous to Equation 1, the formula for the carbon Ecological Footprint (EF_{co2}) is

$$EF_{co2} = \frac{P_C \cdot (1 - S_{Ocean})}{Y_C} * EQF \qquad \text{(Equation 14)}$$

where P_C is the annual anthropogenic emissions (production) of carbon dioxide, S_{Ocean} is the fraction of anthropogenic emissions sequestered by oceans in a given year and Y_C is the annual rate of carbon uptake per hectare of world average forest land.

- SFA workbook location: fossil_efp (column titled 'EF_P')

Embodied Carbon Footprint

In the NFA embodied carbon emissions in traded goods are calculated by multiplying estimated embodied emissions by the world average carbon intensity of electricity and heat production. The embodied energy figure for each product category represents the sum of all energy use for production of a good up to the point at which it is traded.

→ The emissions embodied in products exported from California were taken from the US average carbon intensity (from the USA National Footprint Account for 2008).

The corresponding carbon Footprint was determined by using the global data on embodied energies and using a correspondence table to aggregate Standard International Trade Classification (SITC) to Standard Classification of Transported Goods (SCTG) codes (weighted by production at the US level). This was then multiplied by the various constants to get it in terms of gha (i.e. energy to tonnes of carbon dioxide per year to gha).

Appendix C: Guidance for State Footprint Accounts (SFA) workbook

The MS EXCEL workbook used to calculate the bottom-up Ecological Footprint for California is a replicate of the workbook template that is used for the 2011 edition of the National Footprint Accounts (NFA), modified to accommodate the California-specific data sources listed in APPENDIX A. This modified file is called a State Footprint Accounts (SFA) workbook.

The general layout and sequence of calculations in this SFA workbook follow what is described in the NFA Guidebook (Gracey, et al. 2012). The NFA Guidebook includes detailed descriptions of what is in each worksheet of the NFA template. What follows in this APPENDIX is guidance for the SFA workbook; these are top-level, general descriptions of the structure, hierarchy and formatting to help the user navigate through the calculations from the product (source data) to the Footprint (results).

Structure

This SFA workbook has 76 different worksheets that are divided into a hierarchical structure with five levels. Generally, worksheets in Level 1 depend on calculations in Level 2 worksheets, worksheets in Level 2 depend on calculations in Level 3 worksheets, and so on. Level 5 worksheets contain raw data drawn from outside the SFA 2011 workbook. These Level 5 worksheets do not contain any calculations, but rather serve as data sources for calculations in higher level worksheets. Worksheets are named descriptively according to their function within the Footprint and biocapacity calculation sequence.

In addition to being divided into levels, worksheets are divided into groups according to the major area type they represent. The six major area types are cropland, grazing land, forest land, fishing grounds, carbon and built-up land. Each of these six major area types has a single Level 2 worksheet, and an associated group of Level 3, 4 and 5 worksheets. The SFA 2011 workbook also contains a seventh Level 2 worksheet which performs the biocapacity calculations for all area types. Worksheets are color coded to aid in understanding their groupings. This color coding applies to all of the actual worksheet tabs in the SFA 2011 workbook.

Level 1 worksheet

There is only one Level 1 worksheet. The *summary* worksheet combines the calculated Ecological Footprint and biocapacity of each major area type.

The *summary* worksheet contains three tables and two charts. The first two tables each contain one row corresponding to each area type, with columns giving the Ecological Footprints of production, imports, exports and consumption, as well as biocapacity. The last row of each table sums each column and calculates Footprint and biocapacity totals. The first of these tables lists total Footprint and biocapacity for each area type, while the second reports a country's Footprint and biocapacity per person.

