ECOBALANCE: A Sustainable Land Use Planning Game

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ABSTRACT

Using an "ecological footprinting" approach, an interactive game has been developed whereby participants plan land uses at a settlement or regional scale according to the footprints required to balance natural resource supply and sink functions (i.e., natural capital) with human life support needs. Attainment of sustainability is determined by either the ratio of the amount of life support the land is supplying verses that needed by humans or by the ratio of on-site supplied life support needs verses that laying outside of the site boundaries. The game objective is to achieve a natural capital-human land use balance either by more efficient use of resources, a reduction in needs (i.e., change in lifestyle), or both. To frame the objective as a question, can human consumption be balanced with the sustainable output of the natural resources within a given site boundary?

1. INTRODUCTION

There are few land use planning methodologies that incorporate sustainability principles in a manner that can guide users in the shaping of sustainable communities. To our knowledge there are no land use planning methodologies that incorporate natural resource balancing as a principle even though such techniques are presently being followed in the areas of life cycle analysis, ecological footprinting, and industrial ecology. Over the last 25 or so years, a gradual conceptual evolution has occurred shifting the focus of design and planning from conservation, or more efficient use of non-renewable resources, to sustainability. "Sustainable design," however, simply expands the concept of conservation through the inclusion of more resource conservation topics such as water conservation, recycled content materials, and farmland preservation.

The pro-active concept of "balancing" has only recently come to the forefront spurred by the application of industrial ecology and ecological footprinting methods to the design and planning disciplines. This shift of focus is primarily due to the fact that the ecological impacts of human activity continue to grow rapidly due to both total (due to population increases) and per capita (due to increasing standards of living) increases in the use of resources. This is true even in those cases where exceptional conservation practices are promoted and reinforced.

A case in point is the City of Austin's Green Builder Program. A detailed critique of the program found that although improvements in residential energy efficiency have decreased consumption *per square foot* by 29%, residential energy consumption *per capita* has increased by 13%. This is due primarily to two facts: the average number of persons per household fell by 32% and the yearly average size of new residences has increase by 47% in the past 30 years. In addition, most of these new residences are built in areas characterized by urban sprawl increasing urbanized land in the county by 28% since 1985. Consequently, transportation energy consumption has also increased. Thus, gains at one scale have been largely offset by a lack of planning at a larger scale. Such offsets in gains at one scale by failures in another scale are not uncommon. The land use planning implications are great especially if one were to look closely at international agreements such as the Kyoto Protocol which sets conditions for global warming that are almost impossible to meet simply through the piecemeal approaches presently being taken.

A holistic planning approach is needed that can be applied to all planning scales from the neighborhood to the region. Application of the ecological footprinting technique described in this paper is a preliminary step in responding to this need. Balancing human consumption with the resources available for a particular need *within a given boundary* by admitting that actions must be taken to re-source and replenish these resources is one of the objectives of the EcoBalance game.

Unlike less developed areas of the world, the confusion over what can be balanced and what cannot within the confines of a particular site in our culture is difficult. Therefore, careful definitions of the topic areas are key to enabling this type of planning to work. This is accomplished by differentiating between what we call "orders of balance" and between energy verses mass flow. The first order of balance occurs at the most direct human physiological needs of air, potable water, food energy, (both passive climatic and electric power), and materials, both biomass and inert, for shelter.

The second order of balance involves the resources that these first order interactions require or supply. For example, a forest used as a wastewater treatment system actually provides more CO_2 sequestering potential than a "natural" forest so the amount of forestland originally needed for carbon sequestration has now changed.

The third order of balance is represented by the materials and energy needed to produce the second order of balance needs such as a forest wastewater treatment system. This order of materials and energy are often produced off-site. The materials that occur on-site are represented by a tool kit of indigenous materials that can be used for on-site manufacturing. This material topic can require knowledge of a whole set of new technical skills in order to accomplish these balances. These often are quite different than those normally incorporated within the professions of architecture, engineering, and of landscape architecture and are a unique mixture of appropriate technologies and permaculture along with a new manufacturer's dictionary of sustainable development practices. Techniques in general are based upon regional data, per capita benchmarks for productive land appropriated for human uses are calculated for each lifestyle.

2. GAME PRINCIPLES

A set of game principles must be understood by the participants and used as guidelines in making decisions regarding future land uses on the site. A set of five game principles used in previous sessions of EcoBalance is presented below.

