Florida International University
FIU Digital Commons

FIU Electronic Theses and Dissertations | University Graduate School

11-9-2016

A Framework for assessing Alternative Agro-Ecosystems: finding Multi-Functional Solutions for Sustainable urban landscapes.

Thais H. Thiesen Ms.
tbeck016@fiu.edu

DOI: 10.25148/etd.FIDC001192

Follow this and additional works at: https://digitalcommons.fiu.edu/etd

Part of the Agricultural Economics Commons, Agricultural Education Commons, Agricultural Science Commons, and the Landscape Architecture Commons

Recommended Citation

Thiesen, Thais H. Ms., "A Framework for assessing Alternative Agro-Ecosystems: finding Multi-Functional Solutions for Sustainable urban landscapes." (2016). *FIU Electronic Theses and Dissertations*. 3042.
https://digitalcommons.fiu.edu/etd/3042

This work is brought to you for free and open access by the University Graduate School at FIU Digital Commons. It has been accepted for inclusion in FIU Electronic Theses and Dissertations by an authorized administrator of FIU Digital Commons. For more information, please contact dcc@fiu.edu.

FLORIDA INTERNATIONAL UNIVERSITY

Miami, Florida

A FRAMEWORK FOR ASSESSING ALTERNATIVE AGRO-ECOSYSTEMS: FINDING MULTI-FUNCTIONAL SOLUTIONS FOR SUSTAINABLE URBAN LANDSCAPES

A thesis submitted in partial fulfillment of

the requirements for the degree of

MASTER OF SCIENCE

in

ENVIRONMENTAL STUDIES

by

Thais Thiesen

2016

To: Dean Michael R. Heithaus
College of Arts, Sciences and Education

This thesis, written by Thais Thiesen, and entitled A Framework for Assessing Alternative Agro-Ecosystems: Finding Multi-Functional Solutions for Sustainable Urban Landscapes, having been approved in respect to style and intellectual content, is referred to you for judgement.

We have read this thesis and recommended that it be approved.

____
Robeto Rovira

____
Hong Liu

____
Mahadev Bhat, Major Professor

Date of Defense: November 9, 2016

The thesis of Thais Thiesen is approved.

____
Dean Michael R. Heithaus
College of Arts, Sciences and Education

____
Andres G. Gil
Vice President for Research and Economic Development
And Dean of the University Graduate School

Florida International University, 2016

© Copyright 2016 by Thais Thiesen

All rights reserved.

ACKNOWLEDGMENTS

I sincerely would like to thank my major professor, Dr. Mahadev Bhat, for his guidance, support and direction in the development of this work and my academic career. I am grateful to my committee members Dr. Roberto Rovira and Dr. Hong Liu for their insightful and helpful advice. I would also like to thank other members of the department who have provided me with valuable support throughout my graduate program, , Dr. Krish Jayachandran Ms. Stephany Alvarez-Ventura, Dr. Amir Khoddamzadeh, and my fellow graduate students. And to acknowledge Mr. Mario Yanez who has been a trusted mentor and friend.

I also would like to acknowledge the United States Department of Agriculture (USDA) for granting me the scholarship and funding for my research through the NIFA-Hispanics Serving Institutions Higher Education Grants Program (Contract 2011-38422-30804) and National Needs Fellowship Program (USDA-NIFA-NNF-213-38420-20499).

I am deeply grateful to the farmers and operators who took the time to participate in this study as sources of information and insight. For their passionate work, care of the land and sharing with me the success and challenges in their projects.

ABSTRACT OF THE THESIS

A FRAMEWORK FOR ASSESSING ALTERNATIVE AGRO-ECOSYSTEMS: FINDING MULTI-FUNCTIONAL SOLUTIONS FOR SUSTAINABLE URBAN LANDSCAPES

by

Thais Thiesen

Florida International University, 2016

Miami, Florida

Professor Mahadev Bhat, Major Professor

Creating sustainable urban landscapes in light of growing population pressures requires interdisciplinary multi-functional solutions. Alternative agro-ecosystems described as food forests, permaculture gardens, and/or edible landscapes among others could offer potential ways to address the social, economic and ecological goals of various stakeholders simultaneously. The present research used a unique rubric, the Permaculture and Agro-ecosystems Sustainability Scorecard (PASS) that combines existing agricultural and landscape sustainability indicators in order to assess alternative agro-ecosystems. The rubric evaluates provisioning, regulating, supporting and cultural ecosystem services such as pollinator presence, biodiversity, pesticides and fertilizer use, carbon sequestration and human interactions. The PASS was used to score twelve sites in South Florida that meet specific criteria in the small farm, residential and public space categories. The results showed that the majority of the sites scored highest in the supporting services provided, followed by regulating and cultural services and lowest in the economic services category.

TABLE OF CONTENTS

LIST OF TABLES

TABLE PAGE

LIST OF FIGURES

FIGURE PAGE

1.0 INTRODUCTION

1.1 Brief Background

The Millennium Ecosystem Assessment (MA), the largest assessment of the health of the Earth's ecosystems to date, found that the last 50 years have brought unprecedented change in the structure and function of ecosystems primarily to meet demands for food, fresh water and other products (MA, 2005). The report also found that although there have been substantial gains in human well being and economic development these have come at a great cost, whereby 60% of ecosystem services are being used unsustainably, and will continue on this trend as population and demand is projected to rise by 50% in the next two decades. Agriculture is intrinsically related to the ecosystem services that support it; therefore future productivity depends on the ecological sustainability of services such as air quality, climate regulation, erosion, pest control and pollination (Dale et al., 2007). Furthermore, the International Panel on Climate Change (IPCC) and 98% of the scientific community have agreed that civilization is facing unparalleled climate change caused by human activity (IPCC, 2013). Second only to the burning of fossil fuels agriculture, including production, packaging, transport, retailing, land clearing and deforestation accounts for nearly half of all greenhouse gas emissions worldwide. The degradation associated with agriculture will only worsen without significant changes being made in policies, institutions and practices around the world (MA, 2005).

Nowhere are the impacts of these changes in ecosystem structure felt more than in urban and peri-urban areas, with over 60% of the world's population predicted to reside in cities by 2030 (United Nations, 2004). These hot spots for global environmental change are central to the discussion of sustainable development and growth (Grim et al., 2008). How do we meet the growing demand for food while maintaining or better yet, regenerating the ecosystem services on which production and human welfare relies? The solution is certainly not simple as it entails a vast array of ecological, policy, economic, management and social issues. As with other complex subjects the debate can be highly polarized, on one side, those in favor of improved genetics, mechanization and intensifying production and the other focuses on localized and small-scale organic farming that follows ecological principals. While both sides have valid arguments and have shown evidence of the potential to increase food production, the capacity of alternative farming systems to increase productivity, endure environmental variability and regenerate ecosystem services has been demonstrated in harsh environments around the world (Scialabba et al., 2014; Altieri, 2012). These alternative agro-ecosystems are characterized by high levels of biodiversity, recycling of materials and wastes, use of local cultivars, integrated pest management, and food sovereignty (Altieri, 2002).

Issues surrounding industrial farming vs. smallholder food production, both in urban and rural areas, are not only ecological but have social-political implications as well. The United Nations "Special Rapporteur on the Right to Food" conducted over six years in 13 countries conclude that current food systems primarily serve to increase the profit of agri-business corporations and marginalize food producers (De Shutter, 2014). The report further states that "a new-paradigm focused on well-being, resilience and sustainability must be designed to replace the productivity paradigm and thus better support the full realization of the right to adequate food."(De Shutter, 2014, p.13)

1.2 Interdisciplinary and multi-functional solutions

The new paradigm will require innovative thinking and interdisciplinary approaches which are possible only through a proper collaboration between scientists, planners, policy makers, and engineers. In urban and peri-urban environments the process of design is a potential bridge that can help stakeholders collaborate and make important connections between the built and natural environment (Clark, 2013). Making this connection will involve more than simply the form and function of design, but also reach into social and economic issues and strategies of which food production is a central aspect (Ahern, 2013). Over the last few decades many cities have adopted green infrastructure programs that focus on urban forestry, developing trails that connect neighborhoods, restoring habitat and urban agriculture as comprehensive solutions to urban challenges (McLain, 2012). Multi-functionality is being promoted to address multiple needs and functions simultaneously as natural and financial resources become more limited with increasing population pressures. In landscape planning, multi-functionality refers to multiple ecological, social and economic functions being considered and combined in the process of design and decision making in order to use space more efficiently (Hanse, 2014). Multi-functionality is particularly important as a consideration in agricultural activities in urban areas because of the pressures of other development potentials such as housing and roads (Zasada, 2011). The design of urban agricultural systems is a potential way to bridge the gap between aesthetic and practical functions of the urban landscape, having far reaching implications for both food security and public health among other benefits.

1.3 Incorporating Agriculture in Urban Environments

Urban Agriculture (UA) involves diverse practices of growing, processing and distributing food in the urban environment. The United Nations reports over 800 million people practice some form of UA worldwide and recognizes it as a major strategy to relieve hunger especially among the poor in developing countries (Altieri et al., 1999). Urban gardening also serves as a source of income for the poor in places like Madagascar, Nigeria and Nepal where the share of income from these activities can be as high as 55% (Orsini et al., 2013, Zessa, 2010). For instance, the city of Havana produces 8,500 tons of produce, 7.5 million eggs and 3,650 tons of meat in its urban agricultural systems (Altieri et al., 1999). In developed countries such as the U.S. because of the high value of urban land and competing land use requirements agriculture does not always seem like an appropriate alternative to development. Certain agricultural practices such as conventional grain production could certainly not be appropriate for urban environments but other types of agriculture that can serve multiple ecological, economic and social functions could be significant as a land-use strategy in cities of developed nations (Lovell, 2010). Although the number of poor households in the United States that practice some form of UA is small, food insecurity is a real problem in the lives of America's poor and near-poor, especially for growing children. A 2014 report by the United States Department of Agriculture's Economic Research Service showed that 14% of American households were food insecure or had difficulty at some time during the year to provide enough food for all members of the household (Coleman-Jensen et al., 2015). The connection between poverty, food insecurity and the potential for income for poor communities in the cities of developed nations such as the U.S. is only beginning to be explored (McClintock et al., 2102). However, literature indicates that despite a lack of support from federal and state governments, urban agriculture in developed countries continues to gain momentum through local food policy council and advocacy groups, especially in cities that have lost industrial jobs such as Detroit, Michigan. (Sarah, 2010). In fact there has been a steady increase in households in the US that are involved in some type of food gardening, especially amongst lower income households where studies show this can make a significant contribution to the gardeners' vegetable intake (Algert et al., 2016). The challenge in affluent societies is to view UA within the conceptual framework of the design and construction of cities and as a component to address economic and environmental issues rather than as a competing land use (Pearson, 2010). There are several forms of UA currently being practiced in vacant lands, rooftops, school grounds, housing facilities and other locations with most involving individual garden plots or beds with annual vegetable production (Lin, 2015). Relatively new practices in the urban environment such as urban food forests seek to integrate urban agriculture, urban forestry and agroforestry practices in productive landscapes that maximize utility and services. One example is found in Seattle, Washington where part of the green infrastructure vision was to utilize urban forests not only for the services they provide such as improving air and water quality and reducing storm-water run-off, but also as a source of goods such as fruit, nuts, building materials and fuel in order to achieve the highest potential of urban sustainability (McLain, 2012). Permaculture gardens are another alternative found primarily in private land but with a tremendous potential across different scales and functions.

