Assessing the ecological impact of a university

The ecological footprint for the University of Redlands

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Abstract *Since the environmental movement began, teachers, researchers, and activists on college and university campuses have made great strides toward making campuses "greener" places. As effective as these efforts have been and continue to be, some increasingly salient questions about sustainability remain unanswered. This paper offers an answer to the question, "How big is the University of Redlands's ecological impact?", using a recently developed technique called ecological footprint analysis (EFA). The output of EFA, as used here, is a partial ecological footprint for the University of Redlands (UR). UR's ecological footprint is then evaluated using criteria derived from several different theoretical approaches to sustainability.*

Introduction: the campus quandary

A community pursuing environmental sustainability does not exist in and of itself. Trade, transportation, and air borne pollutants, to name several examples, can put it directly in touch with those carrying on in less than sustainable ways. Similarly, college campuses do not exist in and of themselves. It is fairly safe to say that the typical college campus is unlikely to be able to support the livelihood of its human residents without importing some food, energy, materials, and so on, and exporting some waste – solid or otherwise. Still, the degree of the environmental impact that ensues is not cut in stone nor is it necessarily unsustainable. Like the community aspiring toward sustainability, many things on a college campus can be done that help increase the effectiveness of actions that reduce environmental impacts.

Since the 1960s, people on college and university campuses have made great strides toward making their campuses "greener" places. Because of these actions, in some places more trees have been planted, a higher percentage of less waste is being recycled or composted, energy is being conserved, there has been a decline in the use of some toxic products, and the list goes on (Smith, 1993). Several examples of particular note in advancing such endeavors are Project Green Tree started in the 1970s, John Tillman Lyle Center for Regenerative Studies, an ongoing experiment at California Polytechnic Pomona, and the National Wildlife Federation's "Campus Ecology" program. The latter of these publishes an extensive series of worksheets that can be used to guide campus centered research on various environmental impacts (Smith,

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1993). As effective as these and other efforts have been, and continue to be, there is still room for more progress.

In the spring of 2000, Ben Nicholson, Jonathan Bulkley, and Greg Keoleian found that the University of Michigan's Center for Sustainable Systems (CSS) was one of a handful of campuses using or working on the development of indicators to quantify, assess, and manage campus environmental performance within the context of sustainability (Nicholson *et al.*, 2000). Of the campuses that have programs in place that utilize indicators few seem to share a common vision of what sustainability means. Likewise, academic researchers have not appeared to agree on a consistent theoretical foundation and set of indicators that can be used to analyze environmental impacts using sustainability criteria (Stern *et al.*, 1997). As Leal Filho (2000) persuasively argues, there are some areas in higher education where the concept of sustainability is not yet fully understood.

This is not to say one set of indicators or theory can fully capture the complexities of what sustainability means throughout time and space, much less quantify it without error. In fact, the diversity of approaches and indicators that are playing out at the local and regional level has been welcomed (Rees, 1996; ICLEI, 1997; Hempel *et al.*, 1998; Hempel, 1999; Mazmanian and Kraft, 1999; Venetoulis, 2001). Given the state of the field, however, fundamental questions have remained difficult if not impossible to approach. For example: what and how big is a campus's environmental impact? Is it bigger than the area of the campus? If so, how much bigger? Without these basics, more difficult questions about whether or not the impact might be considered sustainable or not cannot be systematically answered – much less done so in a way that informs those aspiring toward sustainability.

In light of this situation, it should not be surprising that many researchers and teachers continue to use cost-benefit analysis and piece-meal environmental impact reports (EIRs). Though some of this work has been of much use, it is not always well suited to answering the types of questions raised above. This is the case, in part, because the focus is singularly on economic implications (ignoring ecological impacts) or, in the case of EIRs, impacts are considered in a local or policy specific context (which can miss global sustainability dimensions associated with "every day" consumption/ waste). Without an approach that can take into account global sustainability concerns on ecological grounds, those interested in doing work on campus sustainability can find themselves in a bit of a quandary.