1. **Life cycle assessment** methodology considers the impact of a design or building material throughout four life cycle stages – 1) resource extraction, 2) processing or manufacturing, 3) installation, use, and maintenance, and 4) reuse, recycling, or disposal – and the transportation requirements between each of these stages.
2. **Ecological footprinting** maps the appropriated resource base that an individual or community requires to maintain a particular level of consumption (lifestyle).
3. **Scales** refers to the varying generic boundaries within which the planning game can be played from the household, to the neighborhood, community, or town, up to the metropolitan region, bioregion, or country.
4. Resource **balancing** refers to the attempt to limit human consumption of resources to the sustainable output of a resource base within specified boundaries.
5. **Integration** is the overlapping or multi-use potential of a single landscape or building component. For example, roof-mounted solar photovoltaics can generate electric power and harvest rainwater within the same spatial footprint.

3. GAME BOARD

3.1 Base/Inventory Maps

The game board is basically a graphic summary of site analysis data. The first step in preparing the game board is the presentation of site data in the form of "Base/Inventory Maps." These are inventories of site characteristics and resources such as topography, soil types, geology, hydrology, vegetation, site improvements, and special features. Each base map topic may include sub-topics such as digital elevation model, slope, and aspect sub-topics under topography. Each of the Base Maps is a separate document that can be overlaid on an aerial photo of the site and on other Base Maps.

3.2 Composite Maps

In various combinations the many Base/Inventory Maps form "Composite Maps" illustrating five human life support themes - Air, Water, Food, Energy, and Materials – as well as the site themes of Ecosystems and Hazards. For each life support theme the amount of land available to fulfill both sourcing and re-sourcing is determined. Then, using figures for the minimum amount of land required to support one person (a per capita ecological footprint), the carrying capacity of the site is determined for each of the five life support themes.

For example, the composite map for the life support theme "Food Production" includes the amount of land area suitable for vegetable gardens, orchards, cropland, and grazing land (source) as well as composting of food wastes (re-source). Similarly, for "Water Availability" water harvesting areas (source) are balanced with the area required for ecological treatment of wastewater (re-source, e.g. wetlands, forest mantle etc.). The amount of land suitable within the site boundaries for each life support need divided by the per capita ecological footprint for that need results in a site population total representing the carrying capacity of the site for each life support need. Proposed land uses can be represented in icon form with icon tiles representing per capita needs correlated in scale to the base map balancing the proposed land uses with site carrying capacity. Each of the five life support needs will likely result in a different site carrying capacity total population number.

3.3 Suitability Maps

The final step in preparing the game board is to prepare three "Suitability Maps." These are composites of the five life support need maps plus the Ecosystem and Hazards maps. The game works on the premise that all land uses can be divided into three basic types – natural, productive, and built (or developed land). Natural land includes those uses that preserve, protect, and regenerate ecosystems. Productive land includes all uses appropriated for human needs such as agriculture, forestry, and fisheries. Building land includes the actual footprint of land development including buildings, facilities (e.g., athletic fields), and infrastructure.

Each Suitability Map is a separate document that can be overlaid on the site aerial photo and on other Suitability Maps. These Maps comprise the actual game board for EcoBalance. In short, the game board is a graphic summary of all the previous maps – the Base/Inventory Maps and the Composite Maps - organized according to three main land use topics. The game board is a graphic indication of inherent site characteristics, i.e., what the land is most suitable for without human intervention. No new human land use needs have yet been imposed on the site.

4. LIFESTYLES

Next, the ecological footprint (resource consumption) of three different lifestyles – Average American, Conservation, and Sustainable – is estimated. Based upon regional data, per capita benchmarks for productive land appropriated for human uses are calculated for each lifestyle. If data is unavailable, the Conservation lifestyle is assumed to be 50% of the resource consumption of the Average American lifestyle and the Sustainable lifestyle is assumed to be 50% of the resource consumption of the Conservation lifestyle. The Sustainable lifestyle is therefore 25% of the Average American lifestyle.

5. PLAYING THE GAME

5.1 Game Components

A summary list of the game components is presented below. There are seven essential game components:

1) Game principles of (listed above),
2) A set of Suitability Maps (described above),
3) Lifestyle definitions (summarized above),
4) A grid overlay that enables the quantifying of areas and resources over the Suitability Maps (described below),
5) Icon tiles representing ecological footprint land areas at the same scale as the Suitability Maps (described below),
6) Game sequence (described below), and
7) Support data.

5.2 Grid Overlay

The base maps use a spatial management grid overlay technique called "the infinite grid." It can be based on grid cells of 7 1/2 minutes of latitude/longitude or on the conventional land surveying units of sections, quarter sections, etc. This grid, which is stored and analyzed in arrays and matrices, performs many roles. These include showing distributions of data, providing a rapid sorting method to access data at finer, or coarser, scales, and organizing all our spatial data in an array of grid cells. Programs have been developed to project areas of the in various conic and poly-conic cartographic projections such as Albers Equal area and Lambert. Combining the grid cell approach with the capabilities of a commercial GIS system, EcoBalance has spatial information processing capabilities that are compatible with many land use and geographic mapping systems.