1.4 Statement of the Problem

Alternative agro-ecosystems characterized by diverse perennial polycultures, have both aesthetic and functional value and great potential for meeting human needs, while providing essential ecosystem services in urban landscapes. However, as a result complexity and heterogeneity of these productive landscapes there is a lack of information and understanding of their overall benefits. Ecosystem services such as pollination, water and air purification, and aesthetic value can be useful as indicators of the performance of these designed systems, which link science, design and management (Ahern, 2013). There is a need for researchers to design tools that quantify and monitor these benefits so that decision makers can make informed land use policy decisions (Aubry, 2012, Person, 2010, Ahern, 2013, Steiner, 2011). Furthermore having tools to measure the post implementation outcomes of the ecosystem services provided by agro-ecosystems will insure that future projects carry less risk and have more realistic goals, helping cities become laboratories for regenerative practices (Ahern, 2013).

1.5 Objectives of the Study

The overall goal of this research is to assess the sustainability of alternative agro-ecosystems in South Florida that have both functional and aesthetic values for productive landscapes in urban environments specifically:

- To develop a rubric called Permaculture and Agro-ecosystems Sustainability Scorecard (PASS) for assessing alternative agro-ecosystems.
- To define and assess alternative agro-ecosystems in South Florida’s urban and peri-urban environment which will have optimal combinations of ecological, economic and other functional traits.

- To develop a set of best practice guidelines for the implementation of these systems.
- To assess the potential benefits of these system and to draw policy recommendations for their implementation.

1.6 Outline of the Thesis

The thesis will be organized as follows: Chapter II will provide background for trends in alternative agro-ecosystems and the history and basis for the formulation of sustainability indices. It will also include a description of the indicators and metrics used to formulate the rubric and the benefits and limitations of indices. Chapter III will outline the framework used for the criteria and indicators, and the criteria used to select the sites and to collect the data. Chapter IV will present the results beginning with an overview of the sites in the study, the weights given to the indicators, the resulting scores for each of the sites in the study and an analysis of the results for each of the three site categories: farm, residential and public. Chapter IV will also analyze the results and find correlations between successes and failures and particular site attributes. Chapter V will summarize and make best practice recommendations for practitioners as well as where future research is needed.

2.0 LITERATURE REVIEW

2.1 Introduction

The present chapter provides a summary and synthesis of various published works on alternative agro-ecosystems and the formulation of sustainability indices. A summary will be given of the history and progression of alternative agro-ecosystem terminology, as well as their relationship to each other. Followed by a background on sustainability assessment indices, ecosystem service indicators, the benefits and limitations of indices and the specific indicator areas that were used in the PASS framework.

2.2 Alternative Agro-ecosystems

Beginning in the 1970s with increasing access to information and awareness of the tremendous environmental costs attached to the productivity of industrial agriculture, several "alternative" movements and practices that followed traditional systems began to take shape (Angotti, 2015). They are alternative in that unlike modern agricultural practices they rely on ecological and regenerative practices that are adapted to their local environment, and are self-sustaining, low-input, diversified, and energy efficient. Terms, such as agroecology, urban agriculture, edible landscaping, permaculture, food forests, perennial polycultures, urban food forestry, landscape machines, urban foraging, are being utilized by planners, scientists, farmers and policy makers to describe some of these alternative production methods and systems. Table 1 below provides a summary of terminology with their description, significance and examples sites in this study.

Table 1: Alternative Agro-Ecosystem Terminology

Type	Description	Significance	Sources	Study Site Examples
Agricultural Urbanism	A type of urbanism in which all aspects of design and development are focused on the production of food. Every dwelling built will participate in some measure in the production of food.	-food sovereignty -economic self-sustainability -closed nutrient cycle -better control over food production standards -designed and incorporated	Porter, 2015; DPZ, 2009	Gaia Ma, Treehugger Farm, Earth n Us Farms, Ed Fund Garden, Booker T. Garden
Agroecology	A scientific discipline, agriculture practices, and political and social movement involving various approaches to solve challenges of agriculture production.	-some practices preserve traditional knowledge -especially significant for poor farmers and in marginalized areas -techniques have over 80 years of scientific backing	Wezel et al., 2009; Altieri 2002, Gliessman 2014,	All sites in the study
Agroecosystem	A man-made system including biotic and abiotic components that mimics a natural system whose purpose is to produce food or other raw materials for human use.	-looks at agricultural system as an ecosystem -interdependent -network science	Odum, 1969; Altieri, 1995; Wezel et al., 2009; Lovell, 2010, Gliessman, 2007	All sites in the study
Agroforestry	Land use that combines tree-growing and conventional agricultural practices on the same land unite to maximize social, economic and environmental benefits and services.	-significant carbon sequestration potential -reduced erosion -reduced need for inputs -increased biodiversity	Anderson, 2012: Nait et al. 2009, Sinclair, 1999;	Guara Ki Eco Farm, Treehuggers Farm, Muni Farms, ECHO, FGCU Food Forest, Booker T. Garden, Unbelievable Acres
Carbon Farming	Generally a suite of crops and practices that sequester carbon while meeting human needs. But also an offset scheme to derive carbon credits worldwide from farming initiatives.	-potential for income through carbon credits -climate change mitigation strategy -agricultural intensification -reduced erosion and flooding	Toensmeier, 2016; Oosterzee, 2012; Tang, 2016	All site in the study to various degrees
Conservation Agriculture	Utilizes farming practices that protect and conserve the abiotic and biotic elements of the soil by causing little or not disturbance while	-reduction in labor requirements benefitting small farmers -higher rates of water infiltration	Kassame et al. 2011; Scialabba, 2014; Wuest et	All sites in the study.

	also increasing the overall biodiversity.	-reduced water requirements -increased soil sequestration	al., 2006; Mitchell et al. 2016	
Diversified Farming Systems	An approach to farming that prioritizes diversity on all scales, including species, uses, economics and more in order to maximize the ecosystem services provided.	-works on multiple spatial and temporal scales -increase biodiversity -looks at social issues	Kremen et al., 2012;	Guara Ki Eco Farms, Treehuggers Farms, Muni Farms, Little Haiti Garden, ECHO
Ecoagriculture	Landscape planning strategies that integrate agriculture as part of a larger conservation and development strategy. Economic, social and ecosystem needs and contributions are taken into consideration.	-large scale: -closes the traditional gap between conservationist and agriculturalist -use of agricultural landscapes to link fragmented ecosystems -use local communities expertise	Scherr et al., 2002, Falk, 2013; Scherr et al., 2013	All sites in the study
Edible Forest Garden	"A perennial polyculture of multipurpose plants supplying food, fuel, fiber, fodder, fertilizer and medicines. Each plant contributing to the success of the whole by fulfilling many functions."	-ecological restoration -builds resilience and stability -increased biodiversity -works with natural succession - decrease in maintenance overtime	Jacke et al., 2005;	FGCU Food Forest, ECHO , Booker T. Garden, Ed Fund Garden, Muni Farms, Unbelievable Acres
Edible Landscaping	Utilizing food crops such as fruit trees, vegetables and herbs as a replacement for ornamental plants in landscape design. Unlike purely agricultural production gives consideration to aesthetics, placement and functionality of plants utilized.	-recreational activity -increased food security and reduced food costs -convenience -aesthetic, colorful, designed	Tayobong, 2013; McLain et al., 2012; Worden,	Gaia Ma, Mounts Botanical Gardens
Landscape Ecological Urbanism	A synthesis of urban ecology and landscape urbanism whose goal is to design and plan cities to increase, rather than decrease ecosystem services.	-evolution of aesthetic understanding -deeper understanding of human agency in ecology -reflective learning through practice	Steiner, 2011	Earth n Us, Booker T. Food Forest, Twin Lakes Food Forest
Landscape Machines	Experimental designs that contain elements of a machine, like predictability, production, input/output efficiencies; and of natural ecosystems such as patterns of disturbance and connectivity/fragmentation.	-complex systems with self-sustaining cycles -laboratory to test various interventions in the landscape -redefines nature and human interactions -combines leisure areas with human needs	Roncken et al., 2011;	Gaia Ma, ECHO, Guara Ki Eco Farms

Multifunctional Agriculture	A way of viewing agriculture's changing role in industrialized nations from a base of solely food production to a more inclusive one that encompasses ecosystem, cultural, rural development and recreational management.	-assigns economic value to non-market goods and services of agriculture -help to justify and assess government subsidies -encourages the production of ecosystem services	Wilson, 2008; Moon et al., 2011; Boody et al., 2005; Sarah, 2010;	All sites in the study.
Perennial Polyculture Planting	Refers to herbaceous plants, small shrubs and large shrubs or trees that flower and produce seeds more than once that are either intercropped, or grown simultaneously or sequentially with two or more species.	-drop in soil erosion -reduction in soil degradation -increased biodiversity	Dewar, 2007; Vandermeer, 1989; Scialabba, 2014	All sites in the study
Peri-Urban Agriculture	The multi-functional type of agriculture that occurs in the landscape interface between urban and rural areas, which is characterized by its diverse environmental and recreational value.	-multi-functional land use -more sustainable practices used due to proximity to population -proximity to consumers -leisure and recreation value -conservation of farmland and cultural heritage -poverty and hunger alleviation	Zasada, 2011; James et al., 2016; Yang et al., 2016	Treehugger Farm, Guara Ki Eco Farm, Muni Farms, Unbelievable Acres
Permaculture	"An alternative agroecology movement and ecological design system which mimics the patterns and relationships found in nature, while yielding food, fiber and energy for provisions of local needs."	- integrative design system -can be used at various scales -emphasizes ecological relationships elements perform many functions -over 40 years of "case study" examples implemented worldwide	Ferguson, 2014; Holmgren, 2008; Morrow, 2006; Akhtar et al., 2016	All sites in this study
Regenerative Agriculture	Agricultural practices that help in the restoration of marginal and degraded lands by improving the soil, increasing biodiversity and other ecosystem services while meeting human needs.	-can be used in marginal and underutilized areas - focuses on soil building and formation -	Toensmeier, 2016; Rhodes, 2012; Pearson, 2007	Little Haiti Community Garden
Tropical Homegarden Agroforestry	An agroforestry cropping system popular in many tropical and sub-tropical regions of the world, which involves a polyculture of	-increased biodiversity -develop ecological complexity overtime	Islam, 2015; Webb, 2009; Toensmeier,	Gaia Ma, Booker T., Ed Fund, Guara Ki Eco

	multistory layers of useful and edible plants around a homestead. It has been shown to have some of the highest rates of biodiversity and carbon sequestration of all man made system.	-potential as conservation strategy -carbon sequestration potential -diversity of food products -promotes social justice and preservation of cultural knowledge and species	2016; Nair,	
Urban Agriculture	Food produced locally in urban areas in community gardens, roof top gardens, residences or a variety of other urban sites for the consumption of local residents and providing a variety of other ecosystem services such as biodiversity and cultural activities.	-Availability of foods in proximity to consumers -access to fresh food in food deserts -increase in fresh vegetable intake -economic value of intensive high value crops -ecological functions -environmental benefits to urban areas	Lovell, 2010; Pearson L.J, 2010;	Earth & Us, Little Haiti Community Garden
Urban Food Forestry	"The intentional and strategic use of woody perennial food producing species in urban edible landscapes to improve the sustainability and resilience of urban communities."	-multi-functional land use -improve urban food security -increase biodiversity and carbon sequestration capacity -sociocultural and material benefits to city residents	Clark, 2013; McLain et al., 2013	Booker T. Garden, Ed Fund Garden, Earth n Us Farms FGCU Food Forest
Urban Foraging	The practice of collecting plants or parts of plants such as fruits, leaves or pods in the urban environment by residents for the purpose of personal use or for resale, or as a way to connect with nature and with the social groups tied to these practices.	-fosters cultural belonging -place-building - increased stewardship and public participation in conservation -challenges regulations and views of humans in green spaces	Poe et al., 2014; McLain et al., 2014	FGCU Food Forest, Booker T. Garden, Ed Fund Garden
Urban Forestry	"The art, science and technology of maintaining trees and forest resources in and around urban community ecosystems for the physiological, sociological, economic, and aesthetic benefits trees provide in society."	-connection to social wellbeing and place making -economic benefits / willingness to pay -temperature, air and water quality control -habitat creation	Konijnendiijk et al., 2006; McPherson, 1992; Escobedo, 2015; Nowak, 2007; Dobbs, 2014	Booker T. Garden, Ed Fund Garden Earth n Us Farm

Some terms such as Agroecology, have several decades of history behind them and are widely recognized in scientific communities (Wezel et al., 2009). Others such as Edible Forest Garden are emerging and popular alternatives, but they can offer equally significant methodologies to meeting human demands for food while regenerating and supporting ecosystem services.

