Life Cycle Assessment of Ecosystem Services for Phoenix's Building Stock

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Central Arizona-Phoenix Long-Term Ecological Research
CAP LTER

Introduction

Ecosystem services are crucial to sustaining human existence, yet are generally poorly accounted for in urban sustainability assessments. More comprehensive, transparent, and robust methods are necessary for holistic understanding of urban technosphere and ecosphere systems, including their interfaces. Ecosystem services are the human benefits derived from ecosystems which the Millennium Ecosystem Assessment defines as "dynamic complex[es] of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit" (Arico et al., 2005). Ecosystem services are often indirectly gained from the natural environment, so the linkages between human activity and declining in ecosystem services are not always well understood. Including ecosystem services in life cycle assessment (LCA) is an important step to provide rigorous environmental impact accounting to decision makers.
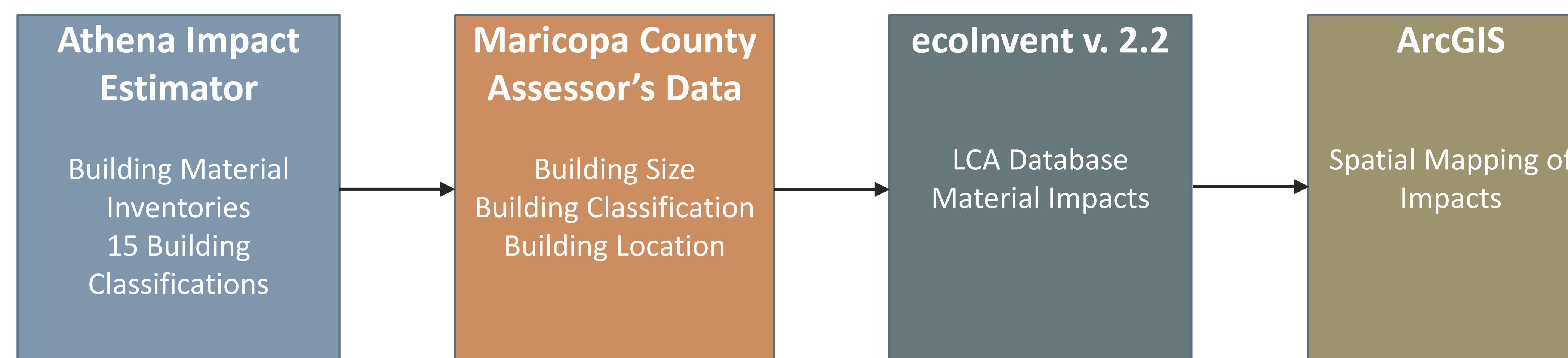
Goal