This paper takes a small step toward addressing the campus quandary. This is done by answering the question, "How big is the University of Redlands's ecological impact?" using a modified version of a recently developed technique called ecological footprint analysis (EFA). Once calculated, the campus's footprint is evaluated in the context of three different approaches to sustainability: ideal, strong, and weak. Admittedly, this article and the methodology that it uses cannot capture the full significance and measurable impact the university's student, faculty, and staff have on nature. Still it is hoped that it can add to work in the field by offering some partial answers to basic questions that have heretofore gone unanswered, and that these efforts can contribute to new opportunities for learning, teaching, research, and action.

Finally, because EFA is a reproducible methodology, there are possible positive spin-offs, the main one being the introduction of a tool that can be used for similar research on other college campuses. The final pages of this paper contain a series of worksheets that can be used to estimate a partial ecological footprint.

Brief background: what is an ecological footprint?

An ecological footprint (see Appendix 1) is the area, for example acres (or hectares), of productive land and water required for a given population to maintain their consumption and absorb the ensuing waste over the course of one year – at prevailing levels of technology. For example, say two people consume about 100 pounds (45 kilos) of beans and 100 pounds of rice in a year and that this requires approximately half an acre (about one-fifth ha) of ecologically productive (arable) land. The per person footprint would be half this amount and their combined footprint would be half an acre. Of course, ecological footprints are more complicated than a hill of beans.

Developed in the mid-1990s by William Rees and Mathis Wackernagel at the School for Community and Regional Planning, University of British Columbia, ecological footprint analysis starts with the observation that within a given period of time all consumption of energy and materials, and all discharge of wastes, require a finite amount of land and water area for resource production and waste absorption (Wackernagel and Rees, 1996). Building upon Rees's and his own work, in 1997 and again in 1999, Wackernagel led a team of researchers that estimated the amount of ecologically productive land available and consumed in 52 countries and "the rest of the world" (Wackernagel *et al.*,1997, Redefining Progress, 1999). The most recent work in this area (Chambers *et al.*, 2000) indicates that consumption of ecologically productive land across most countries is beyond renewable rates and globally there is "consumption gap" – consumption beyond the renewable services that the stock can provide over the course of a year (indefinitely).

Cases studied at the city and regional level reveal similar findings. After conducting a EFA for Vancouver, Canada, Rees and Wackernagel write: "Even if the land in the Lower Fraser Valley were twice as productive as global averages, the people of this region would still require the ecological output of nine times as much such land than is locally available" (1996, p 88). Folke *et al.* (1997) estimated the ecosystem appropriation (footprints) for 29 of the largest cities of the Baltic region of Europe. One of main conclusions was that the cities combined impact was at least 565 times bigger than their geo-political boundaries. For the five-county Los Angeles metropolitan area, Pincetl and Wolch (2000) estimated a partial footprint that was about 25 per cent bigger than the area that the population inhabits. Also, in southern California, Venetoulis (1998) found that the footprint of the 9.5 million residents of the 4,080 square mile (6,500km^2) county of Los Angeles required approximately 444,000 square miles (710,000km^2) of footprint space (30 acres/12.1ha per person). This ecological footprint is nearly twice the per person amount of ecologically productive land area available in the USA and about five times bigger than global averages.

These studies and others reveal that the natural services now being consumed in many places throughout the world are having an impact that is in excess of nature's renewable productivity and assimilative capacity. This means that the stock of nature's capital is being used up to fill the "consumption gap". If this persists over enough time, one possible result is a decrease in the amount of life (including people) that can be supported even at subsistence levels. Another possibility, some argue, is that technology can rectify this situation – a topic taken up briefly in the conclusion of this article.

Estimating the ecological footprint of the University of Redlands

Ecological footprint analysis can be used to assess the associated environmental impacts of many things, from beans and beef to gasoline. On the following page the focus is on some of the ecological impacts associated with water (hydroprint), solid waste (wasteprint), energy (energyprint), and transportation (transportprint). These sub-components of a full-blown EFA were focused on in an effort to:

- account for consumption that was of ecological significance;
- meet the interests of those (students, faculty, and research assistants) carrying out a large brunt of the applied interdisciplinary research; and
- make the task manageable over the course of a semester.