Below these two tables there is a third, smaller table that provides a broad overview of the results of the California Ecological Footprint calculation in both total area and area per person. The first two rows report biocapacity and Footprint of production for California and the world. The next row shows the net imports of the Footprint (this doesn't apply for World), and the fourth row summarizes the Footprint of consumption. The row labelled BC - EF_P shows the biocapacity minus the Ecological Footprint of production, which represents the unused local biocapacity (since CO_2 emissions can cross borders easily – like waste water being moved over a national boundary - the level of extraction beyond regeneration can be calculated by computing BC – EF_P – carbon $Footprint_P$. The final row, BC - EF_C, only applies to California and represents the net biocapacity that California has available after accounting for the amount taken by consumption.

To the right of this table is a simple tally of the number of planets required if everyone lived like the average California resident.

At the bottom of the sheet, the left chart illustrates the relative sizes of the Footprint of production, Footprint of consumption, net Footprint of imports and biocapacity. The pie chart to the right shows the relative contributions of each area type to the Footprint of consumption.

Level 2 Worksheets

The Level 2 worksheets summarize the Footprints of production, imports, exports and consumption. There are seven worksheets in total: one worksheet for each of the six area types; and a single worksheet for biocapacity, which calculates biocapacity for every area type except carbon. The worksheets that report the Footprints for the six area types are named with a prefix of *ef_* followed by the name of the area type. All level 2 worksheets rely on calculations from associated lower level worksheets.

- *ef_carbon* summarizes the carbon Footprint of fossil fuel use (both domestically emitted and embodied in traded goods).
- *ef_crop* summarizes the Footprint of cropland embodied in both crop and livestock products.
- *ef_grazing* summarizes the Footprint of pasture grass embodied in livestock products.
- *ef_fish* summarizes the Footprint of marine and inland water areas embodied in fish and other aquatic products.
- *ef_forest* summarizes the forest land Footprint embodied in primary and processed forest products.
- *ef_built* summarizes the Footprint associated with buildings, infrastructure and hydroelectric reservoir area.
- *biocap* reports California's actual bioproductive area and biocapacity in each of the six area types.

The structure of each of the six ef_ worksheets is very similar. Each worksheet reports the Footprint of production, imports, exports and consumption for the different sub-components (product categories, or more specific area types) that make up each area type. The final row in each table sums the Footprints of all sub-components to calculate a total Footprint for that area type. These totals are used in the *summary* worksheet. To the right of the summary table is a graphical representation of the flows of data that comprise each row, and below the table is a chart illustrating the overall resource throughput of each area type.

These six *ef_* worksheets apply an identical formula to calculate the Ecological Footprint of consumption from the Footprints of production, imports and exports. The Footprint of consumption is calculated according to **Equation 5** (above).

The Footprint of consumption of individual products or CO_2 emissions are summed to obtain an aggregate Footprint of consumption for a given land use category. Adding together the Footprints of all of the major land use categories gives the Footprint of California.

The single *biocap* worksheet displays a summary of the biocapacity calculation for each area type, using data on area, yield factors, intertemporal yield factors and equivalence factors. Below the table and the data flow graphics is a pie chart illustrating the relative composition of domestic biocapacity. The calculation of biocapacity follows **Equation 9** (above).

The calculated biocapacity of the major area types are summed to obtain an aggregate biocapacity for California.

Level 2 worksheets are *Blue* in the SFA workbook.

Level 3 Worksheets

In general, Level 3 worksheets convert tonnes of a product into the number of global hectares necessary to provide that product. Data used by Level 3 worksheets are usually drawn from Level 4 or 5 worksheets. Level 3, 4 and 5 worksheets hold a single table with multiple fields (columns) and records (rows). The first row of each table contains the column headings and is printed in bold type. The second row contains the units of each column, printed in gray, and the remaining rows contain the table's records. Each record is found in a single row, and generally begins with the item name and official code, if applicable, in the first and second column. These codes are drawn from supporting databases and the code classification system is noted in a comment on the column heading.

When necessary, a third column, labelled "Unit," may be used to indicate the units of a record, and a fourth column, labelled "Primary/Derived," may be used to indicate whether the record describes a primary product or a product derived from a primary product.