The goal of this research is to develop a methodology for assessing the ecosystem services impact from the use of building construction materials in the Phoenix metropolitan area through the use of LCA. A life cycle accounting of Phoenix's embedded building materials will inform infrastructure policy and decision makers, assist with community education, and inform the urban sustainability community of consequences. Additionally this lays the foundation for future, more refined ecosystem service LCAs.
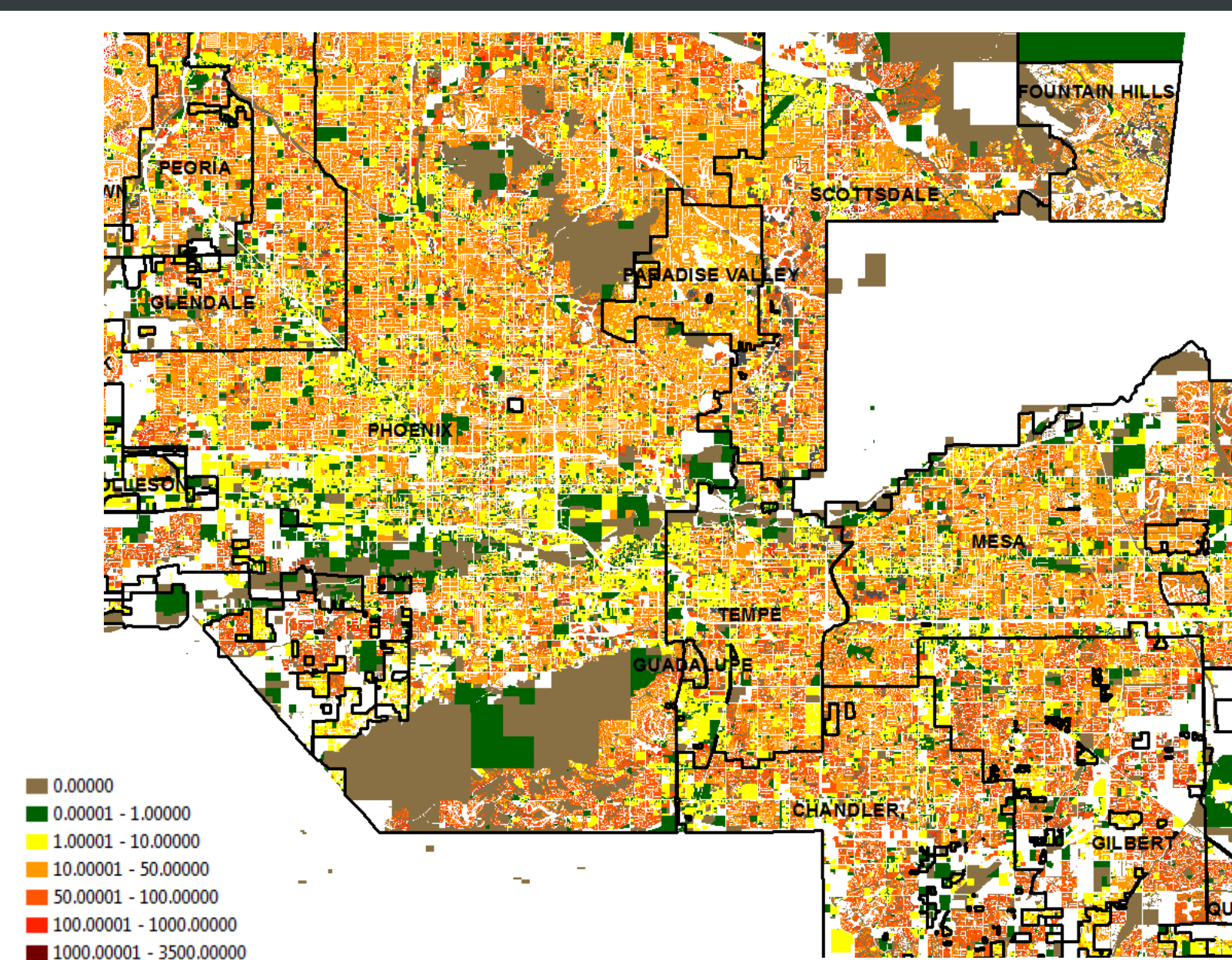
Existing Literature

A comprehensive inventory of present inclusion of ecosystem services in LCA was performed by Zhang, Singh, & Bakshi, 2010. In a second paper, Zhang, Baral, & Bakshi, 2010 introduced a web tool called Ecologically Based LCA (Eco-LCA) that includes new impact categories to account for more ecosystem services. The Eco-LCA tool has included many new ecosystem service impact categories, such as pollination, but has stopped short of providing a process-based approach of including ecosystem services in LCA. Instead, the impact categories have been linked to Economic Input-Output LCA, which models the entire 1997 US economy as 491 sectors. The advantage of this approach is that no section of the system boundary is "cut off", which is consistent with systems-oriented thinking. The disadvantages of this method are the loss of detail in specific processes since impacts are aggregated by sector and the loss of regional specificity by presenting US average impacts. Studies have shown that spatial scale is especially important in developing new ecosystem service impact categories (Saad, Margni, Koellner, Wittstock, & Deschênes, 2011). A process-based LCA would be a more appropriate approach since it considers the exact processes and accompanying impacts.