The hydroprint, wasteprint, energyprint, and transportprint do not provide a comprehensive estimate for all the potentially relevant ecological impacts. For example, in the analysis of transportation only the forest land needed to absorb carbon dioxide emissions associated with gasoline and aviation fuel use related to campus activities over the course of one academic year (37 weeks) were counted. A more exhaustive analysis might, for example, also include roads and material for automobiles, and information on summer and winter interim transportation activities related to campus life. The data for the other sub-components was for an entire year, but they also were not comprehensive. More research on things like electricity transmission lines, wildlife habitat loss, and nuclear waste, for example, would make the energyprint better. In the case of water, aqueducts and other infrastructure could be amortized into the calculations. More and lengthier lists could probably be easily drawn up. The point remains, the findings presented in this paper only reflect part of the

University's total ecological impact. As we shall see, even this partial ecological footprint has important sustainability implications.

Summary of methodology

The basis for the calculations of footprint components associated with solid waste and recycling came from an online spreadsheet created by Wackernagel and Richardson (1999). To account for water, the hydroprint team tested a new methodology developed by Monty Hempel and Jason Venetoulis. The hydroprint is calculated by estimating the amount of water available from rainfall and reservoir capacity on the 140 acre campus over the course of one year. Total use is then analyzed at average (per acre) water yields. Though not without its shortcomings, the hydroprint provides an area-based measure that can be incorporated into the EFA framework. It also affords a way to begin to address regional variations in water availability (or scarcity) – which has heretofore been a sticking point in methodological advancement. Estimates for some of the impacts related to wind and solar energy use were also produced using original research. A more detailed description of the methodology, variables, and formulas used for the hydroprint, energyprint, and the other categories can be found in Appendix 2.

Data collection was carried out by four teams of students with the help of two research assistants, and led by a faculty member. Information on energy, water, and transportation come from UR's physical plant, recycling program, a random survey of students, staff, and faculty, and other sources – also discussed in Appendix 2.

Some of the raw figures on energy, natural, gas, water, and waste are presented in Table I. In the next section the 10.4 million kWh of electricity, 605 short tons of waste, and other consumption/waste categories are aggregated using the footprint analysis methodology to calculate UR's footprint.

How big is the UR's ecological footprint? Findings

This section provides a summary of the main findings from the analysis of the ecological footprint coming from water, energy, and waste output at the University of Redlands over the course of 1998. The findings are then aggregated and the university's ecological footprint is evaluated using criteria derived from three approaches to sustainability (shown in Table II).

Table I. Sampling of raw consumption and waste data for the University of Redlands (1998)

	Total	Per campus community member (n = 2,727)
Electricity	10.4 million kilo-Watt-hours	3,810kWh
Natural gas	680,000 therms	2,500 therms
Gasoline	140,000 gallons	51 gallons
Water	13.3 million gallons	48,750 gallons
Solid waste	605 tons	440lb

Hydroprint

The ecological footprint associated with indoor water use was about 63 acres and 223 for outdoor use, for a total hydroprint of 286 acres (116ha). This is the smallest component of all the categories taken into account. Given Redlands' semi-arid desert landscape, however, this size of a hydroprint can only occur with the importation of water, most of which is used for irrigation of nearly 80 acres of lawn on campus. This is a regionally specific estimate, as described in Appendix 2.

Wasteprint

The footprint component from non-recycled waste was 687 acres and 23 acres for recycled, for a total of 710 acres (287ha). This amounts to about one quarter of an acre for each of the 2,727 administrators, faculty, students, and staff included in analysis. The 127 tons of non-recycled paper was the largest contributor to the university's wasteprint, with metal and glass following respectively.

Energyprint

The energyprint has three components:

(1) natural gas;
(2) electricity; and
(3) gasoline.