In general, the type of data contained in a Level 3 worksheet can be determined by its name. Most Level 3 worksheets begin with the name of the area type they pertain to (e.g., forest), followed by the suffixes _efp (for the Ecological Footprint of production), _efi (for the Ecological Footprint of imports), or _efe (for the Ecological Footprint of exports).

In calculating Footprints of production, imports and exports, Level 3 worksheets rely on the basic Ecological Footprint formula (**Equation 1** above).

Level 4 Worksheets

Level 4 worksheets contain intermediate calculations necessary between the raw data and the calculation of the Footprint. Many Level 4 worksheets contain yield calculations, which often involve using extraction rates to convert from derived to primary product quantities. Common naming conventions for Level 4 worksheets are:

- *Name of an area type followed by the suffix _yield_n or _yield_w*. These worksheets contain the national (_n) or world (_w) yields for the named area type, respectively. World-average yields are applied to all imports and exports in the National Footprint Accounts (and State Footprint Account), with the exception of certain broad categories of fish products.

- *Type of feed followed by the suffix supply_n or demand_n.* In the grazing land section, there are several worksheets that calculate either the amount of feed (residue, grass, etc.) produced in a country (supply_n) or the amount required by livestock in that country (demand_n).

Yields for primary products are calculated based on their respective yearly regeneration rates. For example, the yield for timber reflects the net annual accumulation of merchantable wood on a hectare of forest, not the amount of wood actually harvested from that hectare. Estimates of regeneration rates are used in the yield calculations for pasture land, fishing grounds, forest land and carbon sequestration land. Crop yields are unique in that they are calculated as actual production divided by harvested area; thus, harvest yields and regeneration rates are taken to be identical.

A variety of secondary and tertiary products (derived products) are also included in the Footprint calculations. For any derived product, yield is calculated by multiplying the yield of the primary product (Y^P) by the extraction rate (EXTR) of the derived product. World average extraction rates are currently used throughout to convert secondary products into their primary product equivalents. Extraction rates indicate the amount of the primary product embodied in the derived product. Yields of derived products are calculated using **Equation 6** (above).

Country-specific extraction rates would provide a greater level of accuracy in calculations of the Footprints of exports and consumption, but are not currently implemented. The Footprint of production is not affected by extraction rates, since derived products are not included in the Footprint of production to avoid double counting. The Footprint of imports is always calculated using world average extraction rates, as the NFA 2011 methodology does not use full bilateral trade data. Thus, only the Footprint of exports would be directly affected by including national extraction rates of derived products. The use of world average extraction rates overestimates the Footprint of exports for countries (or states) that produce derived products more efficiently than the world average. This in turn underestimates the Footprint of consumption. For countries (or states) which produce derived products less efficiently than the world average, the Footprint of consumption is overestimated.

Finally, there are a few cases where multiple derived products are created simultaneously from the same primary product. Soybean oil and soybean cake, for example, are extracted simultaneously from the same primary product, in this case soybean. The standard yield calculation procedure cannot be used in the case of simultaneously derived products, as doing so would lead to a double-counting of the total primary product used. As a consequence, the total amount of embedded primary product is split among each simultaneously derived product through Footprint Allocation Factors (FAFs). These use the relative commercial values of the derived products to allocate the Footprint of their shared primary product between them.

Level 5 Worksheets

Level 5 Worksheets contain the raw data that all higher level worksheets use in calculations. These worksheets typically contain data on production, imports and exports in the units of the product (i.e., tonnes for crop products or heads for animals), sometimes with additional information on the area required to produce those goods. When the various products in a table are reported in different units, an additional column specifies the units of each product.