Chief among the above alternative systems, permaculture, is a high profile international movement and ecological design system, which has little exposure in scientific circles but offers significant contributions to the field of agriculture and experimental design and has been applied in many regions of the world (Fergusson, 2014). Developed in the early 1970s by Bill Mollison and David Holgrem, the term permaculture or "permanent agriculture" is a system of design and implementation of sustainable agricultural systems that are modeled on natural ecosystems. Permaculture is an "early adopter" technique and technology whose theory has been tested in practice over time by thousands of practitioners in land-based experiments giving us tried methods that can be adapted to a variety of climates and situations (Rhodes, 2012).

A more commonly accepted practice, Urban Forestry has been well supported by government funding as part of green infrastructure planning for hundreds of years (Johnston, 1996). Ample research has proven the role of urban trees in providing residents with valuable ecosystem services such as air pollution reduction, storm-control, energy savings, as well as a variety of social services like crime reduction, increased real estate values and more livable cities (McPherson, 1992; Escobedo, 2015; Nowak, 2007; Dobbs, 2014). Another universally recognized term Urban Agriculture (UA) encompasses many types of food growing systems from community gardens to urban orchards present in urban and peri-urban environments across the world. “The biodiversity and ecosystem services of UA can have potentially large societal and environmental benefits for cities, such as enhanced food security, air quality, and water regulation” (Lin, 2015, p.1). However, UA is often not integrated in the planning of the ecology of cities (Pearson, 2010). Therefore, the integration of agriculture and forestry has historically not been practiced in cities but only in rural environments classified as Agroforestry.

Agroforestry practiced in rural environments is a natural resource management strategy that combines forestry and agriculture practices to generate social, economic and environmental benefits (Nair et al., 2009). The benefits of Agroforestry systems are well documented in literature including tree products (e.g., fuel, food and building materials), income and employment, health and nutrition, reduction in soil erosion, increased biodiversity, increased water efficiency, biological pest control and carbon sequestration (Anderson, 2012; Palm, 1995; Mbow et al., 2014; Aijt, 2013). Home-garden agroforestry, a popular land use in the tropics, is of particular significance as a model when considering urban land use due to its diversity, provision of multiple services and wide socioeconomic and agro-ecological role in the landscape (Linger, 2014). Integrating urban agriculture, urban forestry and agroforestry practices for both ecosystem services and products is a relatively new practice in the urban environment. As mentioned previously, the urban forestry practiced in Seattle is not valued for the services they provide such as improving air and water quality and reducing storm-water run-off, but also as a source of goods such as fruit, nuts, building materials and fuel in order to achieve the highest potential of urban sustainability (McLain, 2012).

In a 2013 paper Clark labels this integration of services and goods as Urban Food Forestry (UFF), which he defines as “the intentional and strategic use of woody perennial food producing species in urban edible landscapes to improve the sustainability and resilience of urban communities” (p.4). UFF incorporate aspects of urban agriculture, urban forestry and agroforestry in a framework of landscape multi-functionality. If properly designed UFF’s have the potential to address the provision of ecosystem services, food security, and cultural needs of urban environments simultaneously (Clark, 2013). The Urban Foraging practices which support UFF’s is an important way in which communities connect to nature and to each other (Poe et al, 2014). Urban foraging takes many different forms such as gleaning clubs which are community groups that organize to harvest and distribute food, medicine and other products, and asset mapping which are GIS based computer applications that map edible plants in the area for foragers to access (McLain et al., 2014).

The development of UFF practices can be especially meaningful in Peri-Urban Agriculture (PUA), where city and countryside interface and there is a need to preserve and redefine the role of farmlands in the greater urban context (James et al., 2016). This role will vary significantly depending on the existing urban-rural relationships that exist in the region. For example in Africa UA and PUA production is focused on the provision of food and fuel for hunger and poverty alleviation and in Europe the preservation of green space for recreation and education in the form of agro-tourism is emphasized

(Yang et al., 2016). In fact agriculture's multifunctional nature is being utilized as a basis for a reorientation of current agricultural subsidies for certain types of farming from the support of solely commodity production to agricultural diversification and nonmarket ecosystem services (Boody et al., 2005). Multifunctional Agriculture is a term used by policymakers and farmers to recognize these societal benefits of farming beyond products, with the strength of a systems multi-functionality being measured by indicators such as productivity, reliance on external inputs, level of biodiversity and number of enterprises and jobs created related to the farming practice (Boody et al., 2005; Sarah, 2010).

Taking this concept of multifunctional use further, a new concept called Agricultural Urbanism (AU) originated by public design workshop led by the Miami based Duany Plater-Zyberk architecture and planning firm. This method of design, which is now only about 10 years old, involves the concept of integrating food production into new and existing developments with the recognition that the health of natural systems is essential to a sustainable form of urbanism (Porter, 2015). AU develops planning methodology where food growing is incorporated across the transect from natural zones, to rural, sub-urban and urban core zones (DPZ, 2009). Also led by designers and architects, Landscape Machines is a term used to describe a new form of ecological biotope that is part "landscape" and part "machine". For example a dredge landscape park designed in the Dutch delta takes polluted dredge from canals to be collected, separated and cleaned by organic processes that include land farming over a large peri-urban area. Like a machine with its predictability and efficiencies the input into the system is the polluted water and the fuel to run the machine is rainwater collection while the outputs are recreation, drinking water, fish, and agricultural production. The landscape part is the ecosystem created in the park with all of its naturally occurring relationships (Roncken et al., 2012). These design movements call for a new level of interaction with the landscape, one where human beings and collectives are part of nature and both aesthetic and ecological impacts are designed into the landscape.

There are several other forms of alternative agro-ecosystems that are more relevant for larger scale farming but many of the principles behind them can be utilized at various scales. Conservation agriculture focuses on reducing tilling and other soil disturbances, retaining crop residues on the soil surface and fostering crop and soil biodiversity. These practices have been shown in studies to have secondary impacts such as increased soil water storage by 2 inches, reduction of production costs by $100 to $150 per acre across a range of crops, soil carbon contents doubling, and reduction of fine dust particle of up to 85% (Mitchell et al., 2016). Regenerative agriculture also referred to as Carbon Farming takes it a step further focusing on how agriculture can play a significant role in reversing climate change by removing greenhouse gases from the atmosphere using techniques such as no-till systems, crop diversity, agroforestry and perennial cropping systems (Toensmeier, 2016). Although the focus of another system, Diversified Farming (DFS) is biodiversity at multiple spatial and/or temporal scales in essence the techniques applied such as the use of polycultures, non-crop plantings on field boarders, riparian buffers, live fences, hedgerows, rotational grazing and others will also have an impact on climate change mitigation (Kremen, et al., 2012). Beyond the ecosystem impacts, all of these farming system have social, political and economic effects as well, from the more equitable treatment of producers to more direct ways to distribute goods to consumers such as farmers markets and cooperatives.

Alternatives in any given area are driven by the need for other possibilities or solutions. They are often brought on by problems that exist with the established norms and offer techniques, processes or practices that challenge the mainstream. The problems with industrial agriculture have been well documented and the alternative agro-ecosystems that have evolved over the last decades offer various solutions at multiple scales and functions.

2.3 Sustainability Indices

2.3.1 Background on Indices

Sustainability is an objective found in nearly every arena from local governments to multi-national corporations, research institutions to NGO's worldwide. But just as popular as its use in the news and boardroom is the ambiguity of its definition and it real world application, and more than 100 definitions of sustainability can be found in literature (Bohringer, 2007) The Brundtland Report, one of the foundational works on the topic, defined it as "development that meets the needs of the present without comprising the ability of future generations to meet their own needs" (WCED, 1987). The previous definition captures the balance between environment and development that must be achieved in order for humans and their environment to thrive (Adam, 2006). The United Nations Conference on Environment and Development (UNCED) that occurred in Rio de Janeiro in 1992 called on government and non-governmental organizations to "develop and identify indicators of sustainable development in order to improve the information basis for decision making at all levels”(UNCED, 1992; Agenda 21, Chapter 40) Since that time many indices have been developed and attempts have been made to utilize indicators in areas such as social progress, economic development, quality of life and natural resource preservation. Composite assessment tools such as the Life Cycle Assessment (LCA), Cost-Benefit Analysis (CBA), Environmental Impact Assessment (EIA) and Sustainability Standards with Principles, and Criteria and Indicators (PC&I) are developed and used for a wide range of applications such as policy evaluation of projects and environmental standards in targeted areas such as energy and water consumption and levels of pollution (Singh, 2009). However, having a one-size fits all approach is not always appropriate and more targeted assessment systems have been formulated in high impact areas such as agriculture, manufacturing and urban planning. Since the 1970s particular attention has been given to assessing the impacts of agriculture because of the difficulty in achieving a balance between food production for an increasing population and the environmental impact caused by production (Ghisellini et al., 2014)).

Dozens of methods have been widely used in studies to measure environmental, social and economic impacts of indicators such as soil conditions, biodiversity, pest management, use of agrochemicals, work conditions and economic viability (Van der Werf, 2002). In other fields like design and planning, scorecards such as Leadership in Energy & Environmental Design (LEED) certification and more recently the Sustainable Site Initiative (SITES) serve as examples of interdisciplinary and comprehensive rating systems that assesses the design, construction and maintenance of buildings and landscapes (Sustainable Sites Initiative, 2015). LEED was developed by the U.S Green

Building Council, who created a scale to measure green practices, covering the sustainability of the site use, water efficiency, energy, materials and indoor air quality. The adoption of the rating system is driven by both performance-based benefits and marketing benefits from green signaling mechanisms (Matisoff et al., 2014). These assessment systems have also moved beyond the scale of a single building or landscape and developed into assessment tools for entire communities such as City Development Index (CDI), Genuine Progress Indicator (GPI), and LEED for Neighborhood Development. Measuring the sustainable development of urban areas is particularly important because of the close knight interactions between natural ecosystems, the built environment and social and economic networks (Berardi, 2013; Hiremath, 2013, Shen, 2011). These systems vary in their scope from small projects such as a 10 unit neighborhood development to city wide, literature shows that indicators in this area tend to lean more heavily towards efficient planning and design, ecological measures and transportation and less on social and economic measures (Berardi, 2013). The appropriate selection of indicators is the first and most significant factor in formulating effective indices in any sector.

2.3.2 Formulation of Indicators

Defining sustainability and appropriate indicators in any given area is not an easy task. An indicator uses a certain metric or set of measurements to communicate something of interest to a specific audience. They are developed to meet the needs of end users, and take into consideration national or local objectives and targets, for example for clean air or water, and are linked in some way to human well-being (Hammond et al., 1995, UNEP-WCMC, 2014). The complexity in industries such as building, manufacturing and agricultural production makes the need for holistic approaches to indicators a crucial aspect of accurate measurement. Having too many indicators can make the process of gathering data too time consuming and expensive, while having too few indicators could mean missing significant relationships and trade-offs (Bossel, 2001).