The energyprint associated with natural gas use comes from such things as heating and cooking, but not that which is associated with electricity. This portion of the energyprint was estimated to be 1,065 acres (431ha). The electricity component includes the use of coal, natural gas, large-scale hydro, wind, and solar energy. It measured approximately 1,790 acres (725ha). The largest among all sub-components of the energyprint, gasoline use, can be broken down into 438 acres attributable to campus related automobile and truck use, and 1,414 acres for air travel (to and from campus during mid-semester breaks); for a total of just over 1,850 acres (749ha). The total

	Footprint component (acres)	Percentage of total	Per capita footprint (acres)
Hydroprint	265	5.02	1/10
Wasteprint	710	12.45	3/10
Natural gasprint	1,065	18.66	4/10
Electroprint	1,790	31.42	7/10 (0.66)
Transportprint	1,850	32.45	7/10 (0.68)
Total	≈5,700	100.00	≈2.10

Table II. The University of Redlands' ecological footprint: breakdown by category energyprint is about 4,700 acres (1,900ha). Approximately 90 percent of the energyprint represents forest land needed to absorb carbon dioxide emissions from fossil fuel energy use.

UR's ecological footprint

Taken together the total measured ecological footprint for the University of Redlands in 1998 was approximately 5,700 acres (2,300 hectares) or about 40 times the area of the campus (140 acres/57ha). The campus's per capita footprint is just over two acres (or slightly less than one hectare.) Table II shows that of the university's total footprint approximately 5 percent is associated with water use, 12.5 percent waste and recycling, 18.5 percent natural gas (not used for electricity), 31 percent electricity, and the remaining 32.5 percent transportation.

Sustainability analysis

So, what does all this mean in terms of sustainability? In this section the findings are considered from three different but related approaches to sustainability: ideal, strong, and weak. These conceptual frameworks were liberally adapted from Baker *et al.* (1997), who focus more clearly on the political and economic implications of weak, strong, and ideal sustainable development, and Common (1996), who clearly draws the distinction between weak and other forms of sustainability.

We must begin with a caveat, there is no one agreed upon definitive definition of sustainability. Some versions focus on the interactions between governance, civic engagement, economy, ecology, and the distribution of benefits and costs among groups, while others may concentrate on just one or several of these or other factors. Arguably, an approach that balances out these different emphases has not reached definitive intersubjective meaning among theorists, scholars, or practitioners. For some this means "sustainability" is without meaning, while others may see the need for substantial "refinement" (Viederman, 1996). While an interdisciplinary approach to sustainability can pose conceptual ambiguity, it has allowed room for open-minded theorists and practitioners to venture far-a-field in ways that have provided "thicker" meaning to the term. The emphasis here is placed upon three versions of ecological sustainability, though some equity implications could be inferred.

One thing that the three approaches to sustainability have in common is that the use of natural services and capital beyond renewable rates are considered *not* to be sustainable. From all three perspectives, in addition to the university's ecological footprint, the other important piece of information needed to do a sustainability analysis is an area-based measure of how much ecologically productive land (services) is available on a renewable basis annually. The differences among the approaches lead to different answers about how much this amounts to and thus what, at least in part, constitutes sustainability.

An *ideal* approach to sustainability is premised upon the contention: living within the means of nature is sustainable when all consumption and absorption of ensuing waste occurs in the place where consumption directly occurs. The ideal approach implicitly holds that the allocation/availability of natural resources to support a population is predetermined by the "place" they live. So, the endowments of a place provide the empirical ecological limiting factor. From this perspective, the prospects for sustainability are limited to a footprint roughly the size of the campus plus its available hydrospace (the size of the campus again and university's reservoir). All told for the University of Redlands this amounts to about 330 acres (133.5ha) or about 6,500 square feet per campus community member (includes students, faculty, and staff). So, for UR to be sustainable the footprint must be less than this area. Clearly it is not (see Figure 1).