Methodology

This project incorporates ecosystem service impacts within the current LCA framework to highlight the potential of further integrating ecosystem services in LCA. The goal of an LCA is to assess all relevant human and environment impact categories, including those which are ancillary. This is extremely important, as the majority of impacts could potentially exist in the outlying city regions as opposed to processes directly within a city (Chester, Pincetl, & Allenby, 2012). Current day buildings are inventoried by the Maricopa County Assessor's Office, which provides information such as size, year of construction, and building type. Building material models were developed for 15 building classifications to capture the heterogeneity of materials between building types. Athena Impact Estimator software was then used to obtain material inventories for each model. EcoInvent Database version 2.2 material processes were joined with the building material models to determine impacts. The impacts are then normalized based on the square footage of the category model buildings. The normalized factors were joined with the Maricopa County assessor data to determine regional impacts. This study is a cradle to gate assessment and includes extraction of primary materials through building material production at the factory gate. The transportation from the factory to the construction site and the equipment use in building construction are excluded in this assessment.
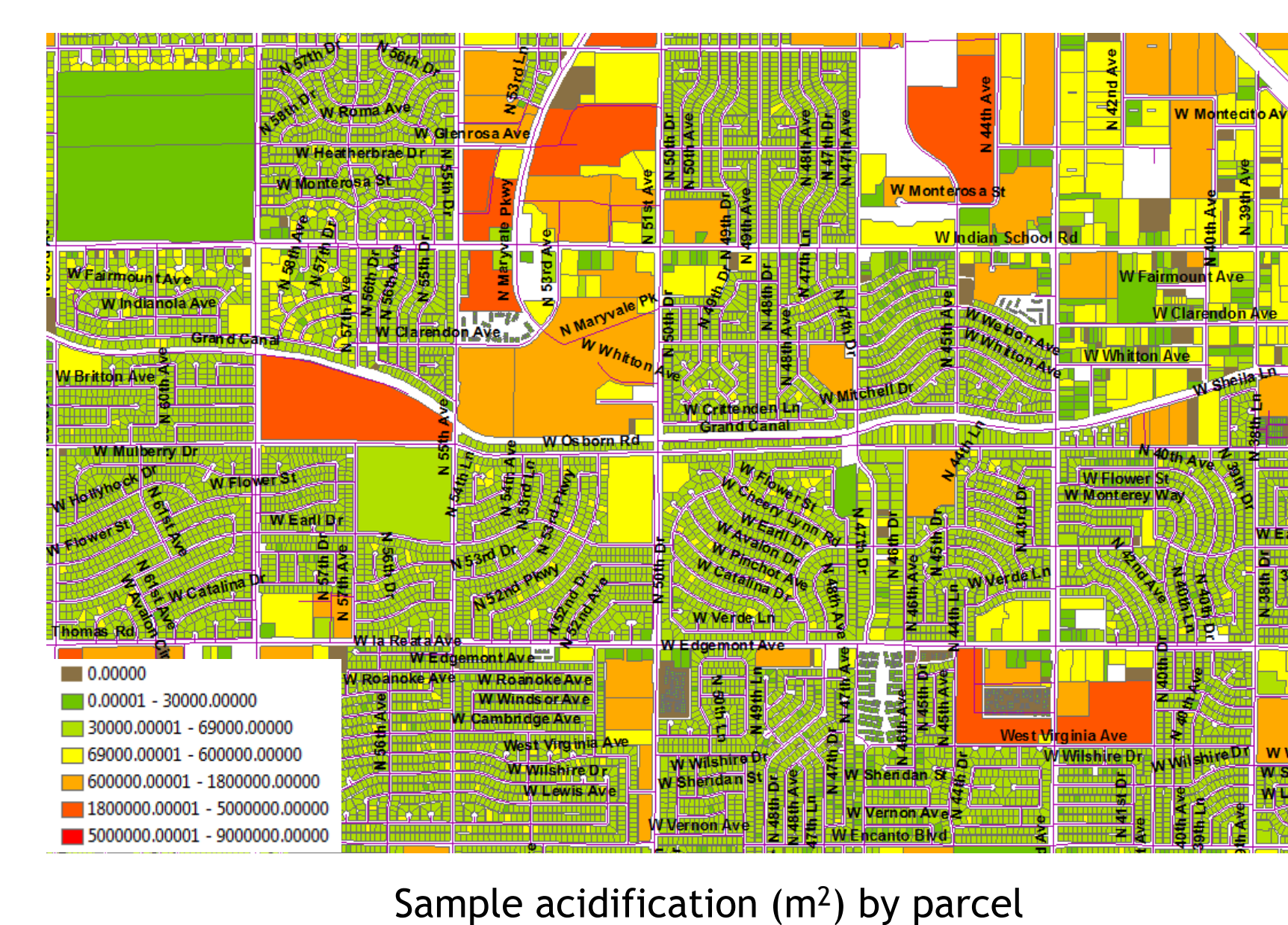
Athena Impact Estimator	Maricopa County Assessor's Data	ecoInvent v. 2.2	ArcGIS
Building Material Inventories 15 Building Classifications	Building Size Building Classification Building Location	LCA Database Material Impacts	Spatial Mapping of Impacts

Results

Ratio of Ecological Footprint of Building Materials to Parcel Area

Impact Methodologies and Ecosystem Service Coverage

Impact Methodology	Ecosystem Service Category
Cumulative Energy Demand	Provisioning
Cumulative Exergy Demand	Provisioning
Ecosystem Damage Potential	Regulating / Supporting
Ecological Footprint	Regulating / Supporting
TRACI	Regulating / Supporting
EDIP	Regulating / Supporting

Multiple Impact Methodologies were used from the ecoInvent database to give a range of impact categories. Samples from the EDIP Acidification and the Ecological Footprint mapping are presented here. These methodologies do not directly quantify reduced ecosystem service functioning, but rather quantify emissions which trigger ecosystem service damages.

	Size (mi²)	Population
Phoenix Building Ecological Footprint (1 year)	120,709	3,880,244
Maricopa County	9,224	3,880,244
Arizona	113,998	6,482,505
United States	3,794,100	311,591,917
World	57,258,915	6,973,738,433

These results demonstrate the potential for producing spatially resolute damages to ecosystem services by using life cycle assessment. Localized indicators need to be developed to increase accuracy of the spatial data. These diagrams map sources triggering impacts (construction location), but not necessarily the location of damages which would occur during the extraction and manufacturing processes.