Two of the main criteria in selecting indicators are that they be objective in measuring progress towards a particular goal and that it be possible for users to apply the indicators. Other significant factors include the ability to measure data, data availability, cost and scientific validity of indicators (Roy, 2011). The United Nations guidance on measuring ecosystem services suggests that in order for an indicator to be successful they must be relevant, understandable, useable, scientifically sound, sensitive to change, practical and affordable (Brown, et al., 2014). When developing a framework and selecting the indicators either a "top-down" approach is used where experts and researchers define it or a "bottom-up" approach which involves different stakeholders in the decision making process (Lundin, 2003). A combination of both approaches is also commonly used. For instance, in a study that looked at sustainability assessment of aquaculture included an analysis by scientists of impacts that are specific to aquaculture such as nutrient release, antimicrobial resistance and spread of disease. Then the tool could be specifically adapted for this purpose and decision-making would incorporate feedback from tools and techniques being used in the field (Biniam, et al., 2012). As in the case of aquaculture choosing the most appropriate indicators needs to be adapted to the particular needs of the discipline and the end users. Criteria for good indicators include having a clear representation of the indicators, relevant cause and effect relationships, high transparency of the derivation strategies among others.

2.3.3 Limitations of Indices

Despite attempts to be impartial and objective there is a great deal of subjectivity that goes into the formulation of these indices including who makes the decision over which data to include, how weighing adjustments are applied and how data are aggregated (Morse, 2005). Experts are often in charge of intuitively deciding which indicators best represent their discipline, which can lead to disciplinary biases (Bossel, 2001). The complexity of the systems being analyzed along with the complexity of the concept of sustainability "would never allow the clear-cut definition of basic properties of sustainable systems" (Taylor et al., 1993). Gaparatos and Scolobig (2012) suggest that value judgments are inescapable attributes of indices, and therefore the selection of appropriate tools carry practical and ethical implications, but as long as these are carefully considered and there is a correct fit between the value judgments of the tool developers and the users it will be a useful tool. In Layke et al. (2011) twenty-one global and sub-global ecosystem service indicators were compiled and ranked in their "ability to convey information" and "data availability". They found that there were many gaps in the metrics, especially in regulating and cultural services, in many cases where data were not available such as in regulating services such as air quality control. Because provisioning services are easier to measure (e.g. fish stocks, farm yield, timber biomass) than other forms of contribution such as cultural and regulating services they are dominant. Proxies offer a solution to the lack of data availability measuring related ecosystem functions or nationally available data. For example, in the case of a service such as water regulation the proxy could be the available supply and delivery of water in the region. In the case of a cultural service such as quality of a recreational space local crime rates and visitors reached could be utilized as proxy (UNEP-WCMC, 2014).

Beyond indicator selections, procedures for normalization and weighing of data also require subjective judgment. Normalization takes raw data with different units and scales and makes it compatible to the same standard while weighing assigns either subjective or statistically derived weight percentages to each of the indicators, depending on their level of significance to the overall index (reference). The inherent problem in normalization and weighing data is that both of these procedures seek to compare variables that are not comparable (Bohringer and Jochem, 2007).

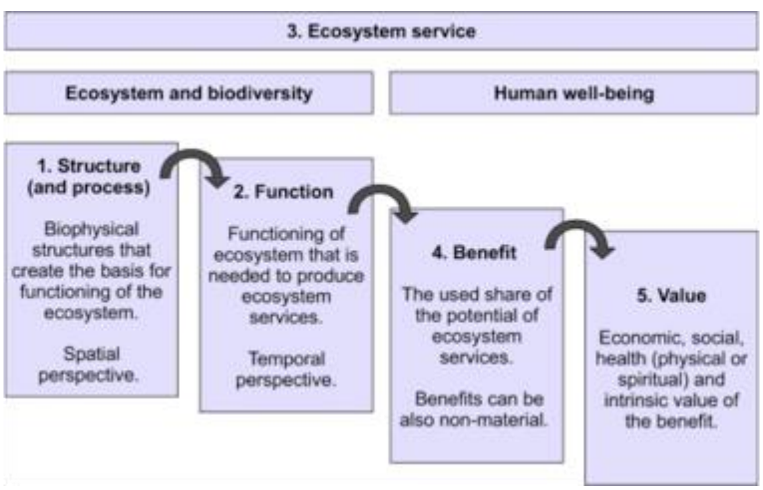
2.4 Theoretical Indicators and Frameworks for Assessing Ecosystem Services

In order to derive criteria and indicators to be used in my analysis, in this section I review disciplines and concepts related to alternative agro-ecosystems including the following: Ecosystem service indicators, agricultural sustainability indices, landscape sustainability assessment tools, agroecology sustainability indicators and permaculture methods.

2.4.1 Ecosystem Services as basis for indicators

Ecosystem services are defined as all the benefits that people obtain from ecosystems including provisioning, regulating, supporting and cultural services (MA, 2005). The United Nation's Millennium Ecosystem Assessment carried out between 2001 and 2005 was a massive undertaking by 1300 scientists whose goal was to link ecosystem services (ES) and human well being. Since the MEA was carried out ecosystem service research has grown exponentially and ES frameworks have been formulated at the global, national, regional and city level, as well as in various industries (Atkinson et al, 2012, Literature points out that although complex and in need of further development ES are optimal indicators to inform decision makers about the relationship between the natural environment and human well-being. Utilizing ES indicators can be especially useful in areas that are not traditionally conservation driven since they are economically motivated and valuated. The challenge continues to be how to link the ES concept into practical tools that can be applied in decision-making processes on different scales, which are relevant for end users (Monomen et al., 2016). The cascade model below shows how ES are tied to human well-being, the chain begins with the biophysical structures that together with the processes of nature create the ecosystem functioning, the benefits are derived from a share that is taken from the ES produced and the values are what is obtained from the benefits.

Figure 1: Ecosystem Service Cascade Model (Mononen et al., 2016)



2.4.2 Agricultural Sustainability Indicators

What makes agriculture sustainable? Traditionally the main goal of agriculture has been to maximize both yield and profit while minimizing instability and degradation of the productivity of the system (Watt, 1973). The intensification of food production has led to well documented ecological consequences such as pollution, loss of genetic diversity, dependence on non-renewable resources, as well as the loss of local control over agricultural production which can lead to large scale inequalities in the distribution of food (Gliessman, 2007). For agriculture production to be sustainable the management of the ecosystem must maintain diversity, productivity, regeneration capacity and vitality today and in future generations (Lewandowski et al., 1999). There are many assessment tools that have been developed for the evaluation of agricultural production systems. In a study conducted by de Olde et al. (2016) 48 agriculture assessment tools were identified and compared. The time requirements, availability of data, transparency, complexity, and applicability and relevance of each tool were studied. The study found that tools ranged from 'full' sustainability assessments to 'rapid,' with 'full' requiring a high investment time with a more scientifically underpinned output and 'rapid' requiring a limited time investment with a lower degree of output-accuracy.

The Sustainability Assessment of Farming and the Environment (SAFE) included in the study mentioned above is a hierarchical framework for assessing the sustainability of agricultural systems. I choose this framework as the basis for my scorecard because although it is content-based it has a holistic approach, which covers all the components of agricultural production lying somewhere in the middle of full and rapid models (Van Cauwenbergh, 2007). Another reason I choose to use this particular framework is that it works on multiple spatial levels from farm or site level to the regional or state level.

2.4.3 Sustainable SITES v2 Rating System

Created as a collaborative effort between the United States Botanic Garden, the University of Texas at Austin and the American Society of Landscape Architects, The

Sustainable Sites Initiative (SITES) are voluntary guidelines that offer a "systematic comprehensive set of guidelines and a rating system that defines sustainable sites, measures their performance and ultimately elevates the value of landscapes." (SITES, 2014) Its goal is to be the equivalent of LEED certification for buildings for outdoor landscapes. The suggestion made by sites is that not only can ecosystem services be maintained but also with appropriate design it can be enhanced. There are 200 potential points in the 48 credits for a given project site. Although they are very comprehensive and key in on items such as soil protection and restoration, which are crucial to agro-ecosystems, they lack in being tailored particularly for multi-functional urban agriculture projects as they are intended for all types of projects from parks to office buildings. Since the SITES guidelines were released in 2009 several projects have been awarded the SITES certification including landscapes at institutions like Cornell University, the National Renewable Energy Lab Research Facility in Golden, CO, the University of Texas in Arlington, the US Federal Office Building in Miramar, FL, as well as private residences, public parks, nature preserves and businesses.

2.4.4 Permaculture Design Principles

The principles that guide permaculture design are based on the three ethical tenets of care for the earth, care for people and a return of surplus. Central to permaculture is the idea of maximizing synergy between elements so that the whole becomes greater than the sum of its parts. Although the term was coined in Australia by David Holgrem and Bill Mollison in 1978 it is grounded on the previous work of Joseph Russel Smith's "Tree Crops: A Permanent Agriculture" and the science of systems ecology which largely focused on interactions and transactions between biological and ecological systems and their relationship to human interactions. What makes permaculture so significant as a contribution to the design and implementation of productive landscapes is how it combines the use of traditional ecological knowledge with modern scientific knowledge and appropriate technology. There are twelve main principles and practices applied:

Table 2: Permaculture Principles and Practices and ES Enhanced

Permaculture Principle	**Ecosystem Services Enhanced**
Observe and Interact- The site and all of its existing ecological and human components must be observed, recorded and taken into consideration before any action is taken.	• All
Catch and Store Energy- Solar energy with photovoltaic panels, water in above or underground catchment systems, gravity fed irrigation system, the use of perennial species that store carbon in their biomass and soils are all ways that energy can be captured and stored.	• Freshwater provision • Raw Materials • Nutrient Cycling • Climate Regulation • Erosion and Flood Control
Obtain a Yield: Production is one of the primary goals of these systems from a variety of products Apply self-regulation and accept feedback: Experiential learning is the key to finding solutions, if a certain crop species is suffering removing it from the system may be the best approach rather than using insecticides.	• Food provision • Raw materials • Economic interactions • Educational Activities
Apply Self-Regulation and Accept Feedback: The landscape becomes an experiment with constant reevaluation of the results and change in strategy to be implemented when necessary.	• Biodiversity • Nutrient Cycling • Educational Activities • Water Flow Regulation
Use and Value Renewable Resources and Services: From the use of solar panels, to the recycling of food scraps in composting systems, all resources available should be utilized.	• Biodiversity • Soil formation • Nutrient Cycling • Pollination and Biological Control

Produce No Waste: The use of recycled materials for buildings and structures and of yard and kitchen waste for compost is an example of this principle.	• Nutrient cycling • Soil formation • Air/Soil Quality
Design from Patterns to Details: Orienting a building to use passive solar heat is an example of designing according to the pattern in this case of solar exposure, also looking at the layout of the land and following the contours for planting that are naturally occurring. The principle and practice is to observe and utilize the naturally occurring patterns.	• Design and landscape aesthetics • Cultural and natural heritage • Erosion and Flood Control
Integrate Rather than Segregate: Inter and multi-cropping methods for the purposes of pest control and soil regeneration. Integrating natural and agricultural systems as well as uses.	• Cultural services • Economic interactions • Nutrient Cycling • Pollination and Biological Control
Use Small and Slow Solutions: In order to test the long term viability of a system it is build slowly over time in order to measure the failures and successes and make adaptations along the way.	• Air/Soil Quality • Pollination and Biological Control • Design and landscape aesthetics
Use and Value Diversity: From human knowledge, to natural plants or "weeds" growing in a site, diversity is preserved and encouraged.	• Pollination and Biological Control • Food provision • Cultural Services • Biodiversity
Use Edges and Value the Marginal: Marginal, disturbed and vacant lands in urban environments are a great example of using undervalued lands. Steep slopes and roadside median are another example. Edges should be valued because the interface between spaces is usually where the most activity occurs (e.g. where a forest meets a field, where a pond meets the land). Edges can be planted to encourage biodiversity for pest control or as a windbreak.	• Soil formation • Biodiversity • Economic interactions • Air/Soil quality • Cultural and natural heritage
Creatively Use and Respond to Change: In Permaculture if a certain crop species has continuous pest problems it is often replaced in the system rather by a plant that is better adapted. If a large population of slugs has arrived in the garden it may be time to	• Biodiversity • Pollination and Biological Control • Cultural Services

incorporate ducks. These are some examples of using and responding to change.	