The *strong* approach to sustainability, in contrast, considers individual ecological impacts associated with consumption within the context of global carrying capacity. To be strongly sustainable, then, campus members – regardless of location – would have to have an environmental impact that on average is the same or less than the global amount of ecologically productive land (nature) available on a per global citizen basis. According to Wackernagel *et al.* (1997) there are roughly five to five-and-a-half acres of annually renewable ecologically productive land/services available in the world on a per capita basis. However, because the data being analyzed in this paper do not include

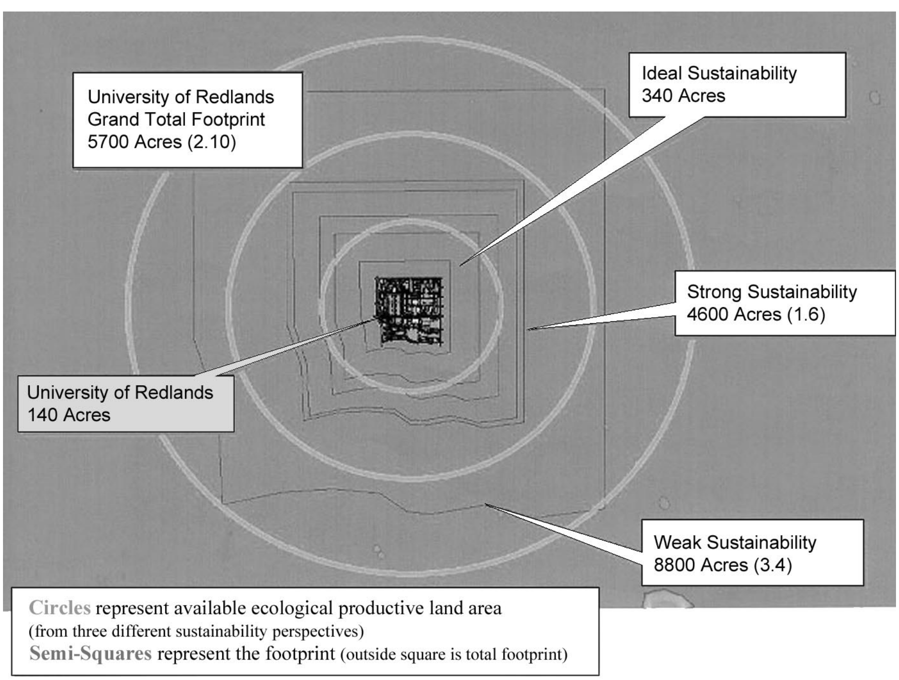

Figure 1.
UR's footprint from three sustainability perspectives (to scale)

food, arable and pasture land cannot be included. What is left is about 1.6 acres per person or about 4,600 acres (1,862ha) of available footprint space for the entire university. From the strong approach, UR's 5,000 plus acre footprint is still not sustainable.

As Table III shows, the two main differences that distinguish the weaker version of sustainability from the others are:

(1) the decline of specific natural factors of production (that would otherwise be unsustainable) can be offset through investment in (or substituted by) other (natural) productive factors; and

(2) consumptive impacts are considered in a national context.

From this perspective, to be sustainable, the average campus community member would have to have a (net) ecological footprint equal to or less than the ecological limits of the USA on a per person basis. Using this criterion as a guide, the university has approximately 3.4 acres (1.37ha) available per person for a total of nearly 9,000 acres (3,643ha). From the weak approach to sustainability, UR's ecological footprint is sustainable. However, it should be reiterated that the research in this paper only included a portion of the campus's footprint. It is likely that, with the addition of other factors such as food, building materials, paved-space, automobiles, buses, and trucks, and so on, UR's footprint might not even be considered sustainable from a weak perspective.

In summary, the main findings are that from an ideal and strong conceptualization of sustainability, since the amount of natural services consumed and waste output is greater than what is naturally provided and absorbed, demand is outpacing supply. Thus there is a net reduction in the amount of natural capital that can be used to provide natural services in the future. This unsustainable pattern is part of the global "consumption gap" identified earlier. From the weak approach to sustainability the campus may be sustainable, though the inclusion of other environmentally intensive consumption factors could counter these findings.

Figure 1 shows the size (to scale) of the campus, the respective footprints (semi-squares), and area of ecologically productive land area available (circles) from the three different approaches to sustainability.