Sample acidification (m²) by parcel

Future Work

Developing new, diverse, and regional-specific indicators for LCA is an important next step to reducing uncertainty and capturing the poorly understood categories of ecosystem service impacts. The greatest remaining challenges to fully incorporating ecosystem services into LCA are 1) properly representing the role of ecosystem services in quantitative terms, 2) aggregating raw LCA data, and 3) properly accounting for direct and indirect human reliance on ecosystems (Zhang, Singh, et al., 2010). Future studies should focus on finding innovative ways to quantify and/or communicate the linkages between natural and anthropogenic systems.

Source: Millennium Ecosystem Assessment
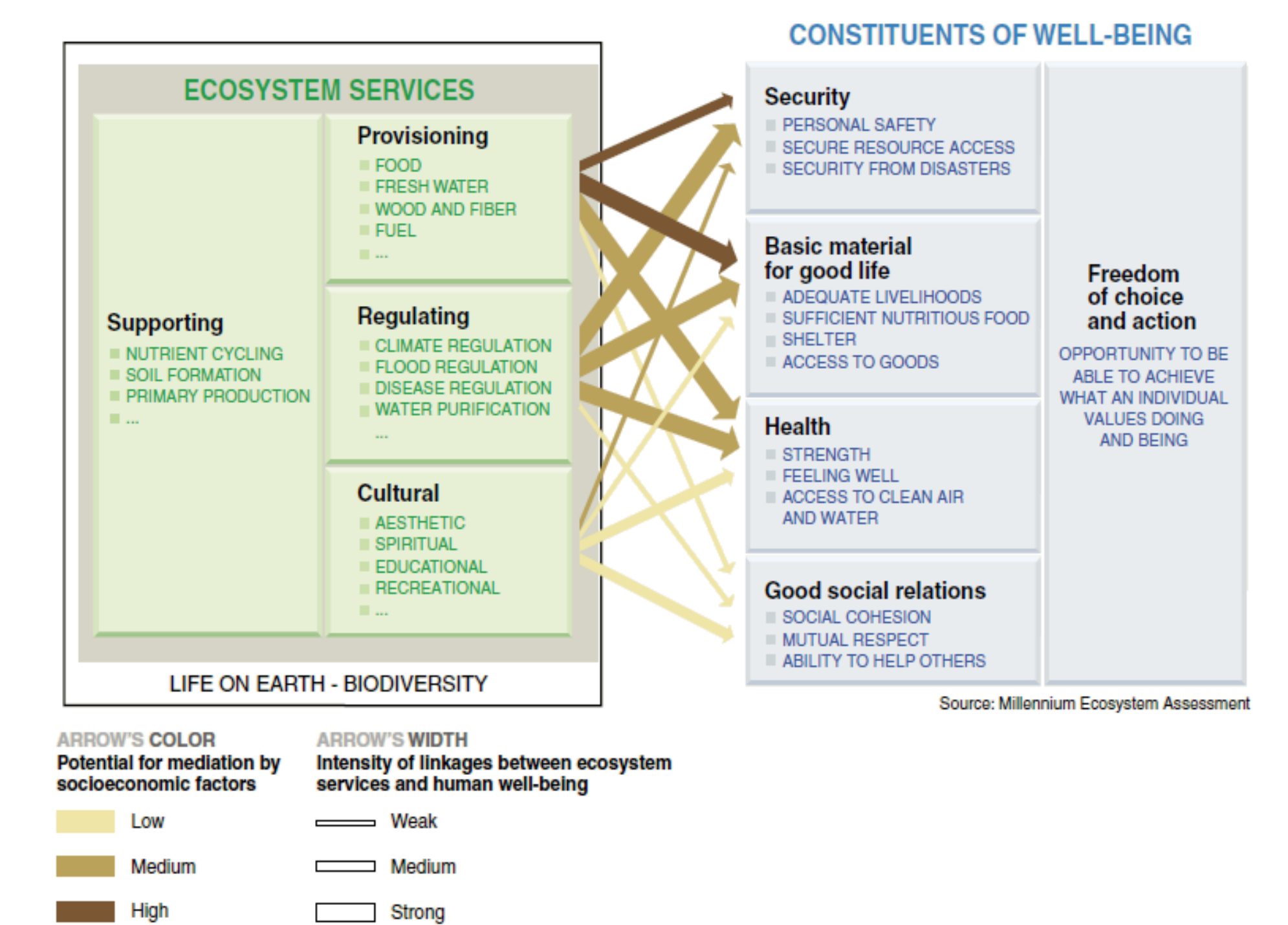
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