Source: **Holgrem, 2002; Morrow, 2006; Veteto, 2008**

The thoughtful and thorough application of all twelve principles in the design, execution and long-term management of the project enhances the sustainability of an agro-ecosystem according to Permaculture. In other words, the adaption of these principles will contribute to one or more related ecosystem services as seen in Table 2 above.

2.4.5 Agroecology Principles

Agroecology is a holistic way to look at the components of an agroecosystem emphasizing their inter relatedness as a complex of ecological processes. The emphasis of agroecology is to look at the environment and social components as a whole and to design natural resource management strategies that empower communities, build self-reliance, and manage productive resources sustainably. Strategies include building on traditional knowledge, mimicking nature, utilizing multi-species in agroecosytems, integrating soil fertility management techniques and utilizing diversification of crops to reduce pest populations (Altieri, 2002; Wezel et al., 2009; Francis et al., 2003; Fernandez et al., 2013). In agroecology a sustainable agroecosystem is defined as "one that maintains the resource base upon which it depends, relies on minimum of artificial inputs from outside the farm system, manages pests and diseases through internal regulating mechanisms, and is able to recover from disturbances caused by cultivation and harvest" (Gliessman, 2007). The natural ecosystem is used as a point of reference and the principle holds that if an agroecosystem is similar in structure and function to the natural systems of that bioregion they will be sustainable. For example, in a natural system resilience and diversity are relatively high while reliance on external human inputs is low, even if not as high as natural ecosystem to compensate for other factors such as increase yield (Gliessman, 2011). Agroecology is just as concerned with the social and cultural relationships of agriculture and suggest that creating more sustainable food systems entails creating bioregional systems with shorter food supply chains and more independent relatively small scale farmers (Fernandez et al., 2013). The framework for measuring and quantifying sustainability within Agroecology come primarily from the science of ecology which already has a well-developed set of methodologies for quantifying ecosystem services such as nutrient cycling, population dynamics and species interaction. Indicators are measured by giving a certain parameter such as soil organic matter content a measurement for the minimum level of sustainability and identifying if the agro-ecosystem in question is within those parameters. They also borrow from behavioral science disciplines to evaluate socioeconomic characteristics such as autonomy or dependence on external forces or stability of organization and activity (Gliessman, 2007).

Drawing from literature on these five broad scientific areas: Ecosystem service indicators, agricultural sustainability indices, landscape sustainability assessment tools, agroecology sustainability indicators and permaculture, I will derive the criteria and indicators for PASS.

3.0 METHODOLOGY

3.1 Introduction

This chapter begins with a list of research questions and outline the method used to formulate the index. I then present an overview of the study area, the stakeholders and audience and the sampling criteria for the sites to be studied. There are also sections on data collection, selection of criteria and indicators for the index, and indicators values and weights.

3.2 Research Questions

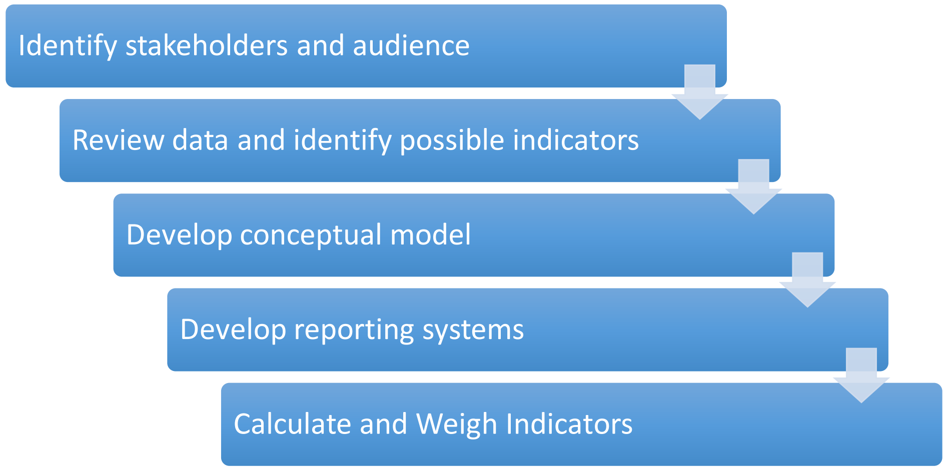
The research attempts to answer the following questions:

- What are the challenges of using these indicators in small scale, heterogeneous urban gardens and farms?
- What are practices that can be used as a proxy for indicators?
- How do examples of urban food gardens and farms in the study area measure up and what does that inform us about the challenges and benefits of these systems ?

3.3 Method to Formulate Index

The method to formulate the index can be seen in Figure 2 below. First the stakeholders and audiences were identified both current practitioners and interested parties. The data and indicators from the literature review were reviewed in order to identify possible indicators for my study site. A conceptual model was developed and indicators and proxy indicators were identified. Finally values and weights were assigned to each of the indicators to be monitored and reported.

Figure 2: Formulation of Index



3.4 Study Area

The study took place in South Florida, USA (Figure 3). The area is unique for many reasons, including being the only subtropical region within the continental US, part of the Greater Everglades Ecosystem and one of the most vulnerable regions to climate driven sea level rise in the world. The sub-tropical climate gives producers a year round growing season and an abundant diversity of potential woody perennial crop species that can be grown. Yet, because its location on a low-lying Peninsula and unique geologic history South-east Florida is particularly vulnerable to extreme conditions including extreme temperature fluctuations, rainfall extremes, saltwater intrusion, coastal erosion and flooding, inland flooding and extreme storms (Miami-Dade, CAP, 2010). Furthermore, fragile ecosystems in the area such as the Everglades and Coral Reefs are also affected by anthropogenic activities in the urban area. Considering these factors there is great interest and opportunity to implement green infrastructure that creates resilience and supports native ecosystems. It is also one of the top 3 most diverse states in the US with 3,500 native species and 1,500 vertebrae species, some which are endemic. Besides sea level rise other environmental concerns facing the region are invasive plants such as Brazilian pepper (*Shinus terebinthifolius*), and foreign pest species such the Asian ambrosia beetle that has threatened the avocado industry (Beckman, 2012). Florida as a whole ranks second in the US as far vegetable production and first in the production of many crops such as oranges, tomatoes, watermelons and squash. Miami Dade County has the largest population in the area, with approximately 2.5 million people from 121 countries, growing at a rate of 2.1% per year (Miami-Dade, 2015). However, South Florida is not as densely populated as other urban areas across the United States. For instance in Miami-Dade County alone nearly 1,271,230 acres of vacant land are present out of which Parks/Conservation and Recreational Spaces had the largest area of 62.2% and 10.6 % of undeveloped vacant land. The human population faces challenges such as food insecurity, public health problems and economic hardships also having the need for greater resilience and support. In a study conducted by Feeding America Miami-Dade had a food insecurity rate of 15.4% (Gunderson, 2015). Miami-Dade is ranked 11th county in the nation for food insecurity. In addition 17 % of all people and 28% of children receive Federal Nutrition Assistance (SNAP) benefits with a sharp increase since the economic crisis in 2007 of +45%. Food insecurity has been shown to also have a direct effect on the health of the population. A Miami-Dade Health Milestone Report named the two main challenges with food in the county as having healthier choices and access to locally grown food (Miami-Dade, Milestone, 2010). Even though Miami-Dade is the second largest agricultural producer in the nation over 95% of produce is sold outside of the county. This not only affects the quality of the food available to people, but also increases the carbon footprint (Miami-Dade Health, 2012). The adoption of alternative agro-ecosystems in Miami-Dade County could help address many of these challenges simultaneously in a comprehensive and deliberate way.

Figure 3: Map of study area: South Florida, United States

Map data @2016 Google

3.5 Stakeholders and Audience

The stakeholders and audience include both the site operators and owners who are currently practicing these forms of alternative farming or those who may be interested in implementing them including landscape architects, urban planners, policy makers, farmers, community gardening organizations, researchers, and schools. I assessed there are three main categories of users that are currently engaging in these types of systems: small farmers, public use areas and private residences.

3.6 Sampling Criteria

Candidate systems to be evaluated using the scorecard are selected according to the following ecological and geographic criteria:

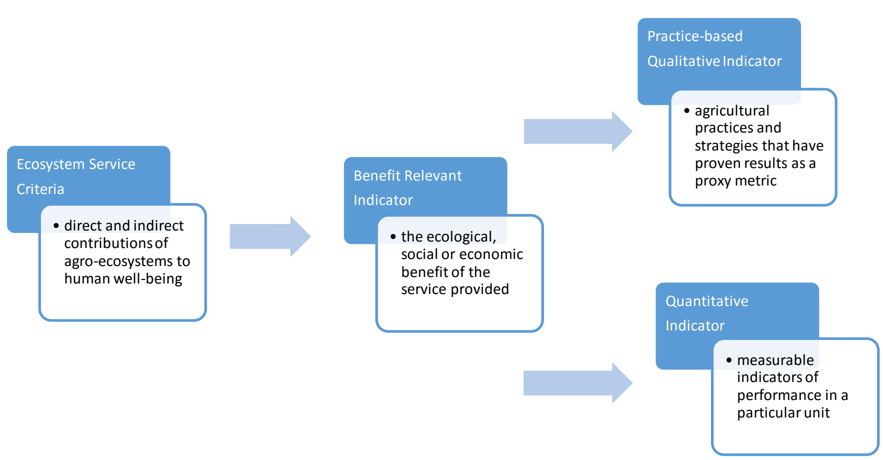
(a) suits one of the following urban built or natural environments: residential homes, public parks/community gardens, or small farms;
(b) 5 or more plant species are grown for food production;
(c) at least 20% of site is comprised of perennial polycultures with 3 or more species;
(d) site is used for 2 or more functions such as production, education, and tourism

3.7 Basis for indicator selection

As seen in the literature review chapter, there is really no agreement among researchers as to what ecosystem service indicators are appropriate for assessing alternative agro-ecosystems. Nor is there an agreement on how one should define and measure each service. Appendix II presents a summary of comparative definitions and meanings, which originated from various sub-disciplines (e.g., agroecology, permaculture, etc.), for relevant ecosystem services. These ecosystem services were adapted in four different previous sustainability assessment frameworks or studies. There are slight variations in the interpretation of each service across different frameworks. For instance, for the SAFE framework, Van Cauwenbergh, et al. (2007) characterize food production service as the production capacity being compatible with society's demand for food, and being able to produce quality food. Permaculture definition of food production focuses more on the practice aspect of food production: having a small intensive production system with diversified species and maximum space utilization (Holgrem, 2002). Similarly, the SITES definition of fresh water service is to reduce water use for landscape irrigation (University of Texas at Austin, 2014) whereas the Agroecology interpretation of the same is more practice oriented such as adaptation to distribution and variability of water (Gliessman, 2007; Altieri, 2002). For the PASS framework developed in this study, I use a synthesized version of all the four main frameworks for each ecosystem service, which is presented in the next sub-section.

The present study needed to compare a variety of sites that were highly heterogeneous both in scale and in nature. Also due to their size, economics and missions most operators did not keep detailed records as in other types of agricultural operations. The major task was to identify suitable indicators to assess the ecosystem service contributions of a system. Previous studies have considered qualitative indicators based on the presence or absence of certain practices, and on potential for certain ecological and socio-cultural benefits (Holgrem, 2002; Mollison, 1988; Gliessman, 2007; Altieri, 2002). The conceptual framework for the study therefore utilizes practices and/or overall qualitative benefits of the service as proxies for indicator measures when exact data was not available at each of the sites. Figure 4 presents the basis on which I decided whether we needed to consider a quantitative indicator or a qualitative indicator for each ecosystem service.