Table III. Components of three approaches to sustainability and the treadmill approach

	Declining natural capital is sustainable	Nature is substitutable	Level of analysis
Ideal	No	No	Local only
Strong	No	Rarely	Glocal (local to global)[a]
Weak	No	Yes	Country
Treadmill	Probably	Always	Economy/policy specific

Note: [a] For a discussion on "glocalism" see Hempel (1996, p. 177)

Conclusion

All the sub-categories that fall under the general headings environmental impacts or consumption/waste cannot be measured with 100 percent precision using EFA. One poignant example is the 16,000 pounds (7,272 kilos) of toxic waste and emissions put out by the university in 1998. Nor can the subtleties and full meaning of the impacts on nature (including humans) from human activities be captured in the type of research carried out in this paper.

The ecological focus and area based measure that footprint analysis provides does, however, help to reveal some of the "hidden" ecological costs of consumption that cannot be captured using some conventional approaches and analysis techniques, such as cost-benefit analysis and environmental impact reports. As useful as these other approaches can be, they do not provide a way in which ecologically intensive consumption can be assessed from a sustainability perspective. Though clearly not providing a perfect measure of the total impact stemming from human activity, footprint analysis can be used to identify "nature intensive" consumption patterns and thereby help inform action aimed at changing the underlying causes.

Since notions of carrying capacity and sustainability emerged centuries ago, the role of technology has remained a controversial issue. It is well known, technology can cut many ways. In some cases it has reduced the potential for some of the environmental impacts of certain types of consumption. One example of this is the advent of photovoltaic solar panels to collect energy from the sun. In some cases, technology has also increased the need for more time, labor, and economic capital to be put to the task of averting environmental impacts related to other technology, for example, catalytic converters and respiratory treatment, and the gasoline combustion engine. Some technological developments have significantly increased the potential for large-scale environmental destruction. Perhaps the most obvious case of this is use of plutonium. "Faith", if you will, in technology has also provided a backstop for those that advocate high levels of and long-term growth in consumption and population (Simon, 1981, 1997).

It is difficult to say whether or not rapid advances in energy and other technology can forestall the impacts of the consumption gap. Footprint analysis cannot answer this question. What footprint analysis does show, however, is that even with current technology there is a gap in the most technologically advanced countries (Chambers *et al.*, 2000). On a more optimistic note, if consumption and population stabilize, old and new technology could prove very useful for increasing some qualitative consumption opportunities in the future.

Are ecological footprint analysis and sustainability important enough to promote awareness about them on college campuses or would campus communities do better without the perspective they provide and the changes they may indicate are needed to move toward sustainability? The answer, like the question, is somewhat loaded and not entirely satisfactory. It depends. It depends on the extent of environmental impacts and what approach to sustainability is taken up, if any. It depends on the desire of students, faculty, and administrators to understand environmentally intensive consumption and make changes that reduce it.

The success of linking sustainability concerns with campus ecology is in part contingent upon an awareness of problems and commitment to ameliorating them so as to be more in line with sustainability aspirations. The position taken here is that whether or not this occurs – and if so, how – should be a democratic decision made by students, faculty, and staff, and not an edict handed down here or elsewhere. For those choosing to pursue sustainability, this paper has aimed to help inform these pursuits by sharing some basic ideas about sustainability theory and a practical way to carry out research into significant aspects of a campus' environmental impact.

The University of Redlands has begun to take up sustainability and some of the preliminary findings of research are in. From a weak approach to sustainability the campus may be sustainable, however, it should be reiterated that the research in this paper only included a portion of the campus's total ecological footprint. It is likely that, with the addition of other factors such as food, building materials, paved-space, buses, and trucks, and so on, UR's footprint could not even be considered sustainable from a weak perspective. From a strong or ideal approach to sustainability there are plenty of opportunities for the university to move toward sustainability.

One final note, the Environmental Design Studio course in Fall 2000 at the University of Redlands used this paper to help guide the initial development of several alternatives that would move the campus toward sustainability by changing the design of the building that houses the Environmental Studies, Math, and Physics departments.

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Campus Ecology Footprint Worksheet

To use the worksheets: Enter figures for one year in the left hand column, complete the multiplication and division, and then add the results **(fp)** to get the corresponding ecological footprint for your campus. For a per person figure divide the campus's footprint by the number of faculty, staff, and students. Note: Figures are US standard.