The names of Level 5 worksheets generally begin with the name of a data source, followed by a suffix indicating the area type (e.g. prodstat_forest). These worksheets contain raw data from the named data source (e.g. ProdSTAT, IEA) that is used in the calculations for the named area type. A final _n suffix on a worksheet name indicates national data, while a _w suffix indicates world data (e.g. prodstat_forest_n or prodstat_forest_w). NOTE: Most of these worksheets have retained the NFA data source in the title of the worksheet tab, although the California-specific data source is identified at the top of the level 5 worksheets.

Constants Worksheets

Constants worksheets — worksheets that contain key constants used in calculations — fall outside of the overall worksheet hierarchy. Constants worksheets contain values in a variety of units and contain a column identifying these units.

The names of constants worksheets generally begin with the prefix *const_* followed by the name of an area type. These worksheets contain constants that are used by Level 3 and 4 worksheets in their calculations.

Those constants worksheets that are used exclusively for one area type are named with the prefix *const_* followed by the corresponding area type.

Other constants worksheets include data for multiple area types and are not named according to this convention. The following is list of all constants worksheets that are not specific to one land use:

- *eqf* contains a table of equivalence factors for the year of calculation.
- *yf* contains a table of yield factors for a given country and year.
- *yf_crop* contains additional calculations necessary to determine the yield factor for cropland.
- *iyf* contains intertemporal yield factors to equilibrate yields within a country and area type across time.
- *bioproductive_area* contains land area data used to calculate biocapacity.
- *popstat_n* contains populations for a given country and year.
- *popstat_w* contains the world population for a given year.

Appendix D: Glossary

Biological capacity (or biocapacity): The capacity of ecosystems to produce useful biological materials and to absorb waste materials generated by humans, using current management schemes and extraction technologies. "Useful biological materials" are defined as those used by the human economy. Hence what is considered "useful" can change from year to year (e.g., use of corn/maize stover for cellulosic ethanol production would result in corn stover becoming a useful material, and thus increase the biocapacity of maize cropland). The biocapacity of an area is calculated by multiplying the actual physical area by the yield factor and the appropriate equivalence factor. Biocapacity is usually expressed in global hectares.

Biologically productive land and water: The land and water (both marine and inland waters) area that supports significant photosynthetic activity and the accumulation of biomass used by humans. Non-productive areas as well as marginal areas with patchy vegetation are not included. Biomass that is not of use to humans is also not included. The total biologically productive area on land and water in 2008 was approximately 12 billion hectares.

Carbon Footprint (and carbon sequestration land): When used in Ecological Footprint studies, this term is synonymous with demand on CO_2 area. The phrase "Carbon Footprint" has been picked up in the climate change debate. Several web-calculators use the phrase "Carbon Footprint." Many just calculate tonnes of carbon, or tonnes of carbon per unit of currency, rather than the demand on bioproductive area.

Consumption: Use of goods or of services. The term consumption has different meanings, depending on the context. As commonly used in regard to the Footprint, it refers to the use of goods or services. A consumed good or service embodies all the resources, including energy, necessary to provide it to the consumer. In full life-cycle accounting, everything used along the production chain is taken into account, including any losses along the way. For example, consumed food includes not only the plant or animal matter people eat or waste in the household, but also that lost during processing or harvest, as well as all the energy used to grow, harvest, process and transport the food.

As used in Input-Output analysis, consumption has a strict technical meaning. Two types of consumption are distinguished: intermediate and final. According to the (economic) System of National Accounts terminology, intermediate consumption refers to the use of goods and services by a business in providing goods and services to other businesses. Final consumption refers to non-productive use of goods and services by households, the government, the capital sector and foreign entities.

Consumption Footprint: The most commonly reported type of Ecological Footprint, it is defined as the area used to support a defined population's consumption. The consumption Footprint (in gha) includes the area needed to produce the materials consumed and the area needed to absorb the waste associated with that consumption. The consumption Footprint of a nation is calculated in the National Footprint Accounts as a nation's primary production Footprint plus the Footprint of imports minus the Footprint of exports, and is thus, strictly speaking, a Footprint of apparent consumption. The national average or per capita Consumption Footprint is equal to a country's Consumption Footprint divided by its population.