Figure 4: Conceptual Basis for Indicator Selection



3.8 Selecting and grouping of sustainability criteria and indicators

Following the literature of existing sustainability assessment and practices a total of sixteen ES criteria were selected within five categories: 3 provisioning services, 3 supporting services, 5 regulating services, 1 economic service and 4 cultural services. The indicators selected were those found in literature, which were utilized as metrics for each criteria. However, in order to be relevant to the end user who may not have the time, money or knowledge to collect data at this level, or since the data is simply not available in these types of projects, the practices found on the sites are used as proxy for the indicators. Finally, our study farms or gardens were so diverse that no single indicator for any ecosystem service would have captured all the study sites. Therefore, we considered multiple indicators for each main ecosystem service criteria. Each main ecosystem service is thus measured by a criterion that is a composite of multiple ecosystem service indicators. See Table 3 for the criteria and indicators.

Table 3: Sustainability Criteria and Indicators

ES Criteria	Description	Quantitative Indicators	Qualitative Indicators
Provisioning Services			
Food Provision	Cultivation of edible plants harvested and used for human nutrition.	harvested crops (t/ha)	maximize use of space by stacking functions
		yield (t/ha)	maximize diversity of productive species
		net primary production (t c/ha)	address local food security needs
		integrated crop-livestock farming (n/ha)	the 7 layers of forest gardening are used
		land cover (for forage crops)	manage canopy cover by regular pruning

Freshwater Provision	Freshwater available for drinking, irrigation and other uses.	withdrawal of fresh water (l/ha)	water is captured, held and recycled on site
		surface water availability (l/ha)	aquatic systems are enhanced or restored
		ground water availability (l/ha)	micro irrigation is used to reduce water needs
Raw Materials	Cultivation and harvesting of other products such as wood for fuel or construction , medicinal plants, forage plants such as mushrooms, oils and ornamentals.	harvested wood, plant biomass m/ha)	biomass is optimized
		yield (t/ha)	apply disturbances that increase productivity
		net primary production (t c/ha)	
supporting services			
Soil Formation	The facilitation of soil formation processes which include chemical weathering of rocks and the transportation and accumulation of inorganic and organic material.	soil organic content matter (%)	elimination or reduction of tillage
		soil moisture content (%)	chop and drop coppicing and mulching
		content of soil life	use of perennial crop species
		earthworm presence	use of green manure and cover crops
		presence of plant residues	organic mulch
			sheet mulching
Biodiversity	The presence of selected species, groups of species, habitat components and species composition.	indicator species (n/ha)	intercropped systems
		number and identity of select species(n/ha)	natural weeds
		simpson index	boarders and hedgerows
		shannon-wiener index	grazing animals
			rotations
			establish wildlife corridors
Nutrient Cycling	The capacity of an ecosystem to prevent the irreversible outputs of elements from the system, and the ability for nutrient and matter cycling.	plants do not show signs of nutrient deficiencies	composting
		nutrient retention (kg/ha)	mulching
		p,k,mg and ca in mg kg compared to recommendations	manures
		area with nitrogen fixing crops (%/ha)	all organic material is recycled on site
		amount and number of decomposers (n/ha)	nitrogen fixers are used
		decomposition rate (kg/ha)	
regulating services			
Climate Regulation	Long term storage of greenhouse gases in	shaded areas	use of long-lived perennial species

	aboveground biomass and soil organic matter. Changes in local climate components like wind, temperature and radiation.	temperature	microclimates are created
		wind	windbreaks are used
		precipitation	use of fire retardant species
		soil carbon content	
		above and below ground biomass (%/ha)	
Air/Soil Quality	Capturing and filtering of dust, chemicals and gases.	leaf area index	reduced or no synthetic fertilizers
		air quality amplitudes (ppb)	reduced or no pesticides used
		air quality standard deviation (ppb)	surplus waste recycled back into system
		level of pollutants in the air	
		critical loads	
Pollination and Biological Control	Animals and insects that contribute to the dispersal of seeds and reproduction of plants. The capacity of the ecosystem to control pests and diseases due to genetic variations and the action of predators and parasites.	plant health (plants do not show symptoms of disease, scarce fruiting	plants are used to provide habitat for beneficial insects
		species numbers and amount of pollinators (n/ha)	allopathic properties of plants are used
		population of biological disease and pest control agent (n/ha)	use of crop diversity for pest management
		pest density	pest problem is managed
		flower visitation rates (flower/time)	number of nectary plants present
Water Flow Regulation and Purification	Maintaining of water cycle features and the capacity of an ecosystem to purity water from sediments, pesticides, microbes and pathogens.	groundwater recharge rate (mm/ha)	water is preserved through a water management scheme
		transpiration/total evapotranspiration	precipitation is managed on site
		aquatic habitat component	water is recycled on site
		respiration/biomass	
Erosion/Flood Control	Soil retention and the capacity to prevent and mitigate soil erosion and to maintain water cycles features such as natural drainage.	vegetation cover	terracing and contours are used to shape land
		loss of soil cover	vegetation is always present to hold soil in place
			soil mass flux is controlled and buffered
economic services			
Economic Interactions	Project is economically sustainable overtime and only minimally dependent on subsidies,	numbers of jobs created	part of local food system
		cost of establishment	short supply chain (community-supported

	supporting and contributing to the local economy.		agriculture, farmers market, etc.)
		cost of maintenance	number of jobs created
		interactions with local economy	cost of establishment
cultural services			
Recreation and Tourism	All forms of leisure and tourism related to the system including tours, volunteer activities, and leisure.	number of individual visitors (n/ha, n/facility)	community service activities
		number of group visitors	environmental stewardship programs
		number of tours	number of physical activities
		number of events	
		travel cost estimation	
Educational Activities	The education derived from the system in terms of traditional knowledge and specialist expertise.	number of users	sites is used as a case study
		number of studies / articles published	site is monitored for performance
		number of students reached	school groups are engaged in learning activities
		number of education-related facilities	health promotion and awareness
Cultural and Natural diversity and heritage	The maintenance of historically important landscapes and types of land use.	results from questionnaire from local peoples preferences	on site selection and preservation of seeds
		number of endangered, protected and/or rare species or habitats	local knowledge and culture is incorporated
Design and landscape aesthetics	The visual and functional quality of the system arrived at by the strategic process of design which influences human well being.	enjoyment of scenery (willingness to pay)	pre design site analysis is conducted
		travel cost estimation	stakeholders are engaged in design process
		preference from questionnaires	aesthetic taken into considerations
		landscape metrics for scenic beauty estimation	functional aspects taken into consideration
			design elements are placed relative to one another with multiple uses in mind

The criteria listed in the table above are ideal for conducting a comprehensive ES assessment. As mentioned before in some of the alternative agro-ecosystem not all of the quantitative indicators can be measured with precision so in this research the qualitative indicators will be used as proxy for some of the qualitative. The following sub-sections will discuss each of the main ecosystem service criterion in detail.

3.8.1 Provisioning Services

Provisioning services include all of the outputs from the ecosystem such as food, fresh water, and raw materials such as wood and fiber, medicines and genetic resources. They are usually the most important from a human perspective and the easiest to quantify.

Food Provisioning

One could easily argue that the primary goal of the scientific advances and technological innovations related to agriculture have been pursued with the sole intention of increasing food production (Kremen et al., 2012). Alternative agro-ecosystems focus on multispecies cropping systems, that although considered harder to manage than industrial systems have many potential advantages such as increased biodiversity, nutrient cycling and carbon sequestration (Malezieux, 2012). But the question remains: can these systems be as productive as monoculture? Currently traditional multiple cropping systems provide about 20% of the supply of food worldwide (Altieri, 2011). Studies have shown that these diversified farming systems out-produce the yield per unit of single crops (Altieri, 2009; Di Falco et al., 2010, Bangwayo-Skeete et al., 2012, Li et al., 2009). Yield advantages can be as much as 20 to 60% due to reduced losses to weeds, insects, diseases and more efficient use of available resources such as water. This is the case for mixed cropping systems such as intercropping, as well as perennial polycultures found in home gardens worldwide. Economically, studies of Cassava production in Nigeria have shown that mixed cropping systems are better income earners due to the aggregation of incomes from other crops (Ajayi, 2014). Keeping the food local is another matter of great importance to keep an alternative agro-ecosystem sustainable. Localized food production benefits have been well documented in literature including decreasing food transportation and packaging with its associated environmental costs, improvement of local economies, fresher and less preserved foods and the preservation of community and culture (Galzki et al., 2014; Bregendahl, 2013; Weber, 2008).

Fresh Water Provisioning

The provision of fresh water is primarily looked at a larger scale, which involves an entire regions watershed. Water has a role in every ES from the cultural role of a river in tourist areas to its supporting role in nutrient cycling. In ES provisioning the significance of fresh water is its availability for consumption for food and materials in the system, as well as for aquatic environments. The primary technique used in alternative agro-ecosystem is simply to adjust to the regional rainfall patterns of a region by picking crops that are suitable for the available precipitation. Another way is to create a water harvesting system, which takes advantage of short, torrential showers, storing the water for later use (Gliessman, 2014). Rainwater can be collected in ponds, and in underground and aboveground tanks or barrels of many different materials. If there are impermeable surfaces such as driveways, roofs or patios on the site, for every 1 inch of rain that falls on a 1,000 sq. ft. area you can collect approximately 600 gallons of rainwater (UCANR, 2016). Even with small elevation changes dams and swales can be used to slow water flow and feed plants by gravity. In permaculture the designer's method is to slow it, spread it and sink it, using three primary methods to accomplish this: using deep rooted vegetation arranged throughout the site, promoting organic matter rich topsoil to store water and shaping the land in a way that promotes slow-spread and sink of water (Falk, 2013). If the site is large enough the addition of a pond can make many significant contributions beyond water storage for distribution: they create microclimates, enhance biodiversity, are aesthetically appealing and can be used for recreation and other food sources such as fish (Hemenway, 2009). Besides catching and storing, water conservation practices such as drip irrigation are crucial to a successful water management plan and are part of a sustainable agro-ecosystem.

Raw Material Provisioning

Raw materials or biomass provisioning includes a broad spectrum of plants such as medicinal and aromatic plants, mushrooms and plants for fuel. This is not only beneficial due to the increase in diversity, but also because many of these plant species can survive conditions that food plants cannot, they contribute to preserving cultural heritage, add to carbon sequestration and further diversify the economic activities of the site (Falk, 2013). Studies show that productivity or the rate of generation of biomass has a positive effect on biodiversity (Bangwayo-Skeete et al., 2012; Malezieux, 2012; Swift et al., 2004). During ecological succession forests reach peak productivity in a certain stage of succession at which point they begin to decline as they mature. Having both a variety of raw material sources and maintaining the system at a mid-level of succession through management practices such as pruning assures its productivity potential.

3.8.2 Supporting Services

Supporting services are the pillar for all the other ES in the system. Without services such as the formation of soil, photosynthesis and cycling of nutrients no provisioning would take place. Laying the foundation for a sustainable agro-ecosytem requires a well-thought out plan for promoting and enhancing these services.