Energy: Powerprint

⇒ Enter the amount of energy from each source (electricity, natural gas, gasoline, and jet fuel). Note: The US average kWh in 1999 was comprised of 54% coal, 23% nuclear, 9 % natural gas, 9% hydro 3%, oil, the remaining is wind, geothermal, and solar and other (EIA, 2000). To get a more accurate estimate, use the "local" energy blend.

Electricity

_________kWh from coal X 0.00063 = ________
_________kWh from natural gas X 0.00005 = ________
_________kWh from large hydroelectric X 0.000128= ________
_________kWh from solar X 0.0000025 = ________
_________kWh from wind X 0.000014 = ________
Subtotal for Electricity ____________ **Footprint component (fp)**

Natural Gas

______ Therms of natural gas X 0.00157 = ________________**(fp)**

Gasoline

Gallons of gasoline for private automobiles related to school activities during school week:
___X 19.6 X 37 = ____________ divide by 7,000 = ________ **(fp)**
Gallons of gasoline used during semester breaks, i.e. winter and spring break:
___X 19.6 = ____________ divide by 7,000 = ________ **(fp)**
Gallons of gasoline for grounds maintenance, i.e. lawn mowers and garbage pick-up:
___X 19.6 = ___________ divide by 7,000 = ________ **(fp)**

Air Travel

Total miles of air travel for school related activities and during breaks:
_______ divided by 587 = ________ X 0.5 = _______ **(fp)**

(or) **Hours** of air travel
________ X 0.5 = _______**(fp)**

Add up the footprints (fp) from this page ____________________

Water: Hydroprint

⇒To calculate a hydroprint, first estimate the amount of hydrospace available and corresponding area based yield factor (#s 1-5) and consumption factor (#s6 &7).

HYDROPRINT

Calculate the yield and consumption factors

Step 1. Enter the average annual rainfall for you community or watershed __________inches
Step 2. Divide step 1 by 12 = __________
Step 3. Enter the area of the community or watershed in acres __________
Step 4. Multiply the results of step two by step three = __________
Step 5. Divide the result by the area or your community/watershed (step 3) = __________ **yield factor**

Step 6. Enter the total amount of water (gallons) consumed in one year __________
Step 7. Divide step six by 325,851 = __________ **consumption factor**

Step 8. Divide consumption factor (step 7) by yield factor (step 5) and enter the result:

Hydroprint__________Acres*

*To partially account for water needed by other species and wildlife, increase the Hydroprint by the corresponding percentage set aside for non-human purposes.

Wasteprint

Paper	_______	pounds X 0.0045	= _______
Aluminum	_______	lbs. X 0.02	= _______
Magnetic metal	_______	lbs. X 0.0048	= _______
Glass	_______	lbs. X 0.0012	= _______
Plastics	_______	lbs. X 0.004	= _______

Subtotal for non-recycled waste__________ (fp)

Recycled Waste (39% average recycling rate

Paper	_______	lbs. X 0.0032	= _______
Aluminum	_______	lbs. X 0.0001	= _______
Magnetic metal	_______	lbs. X 0.004	= _______
Glass	_______	lbs. X 0. 0008	= _______
Plastic	_______	lbs. X 0.0012	= _______

Subtotal for recycled waste __________ (fp)

Add up the hydro and wasteprints ________________

Total Footprint

Sum all the Footprint (fp) categories from the worksheets

____

This is the campus ecological footprint in acres.

Divide by the campus community population

____

This is the campus' approximate per capita footprint in acres.
This figure can be compared to the amount of footprint space available per person in the world, your country, or on campus.

Appendix 2. Methodology: data collection, variable specification and formulas

Data collection

Four teams of students (ranging from two members to five) with the help of two research assistants, led by a faculty member collected information on energy, water, transportation, and waste. These data come from the university's physical plant, recycling program (with assistance of the director Jersey Jeworski), Environmental Studies Department's GIS data base (with the assistance of Steve Hoover and Grant McMurran), City of Redlands, American Forests, California and US Department of Energy, and other sources. In the case of gasoline and aviation fuel use, statistics were not readily available and a random survey of faculty and students' automobile and airplane use during the 37 weeks of classes (1999/2000) was conducted by the transportation team. (The return rate for the survey was just over 18 percent. Except for transportation, all the data used to conduct the footprint are for the 1998 calendar year.) In another instance, important data on water use for irrigating the 80 acres of lawn were not available. As such, the hydroprint team assumed lawn was watered at rates similar to another southern California university, as described below.