Consumption Land Use Matrix: Starting with data from the National Footprint Accounts, a Consumption Land Use Matrix allocates the six major Footprint land uses (shown in the column headings in the table below, representing six area types of the Footprint (cropland, forests, etc.) to the Footprint consumption categories (row headings). Each consumption category can be disaggregated further into sub-categories. These matrices are often used as a tool to develop sub-national (e.g. state, county, city) Footprint assessments. In this case, national data for each cell is scaled up or down depending on the unique consumption patterns in that sub-national region.

Conversion factor: A generic term for factors that are used to translate a material flow expressed within one measurement system into another one. For example, a combination of two conversion factors —"yield factors" and "equivalence factors"— translates hectares into global hectares. The extraction rate conversion factor translates a secondary product into primary product equivalents.

Derived product: The product resulting from the processing of a primary product. For example wood pulp, a secondary product, is a derived product of roundwood. Similarly, paper is a derived product of wood pulp.

Ecological (or biocapacity) deficit/reserve: The difference between the biocapacity and Ecological Footprint of a region or country. An ecological deficit occurs when the Footprint of a population exceeds the biocapacity of the area available to that population. Conversely, an ecological reserve exists when the biocapacity of a region or country exceeds the Footprint of its population. If there is a regional or national ecological deficit, it means that the region or country is either importing biocapacity through trade, liquidating its own ecological assets, or emitting wastes into a global commons such as the atmosphere. In contrast to the national scale, the global ecological deficit cannot be compensated for through trade, and is therefore overshoot by definition.

Ecological Footprint: A measure of how much biologically productive land and water an individual, population or activity requires to produce all the resources it consumes and to absorb the waste it generates, using prevailing technology and resource management practices. The Ecological Footprint is usually measured in global hectares. Because trade is global, an individual or country's Footprint includes land or sea from all over in the world. Ecological Footprint is often referred to in short form as Footprint. "Ecological Footprint" and "Footprint" are proper nouns and thus should always be capitalized.

Ecological Footprint Standards: Specified criteria governing methods, data sources and reporting to be used in Footprint studies. Standards are established by the Global Footprint Network Standards Committees, composed of scientists and Footprint practitioners from around the world. Standards serve to produce transparent, reliable and mutually comparable results in studies done throughout the Footprint community. Where Standards are not appropriate, Footprint Guidelines should be consulted. For more information, consult www.footprintstandards.org.

Embodied energy: Embodied energy is the energy used during a product's entire life cycle in order to manufacture, transport, use and dispose of the product. Footprint studies often use embodied energy when tracking the trade of goods.

Equivalence factor: A productivity-based scaling factor that converts a specific area type (such as cropland or forest) into a universal unit of biologically productive area, a global hectare. For area types (e.g. cropland) with productivity higher than the average productivity of all biologically productive land and water area on Earth, the equivalence factor is greater than 1. Thus, to convert an average hectare of cropland to global hectares, it is multiplied by the cropland equivalence factor of 2.51. Grazing lands, which have lower productivity than cropland, have an equivalence factor of 0.46 (see also yield factor). In a given year, equivalence factors are the same for all countries.

Extraction rate: A processing factor comparing the quantity of a primary product to the quantity of the resulting derived product. When a primary product is processed its mass changes. For example, when wheat is processed into white flour, the bran and germ are stripped, lessening its mass. Therefore, in order to calculate the number of hectares needed to produce a given mass of flour, an extraction rate is needed. This extraction rate in this example is the ratio of tonnes of flour divided by the tonnes of wheat processed to produce the flour.