Soil Formation and Health

Soil is where life begins and ends, the base of the pyramid of life, where the majority of the Earth's diversity and organisms are found. Soil is more than a sum of its parts entailing both habitat and system. The adoption of soil health practices such as cover cropping, crop rotations and conservation tillage are increasingly being adopted by farms primarily due to increase in regulations and conservation strategies (Carlisle et al., 2016). In traditional societies the formation and enrichment of soils has been practiced in many regions of the world. In West African countries such as Liberia and Sierra Leone "in contrast with dominant perspectives that people only degrade natural soils, local knowledge and practice here importantly encompass transformations that upgraded soils, rendering them more fertile and productive" (Frausin et al., 2014). This transformation from the red infertile soils naturally occurring in the region to the black carbon rich soils occurs through the addition of several types of biochar (the charred wood form cooking fires, palm oil production and making of potash), large amounts of organic waste from crop processing such as banana, plantain and cassava, as well as animal byproducts. In fact soil organic matter is probably the single most important factor in sustainable agriculture systems, affecting levels of nutrient availability, contributions to the cation exchange capacity of soil, controlling levels of toxicity, neutralizing toxic chemicals in the process of alleopathy of plants, and influencing the biological properties of soils (Fageria, 2012). Another crucial component for plant health is the diversity of microbes found in the soil, in fact soil microbial communities are some of the largest reservoirs of biological diversity in the world. Practices that encourage these populations include no till methods, addition of compost, manure and crop residues, sheet mulching, and cover cropping (Hemenway, 2009). Beyond microbes the presence of mycorrhizae fungi and rhizobia bacteria perform a host of functions such as assisting plant to uptake phosphorous and nitrogen, the prevention of pathogen colonization by production of antibiotic compounds and enzymes, and activation of immune response (Berebsdsen, 2012) Practices such as green manuring where crops are used specifically to be cut and returned to the soil during winter or summer, using legumes that have bacterium Rhizobium in their roots, using cover crops, using organic mulches, animal manures, especially if found on site, composts, and nutrient broths promote their colonization of soils (Gliessman, 2014).

Biodiversity

The value of biodiversity has been discussed by biologists, economists and philosophers the world over, many of which believe that species have an intrinsic value related to evolutionary heritage, irreversibility, and unity of life which does not require to be measured (Oikos, 2000). However in dealing with highly utilitarian human centered decision making as is often the case in urban and agricultural areas it is useful to make the connection between species diversity and ecosystem functioning and productivity. In natural environments ecological research indicates that diverse natural communities are more productive than simple systems (Tilman, et al., 1996). Increasingly, scientists agree that enhancing functional biodiversity is also a key ecological strategy for resilience in agro-ecosystems (Altieri, 1999;) Resilience is defined as the ability of an ecosystem to absorb change and disturbances while still maintaining its function. Studies across many countries and types of crops from rice to maize have shown that reduction in crop diversity makes the system more vulnerable to disturbances (Matsushita et al., 2016;) Biodiversity is not only a matter of plant species present but also other components such as the variety of pollinators, predators, herbivores, earthworms, soil mesofauna and microfauna in addition to vegetation. Specific cultural practices can serve to either increase or decrease the spatial, temporal or functional diversity of a system. Spatial and temporal refers to high crop diversity in time and space. Cultural practices such as planting perennial crops, high crop densities, genetic diversity, field margins of wild vegetation and reduced soil disturbance and tillage methods that provide a stable environment for microorganisms in the soil (Swift et al., 2004, Altieri, 1999).

Nutrient Cycling

In natural ecosystems nutrients are continuously being recycled moving from the physical environment into living organisms and back (Nair, 2011). Soil biota such as microflora catabolizes organic matter and immobilizes nutrients, the hydrological cycle breaks down minerals in rocky sub-soils making them available to plants. Plants uptake these nutrients for growth, are consumed by animals or lose their leaf litter, which is broken down once again by microorganisms in the soil. Human induced alterations in this cycle includes the removal of nutrients through harvesting, erosion and tillage which kills soil biota; changes in hydrology such as flood control, and water-borne sewage systems which transports nutrients away from the system and into waterways. Although this system is very complex and would be hard to quantify the presence of cultural practices that conserve, harvest and cycle nutrients is the measure by which a system is considered sustainable. By designing and recreating natural cycles sustainable agro-ecosystems should mimic natural system by allowing leaf litter to remain on site, having low levels of disturbance and utilizing a diversity of plant species. In particular those that encourage the uptake of nutrients such as nitrogen and phosphorous.

3.8.3 Regulating Services

Regulating services describe the benefits obtained from the regulation of processes such as climate regulation, water purification and pollination and pest control. This is the most difficult area to measure and

Climate Regulation and Carbon Sequestration

Climate change is a real and current threat the world over (IPCC) and to the South Florida area in particular, not only due to rising seas but also due to weather fluctuations such as drought and deluges. Adaptation and mitigation measures have to be in process and alternative agro-ecosystems could address both of these needs. Empirical evidence has been found that green urban infrastructure, including UA contributes to climate change mitigation and adaptation especially in relation to CO2 reduction from carbon sequestration (Demuzere, 2014; Kulak et al., 2013). Carbon sequestration is the process that removes carbon from the atmosphere and stores it in vegetation, biomass and soils has become a significant way to mitigate climate change, primarily through the introduction of a mixture of trees and woody perennials into agricultural activities (Islam, 2015, Nair, 2011). Soil organic carbon content has also been found to have a positive correlation with tree density (Islam, 2015). Agroforestry which is related to the systems in this study by its integration of tree-growing with food production for maximum benefits has been shown by researchers to have a key role in climate change mitigation schemes (Anderson, 2011; Thangata, 2012; Udawatta, 2012; Takimoto et al., 2008; Oelbermann et al., 2004) In addition it creates a synergy with food security issues connected to climate change (Mbow et al., 2013). Climate regulation also refers to the presence of created microclimates and windbreaks which depending on the way it is designed can serve to collect heat, decrease evaporation, control erosion, provide shelter for animals or plants, act as dust or polluter filters and trap nutrients from leaching (Morrow, 2006).

Air and Soil Quality

Although we may not be aware on a daily basis of the role ecosystems play in regulating air and water quality, terrestrial systems are a key player in these processes. The ability of an ecosystem to retain and assimilate nutrients and organic matter and sediment has a direct effect on water quality since the presence of large amounts of these materials in water is pollutants. Nitrogen and phosphorous runoff in particular is one of the main environmental issues affecting watersheds. The same is true of air quality, which is affected directly by the ability of a system to be able to depose of pollutants and to not emit pollution such as carbon emissions from harvesting (Smith, 2013). There are two primary ways that these systems affect this service: by incorporating agricultural wastes such as manure and crop residues back into the system and by limiting the amount or omitting of nutrients (inorganic and organic fertilizers) and pesticides that are imputed into the system. Adaptive practices such as the creation of habitats like filter strips and wetlands can act to filter out pollutants. Other soil management practices in the supporting category such as no tillage and cover cropping also contribute indirectly to the both the nutrient requirements and prevention of leaching into waterways.

Biological Control/Pollination Services

The cornerstone species for agricultural pollination is the managed honey bee (Apis mellifera) but their colonies have been declining steadily since the 1940's. There are 17,000 species of native bees worldwide, many of which visit crops and contribute to crop pollination (Winfree, 2011). Depending on animal pollination fruit and seed production can be affected by 75%. Pollination services are often considered in isolation but in fact they are influenced by multiple management factors. For crops that are highly dependent on pollination such as cucumbers findings have shown that pollination is the most important driver and herbivore control only affects plants marginally in comparison (Motzke et al., 2015). Diversified farming systems which create habitat through buffer hedges, increase species richness in the garden especially of native flowering plants, and preserve or enhance adjacent semi-natural areas have all been shown to support pollinator species (Batary et al., 2009)

Water use/ Filtration

Water use as a regulating service refers to the purification of water from pollutants. This is a very important service performed by ecosystem especially in urban areas with a large percentage of impermeable surfaces and runoff water. When a water management scheme is present on site to slow and spread the flow of water greater levels of filtration and purification occur. In natural systems water is purified through the percolation of rainwater through forests, ponds, grasslands and wetlands, and the biological processes that occur in the soil. Agro-ecosystems that mimic these natural systems, by adding aquatic features, forest like features, capturing water for slower release or simply adding organic material to the soil through chop and drop mulching encourage this service.

Erosion and Flood Control

Soil erosion is one of the major threats to food production today, losses in developing countries average 30 tons per hectare per year or 1 inch every 12 years. This translates to a significant loss since natural processes take 500 years to create it. Soil loss occurs primarily due to land-use choices and harmful crop or soil management practices which in turn affects yields, releases CO_2, pollutes water and increases floods due to sediment build up in rivers (MEA, 2015). The land use types that are most detrimental are bare or tilled soils, followed by heavy tillage systems and annual monocultures in general. Reduced disturbances translate to reduced erosion. Conservation practices such as no till farming is a great improvement but permaculture practices takes it a step further by shaping the land to capture soil and simultaneously to reduce flooding. The presence of trees in the system, along with its accompanying leaf litter increases the soil's water holding capacity preventing flooding, erosion and leaching (Jacke, 2005).

3.8.4 Economic Services

Economics is often the driving factor in ES valuation with both traditional market commodities such as crop yields and more difficult to quantify service such as recreation or pollination services being given a dollar value. However for this study I have chosen to separate the economic viability of the agro-ecosystems in a separate category since it is but just one of the factors driving these projects. One of the roles of these systems is to directly impact the local economy and to tackle the problem of poverty alleviation and self-reliance directly benefiting the community. Although due to their size this effect will only be felt to a small degree with those directly connected to the project and the immediate surrounding community.

3.8.5 Cultural Services

Cultural ES are any non-material benefits that people obtain from interacting with the site including cultural enrichment, recreational experiences and educational opportunities. These services are considered one of the most difficult to measure and access and the one with the least potential for mediation once it has been degraded (MA, 2005). Community service activities have been shown to help participants establish and a greater sense of connectedness, empowerment and interaction among community members. Edible gardens have been proven to be a versatile and effective tool to teach all age groups about environmental sustainability, healthy eating, cooking. Traditional homegardens in central America and Southeast Asia have been studied extensively and have proven to not only have strong productivity components but also to act as a gathering space for the families and a playground for their children (Cuanalo de la Cerda, 2008). Although a observational approach was used to measure cultural interactions with the sites mainly through the number of visitors and participants for each site other techniques to measure the socio-cultural impact of sites are surveys, focus groups, questionnaires, and in-depth interviews, where more in depth information about the participants could be documented (Scholte et al., 2015).

Design

Design aesthetics deals with how people experience their environment through the senses, combining art and science, intuition and logic. Although very hard to measure visual aesthetic values is an important service of the built environment and a primary consideration for designers, including proportion, scale, proximity and other design principles. The tradition of ecological design goes beyond aesthetic principles also prioritizing ecological functions as a basis for urban and site design where change is embraced and the design self-organizes and persists like nature(Beck, 2013). Permaculture design in particular is holistic in nature and firmly grounded in ecology taking into account the inter-relationship and interdependence of living things and their environment. Using the tools of observation, analysis and synthesis the result are applied to the design, which are a combination of site specific requirement and the goals of the owners (Morrow, 2006). Having a well thought out design that is beautiful, functional and serves the needs of all the stakeholders in the project benefits society in multiples ways.

3.9 Indicator Values

Indicator values were obtained through observation, participant surveys and consulting literature. Since many of the sites do not keep detailed records of the productivity of the site, the practices utilized on site were used as a proxy. The rubric values were derived from matching the use of practices against the optimal recommended uses as seen in Table 3 indicators above. The rubric scale ranging from 0 to 5 is used in such a way that the small number is low (inferior) and large number is higher (superior). Table 4 below shows the rubric values for each indicator and sub-indices.