Hydroprint

The ecological footprint associated with water use in 1998 for the UR was calculated by estimating the total amount of water available from rainfall and reservoir capacity that UR has over the course of one year. The campus is 140 acres and has an average annual rainfall at about 12.8 inches and a 50 acre-feet reservoir. The total available hydrospace is estimated to be 200 acre-feet or about 1.42 acre-feet of water per acre of land. Total acre-feet of water use was estimated to be about 408. By dividing 408 by the yield factor the UR's hydroprint was estimated to be approximately 286 acres.

The amount of water used to irrigate the 80 acres of lawn on campus is not metered. To overcome this data gap, we used a recent study conducted by Stephanie Pincetl and Jennifer Wolch, faculty, at the University of Southern California. The study estimates that the average 1,600 square feet lawn gets (requires) 50,000 gallons of water annually.

Energyprint

Electroprint: Using the average energy mix for California in 1998 (California Energy Commission, 2000), the total amount of electricity (kWh) was broken down by the percentage of electricity (kWh) coming from various sources (coal, natural gas, large scale hydro, wind, and solar). Of the total 10.4 million kWh we estimated that approximately 3.1 million kWh came from natural gas, 2.4 million kWh large scale hydroelectric dams, 2.19kWh coal, 150,000kWh wind and 150,000kWh solar. Nuclear and geothermal energy were not included because a *good* estimate – that fits within the framework of EFA – has yet to be developed.

The portion of the footprint from natural gas and other fossil fuels was estimated by accounting for the acres of trees that it takes to sequester the carbon dioxide emitted. The sequestration rate used was 1 acre (about 2/5ths of hectare) for every 3.5 tons (7,000 lbs/3,181 kilograms) of CO_2. See carbon content figures below.

The footprint space attributable to *wind* energy use was estimated by multiplying the kWh from wind by average yield of kWh per acre at the nearby San Gorgonio Windfield in 1998. This figure was estimated by taking the total energy output of SGW and dividing it by the total area of the windfield (personal communication with Chris Copland, owner of San Gorgonio Windfield, 20 March 2000 by Rob de Micheal). The result was 70, 312 kWh per acre/annually.

A similar approach was used for *solar* energy, except the 404,600kWh per acre of solar parabolic trough field is based on the CA average (US DOE, 2000).

The portion of the footprint associated with *hydroelectric* energy use was estimated using Wackernagel *et al.*'s (2000) spreadsheet. The equation is 10,000kWh equals about 1.2 acres of footprint space.

Transportprint attempts to account for the impacts from gasoline and aviation fuel over the course of the academic year. The use for lawn mowers and other campus vehicles was not included. Data were gathered using a survey. A total of 800 surveys were sent out to students and faculty with a return rate of 18 percent. Annual gasoline use was reduced to campus associated activities during the academic year and breaks. The estimate accounted for car-pooling, average gas mileage, and other relevant factors. The air travel data obtained through the survey is for breaks (i.e. Fall/Winter/Spring) during the school year.

Carbon content figures

The carbon dioxide content of natural gas used is 11 pounds per therm. Gasoline is 19.6 pounds per gallon (American Forests, 2000). Aviation fuel is 2.6lb per mile (Wackernagel and Richardson). Coal is 3.25 pounds per kWh produced. (Our estimate, based on 1.25 pounds of coal needed on average to produce 1kWh of electricity and the 1lb of coal burned results in 3.5lb of CO_2. Sources: Hong and Slatick (1994); Chicago Museum of Science and Industry (2000).)

Wasteprint

Wasteprint figures were based on the formulas taken from Wackernagel and Richardson (1999). The report recycling rate for UR was 39 percent.