Global hectare (gha): A productivity-weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the Ecological Footprint). The global hectare is normalized to the area-weighted average productivity of biologically productive land and water in a given year. Because different area types have different productivity, a global hectare of cropland, for example, would occupy a smaller physical area than the much less biologically productive pasture land, as more pasture would be needed to provide the same biocapacity as one hectare of cropland. Because world bioproductivity varies from year to year, the value of a gha changes from year to year.

IO (Input-Output) analysis: Input-Output (IO, also I-O) analysis is a mathematical tool widely used in economics to analyze the flows of goods and services between sectors in an economy, using data from IO tables. IO analysis assumes that everything produced by one industry is consumed either by other industries or by final consumers, and that these consumption flows can be tracked. If the relevant data are available, IO analyses can be used to track both physical and financial flows. Combined economic-environment models use IO analysis to trace the direct and indirect environmental impacts of industrial activities along production chains, or to assign these impacts to final demand categories. In Footprint studies, IO analysis can be used to apportion Footprints among production activities, or among categories of final demand, as well as in developing Consumption Land Use Matrices.

IO (Input-Output) tables: IO tables contain the data that are used in IO analysis. They provide a comprehensive picture of the flows of goods and services in an economy for a given year. In its general form, an economic IO table shows *uses* — the purchases made by each sector of the economy in order to produce their own output, including purchases of imported commodities; and *supplies* — goods and services produced for intermediate and final domestic consumption and exports. IO tables often serve as the basis for the economic National Accounts produced by national statistical offices. They are also used to generate annual accounts of the Gross Domestic Product (GDP).

National Footprint Accounts: The central data set that calculates the Footprints and biocapacities of the world and roughly 150 nations from 1961 to the present (generally with a three-year lag due to data availability). The ongoing development, maintenance and upgrades of the National Footprint Accounts are coordinated by Global Footprint Network and its 60+ partner organizations.

Primary product: In Footprint studies, a primary product is the least-processed form of a biological material that humans harvest for use. There is a difference between the raw product, which is all the biomass produced in a given area, and the primary product, which is the biological material humans will harvest and use. For example, a fallen tree is a raw product that, when stripped of its leaves and bark, results in the primary product of roundwood. Primary products are then processed to produce secondary products like wood pulp and paper. Other examples of primary products are potatoes, cereals, cotton and types of forage. Examples of secondary products are kWh of electricity, bread, clothes, beef and appliances.[10]

[10] Note: Primary product and primary production Footprint are Footprint-specific terms. They are not related to, and should not be confused with, the ecological concepts of primary production, gross primary productivity (GPP) and net primary productivity (NPP).

Primary production Footprint (also primary demand): In contrast to the consumption Footprint, a nation's primary production Footprint is the sum of the Footprints for all of the resources harvested and all of the waste generated within the defined geographical region. This includes all the area within a country necessary for supporting the actual harvest of primary products (cropland, pasture land, forestland and fishing grounds), the country's built-up area (roads, factories, cities), and the forest area needed to absorb all fossil fuel carbon emissions generated within the country. In other words, the forest Footprint represents the area necessary to regenerate all the timber harvested (hence, depending on harvest rates, this area can be bigger or smaller than the forest area that exists within the country). Or, for example, if a country grows cotton for export, the ecological resources required are not included in that country's consumption Footprint; rather, they are included in the consumption Footprint of the country that imports the cotton to manufacture T-shirts. However, these ecological resources *are* included in the exporting country's primary production Footprint.[9]

Productivity: The amount of biological material useful to humans that is generated in a given area. In agriculture, productivity is called yield.

Yield: The amount of primary product, usually reported in tonnes per year, that humans are able to extract per area unit of biologically productive land or water.

Yield factor: A factor that weights the different productivities of different area types within a given country. Each country and each year has yield factors for cropland, grazing land, forest and fisheries. For example, in 2008, German cropland was 2.21 times more productive than world average cropland. (The German cropland yield factor of 2.21, multiplied by the cropland equivalence factor of 2.51, converts one hectare of German cropland to 5.6 gha).

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