The grid can be enlarged or subdivided to provide the appropriate scale for resource analysis. For example, at the scale of a master plan, perhaps 1"=1,000', a household size rainwater cistern is almost imperceptible. However, at a grid size of 1"=4', the same cistern is a major component of the building's site plan. Conversely, surface water runoff for food irrigation is much too large a land area to illustrate on a building scale plan and is more appropriately shown at the master plan scale.

5.3 Icon Tiles

The game uses graphic icon tiles representing the three major land use topics – Natural, Productive, and Building land. The Productive land tiles are divided into the five different life support topics – air, water, food, energy, and materials. Each tile represents a particular amount of land depending upon the scale used for preparing the Suitability Maps. The tiles are placed on the game board to designate proposed land uses on the site.

5.4 Game Sequence

After preparation of the three Suitability Maps for the game board and selection of player lifestyles, the game proceeds in two steps: 1) mapping proposed Natural, Productive, and Building land uses with land area icon tiles that correlate in scale to the game board and 2) comparing the proposed land uses with site carrying capacity.

After assigning a number of game players (i.e., residents) and selecting a lifestyle, icon tiles representing the five life support needs are placed on the game board. In a "trial and error" fashion, the land areas represented by the tiles are totaled and matched with the land areas inventoried on the Suitability Maps. If there is insufficient resource land area within the site boundaries, the remaining tiles are placed off the game board indicating that those resource needs must be provided off-site.

Attainment of balance is determined by either the ratio of the amount of life support the land is supplying verses that needed by humans, or by the ratio of internally supplied life support needs verses that laying outside of the site boundaries. The objective is to achieve a natural capital-human land use balance by more efficient use of resources, a reduction in needs, and/or adroit techniques for integrating land uses such as those exemplified in permaculture communities (e.g. agroforestry, regenerative wastewater systems, etc). The question "can human consumption be balanced with the sustainable output of the natural resources within a given site boundary" might not be as important a question as "are we aware of the degree of imbalance we are causing once we permanently alter the landscape?" Is this ratio a procedure that needs to become stated on every project?

6. RESULTS

One result of carrying out eco-balance planning was a generic per capita ecological footprint for Austin, Texas. The on-site and off-site land use areas required to meet the needs of one person living a sustainable lifestyle were determined at the scale of a building site. The plan demonstrated that, in spatial terms, human land uses are much greater outside the boundaries of the building site.

At a community scale, the results from testing the plan on an actual eco-village project were both informative and disturbing. While the participants, all of whom were well educated, environmentally oriented people, were able to easily understand the plan's procedures, they were surprised at the results which defined "sustainable" as a balancing of resource used in irrefutable spatial terms. The discovery that their "eco-village" required reliance on resources well beyond their physical boundaries was a powerful statement of how disconnected people are to their "ecological footprint." Heated discussions evolved regarding the potential of people to understand and embrace the land requirements and personal commitment necessary to actualize a sustainable future.

7. CONCLUSION

The EcoBalance™ game is cross-disciplinary by nature and can involve many disciplines in the natural and engineering sciences. For example, the seemingly simple identification of land area resources needed for providing solar electric power through its life cycle, from sourcing materials to the renewable energy resources for manufacturing, to use and final disposal, are quite staggering. When one adds to this other sustainable technologies that are more biologically based, such as biomass energy or the enzymology for soil stabilization, the disciplines are many.

Connecting life support technology to the land from which our resources originate is the core of the EcoBalance™ game. It is important to note that the technologies represented are different than the technologies we have assumed to be appropriate in our current approach to life support. "Life technics," as Peter van Dresser was prone to call such technologies, often possess an obvious connection to the resource's place of origin. These technologies are often a combination of simplicity and sophistication, but not sophistication in the same sense as modern gadgetry. They possess considerable technical sophistication rooted within the character and potential of a particular place.

Particular technologies for our gaming simulation represent a small sampling of what we need in our EcoBalance™ land use development tool kit. But it is extremely important to understand that nature is doing work for us, such as forests giving us oxygen and serving as our carbon sink. It seems that we need a major re-evaluation of what is technology and what is nature. The care and management of the natural life support system itself will become an important community enterprise.

8. REFERENCES

Over 100 references were used in developing the EcoBalance game. Projects, figures, mapping techniques, carrying capacity data are available on request.