Table 4: Rubric Scale for Ecosystem Service Indicators

Indicators	Sub-indices	Unit for rating
Provisioning Services		
Food Provision	diversity of food	5 species (1 low) 40 + species (5 high)
	quantity of food: (1) internal, (2)market, and (3) restaurant	marginal (1) maximized (5)
	food produced year round	no (0) yes maximized all year (5)
	addresses local food security needs	all exported (0) all locally distributed (5)
	maximizes use of space	10-25% (1) 90-100% (5)
	7 layers	1-2 layers (1) 6-7 layers (5)
Fresh Water Provision	water is captured and held on site	no methods used (0), significant portion of water used (5)
	water is recycled on site	no system in place (0) all (5)
	aquatic systems are enhanced or restored	none used (0), methods used to enhance and restore (5)
	micro irrigation is used to reduce water needs	none (0) all (5)
Raw Materials	biomass is optimized	minimal (1), maximized (5)
	canopy structure is managed for optimal rates of light transmission	minimal (1), maximized (5)
	building energy use is minimized	minimal (1), maximized (5)
Supporting Services		
Soil Formation	soil loss is prevented	no methods used (0), 3-4 methods used (5)
	soil chemical and physical quality is enhanced	no methods used (0) 3-4 methods used (5)
	all organic matter is recycled on site	none (0) all (5)
	disturbed soils are restored and enhanced	none (0) all (5)
Biodiversity	Increased biodiversity in the garden	low (1) very high (5)
	diverse habitat in wild places or non-production areas	low (1) very high (5)

	spatial and temporal diversity	low (1) very high (5)
	functional diversity	low (1) very high (5)
	genetic diversity	low (1) very high (5)
Nutrient Cycling	organic matter is utilized on site	none (0) all (5)
	nitrogen fixers	none (0) maximized (5)
	composting	none (0) maximized (5)
Regulating Services		
Climate Regulation	use of long lived perennials	10-25% (1) 90-100% (5)
	windbreaks are used	none (0) maximized (5)
	microclimates are created	none (0) maximized (5)
Air/Soil Quality	use of synthetic fertilizers	all nutrient needs (0) none (5)
	use of pesticides	all pest control (0) none (5)
	surplus waste is managed on site	none (0) all (5)
Biological Control/Pollination	use of crop diversity	5-10 species (1) over 50 species (5)
	pest problems are managed	many pest related problems found (1) little to no pest problems found (5)
	plants present that attract pollinators	2-3 species (1) over 10 species (5)
Water Use /Filtration	water is preserved through a water management scheme	none (0) all (5)
	precipitation is managed on site	none (0) most (5)
	water is recycled on site	none (0) all (5)
	drip irrigation is used	none (0) all (5)
Erosion/Flood Control	soil mass flux is controlled and buffered	some (1) very prevalent (5)
	vegetation is always present to hold soil in place	in some areas (1) always (5)
Economic Services		
Economic	dependency on external finances and subsidies	all (1) none (5)
	project supports local economy	1-2 ways (1) 5-6 ways (5)
	cost of establishment	very high (1) low (5)
	cost of maintenance	very high (1) low (5)

Cultural Services		
Recreation and Tourism	number of visitors per year	0-25 (1) over 200 (5)
	number of special events and activities	1-2 events (1) 6 or more (5)
	community service /volunteer programs	none (0) year-round (5)
Educational Activities	learning activities and events	0-5 (1) over 25 (5)
	site is used as a case study	none (0) most of the time (5)
	site is monitored for performance	none (0) most of the time (5)
Natural and Cultural Heritage	cultural and historic value features are enhanced or maintained	none (0) maximized (5)
	natural value features are enhanced or maintained	none (0) in-depth (5)
	local crop varieties are incorporated	none (0) all (5)
	local knowledge and culture is incorporated	none (0) in-depth (5)
Design	pre design site analysis was conducted	none (0) in-depth (5)
	stakeholders are engaged in design process	primary only (1) all (5)
	aesthetic considerations	none (0) in-depth (5)
	functional considerations	none (0) in-depth (5)
	design elements are placed relative to one another with multiple uses in mind	none (0) all (5)

3.10 Weights of indicators

In assigning a value to each of the criteria it is important to recognize that not all the indicators have equal significance in the eyes of the operators/farmers. Therefore a weight has to be assigned in order to aggregate the indicators within each criterion. This was done in two steps. First, I assigned weights to each of the sub-indices within the five ecosystem service categories according to the literature. Second, a survey of participating farmers or garden owners was conducted to obtain their opinion on the importance of each ES category to their operation. See Appendix II for the survey instrument. The weights were obtained through a pair-wise comparison of factor in Analytical Hierarchy Process (AHP) (Maes et al., 2016)

3.11 Data Collection

Data for the study were gathered through a tour of each site, casual observation and an in-person interview of each owner/operator or relevant staff of the project. The questionnaire can be found in Appendix I. The questionnaire asked specific questions that informed each of the five ES sections in the rubric. The pair-wise comparison questionnaire was taken at eight sites. Questions related to each ES indicator in the rubric were asked to the owners or operators of the site who were familiar with the design, installation and ongoing maintenance of the system.

4.0 RESULTS AND DISCUSSION

4.1 Introduction

This chapter will present and interpret the results of the study. I begin with a description of the characteristics of the sites chosen for the study, followed by the discussion of weights assigned to each ES category and the ranking of each site, using PASS. Finally the results in each site category will be analyzed.

4.2 Sample Characteristics

The sites selected were found through research of the area and from recommendations from colleagues and practitioners in the field. A total of 17 sites were considered before the final 12 that adhered to the sampling criteria were chosen as can be seen in Table 5 below. Eight of the sites were in Miami-Dade County, two in West Palm Beach, and two in Fort Myers in the West Coast of Florida. Four of the sites—two schools, one residence and one farm—were in urban areas while the remaining sites were in peri-urban areas. The sites fit one of three main categories: farm, residential/private and public, with some overlap, for example several employees live on premises at Treehuggers Farm while Earth N Us although considered an urban farm is primarily a residential community. The categories were assigned based on the primary activity conducted on each site. Although the majority of the sites have multiple purposes, six of them had education as their primary purpose, with two others being residences with very close ties to education, two to food production, one to nursery production and one to residence. One of the major difficulties of this study, and of comparing these systems in a rigorous manner is the wide range of sizes and years established. The size ranged from

8,000 sq. ft. to 10 acres and the years established from 1 to over 40 years. It is important to note that in my observations and during the questionnaire I focused on approximately a 8,000 sq. ft. area for the sake of comparison, for example as far as the cost of maintenance. While with other factors such as the presence of a water management scheme the site was looked at as a whole.

The managers that answered the questionnaire had direct involvement with the site, seven were the owners, and the remaining five were either permanent staff /manager or a volunteer.

Figure 5: Map of Site Locations

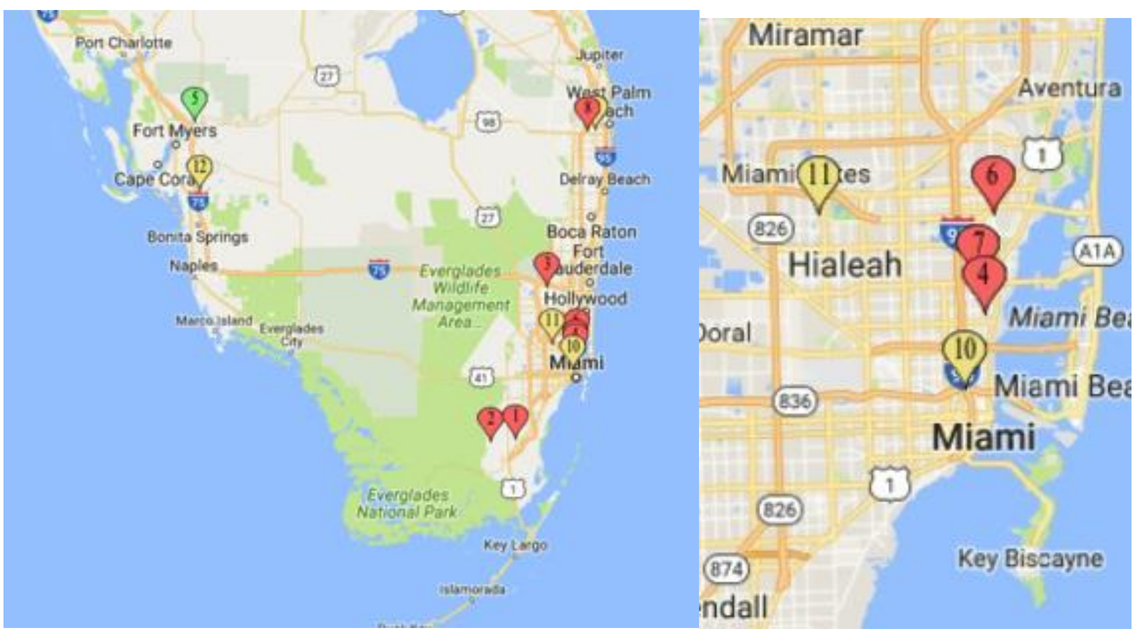


Table 5: Site Information

Sites	Category	Acres	Main Crops	Ownership	Year Established	Location	Primary Goal
Muni Farms	Farm	10	Nursery Plants	private	2012	Redlands	Nursery Production
Guara Ki Eco	Farm	3	Lychees/	private	1996	Homestead	Education

			Mamey/ Greens				
Echo Global Farm	Farm	10	Moringa/ Rice/ Sorghum/ Vegetable	ngo	1981	Ft. Myers	Education
Little Haiti Garden	Farm	0.5	Arugula/ Kale/	private	2008	Little Haiti	Food Production
Treehuggers Farm	Farm	4.6	Annual Vegetable	private	2012	Davie	Food Production
Florida Gulf Coast Food Forest	Public	1	Fruits	public	2011	Fort Myers	Education
Booker T. Washington Food Forest	Public	8000 sq. ft.	Fruits	public	2015	Overtown	Education
Mounts Botanical	Public	8000 sq. ft.	Annual Vegetable	public	2004	West Palm	Education
Twin Lakes Food Forest	Public	13,000 sq. ft.	Perennial greens	public	2011	Hialeah	Education
Earth N'Us Farms	Residential	3	Annual Vegetable	private	1977	Little Haiti	Residence/ Education
Gaia Ma	Residential	8000 sq. ft.	Fruit /Greens	private	2014	North Miami	Residence
Unbelievable Acres	Residential	2	Fruits	private	1970	West Palm	Residence/ Education

4.3 Indicators Weights

Weight was given to each of the indicator within the ES criteria according to Table 6 below.

Table 6: Indicators Weights

Criteria	**Indicator**	**ES Weights**
Provisioning	Food Provision	0.5
	Fresh Water Provision	0.3
	Raw Materials	0.2
Supporting	Soil Formation	0.25
	Biodiversity	0.5
	Nutrient Cycling	0.25
Regulating	Climate Regulation	0.4
	Air/Soil Quality	0.1
	Biological Control	0.1

	Water Regulation	0.3
	Erosion/Flood Control	0.1
Economic	Economic	1
Cultural	Physical/Social Activity	0.2
	Educational Activities	0.4
	Cultural/Historic Value	0.2
	Design	0.2

Weights were given to each Ecosystem Service according to the significance of each as found in the literature. In a comprehensive inventory conducted by the European Commission's Joint Research Center in 2012, which reviewed 70 peer reviewed articles on the use of indicators for quantifying ES, found that within provisioning service indicators 28 dealt with food provision, 20 with water provision and the remaining 10 with other raw materials provision (Egoh et al., 2012). Food provision received the most attention (about 40 % of journals), second was water provision indicators. Regulating services had the largest number of articles (nearly 75% overall) of any ES and within it climate regulation had the overwhelming majority. These articles written between 2008 and 2011 were influenced by the IPCC and REDD+ has become a priority for governments and international organizations. This was followed by water flow regulation with one third of the studies in this category.

In addition, eight of the site owners were chosen to complete the pair-wise matrix survey: four in the farm category, three public and one residence. The survey can be found in Appendix III and an example of one farm's results in Table 7 below. The results from the surveys to 8 of the sites in the study showed that the 6 out of 8 farmer/operators surveyed favored cultural practices overall (see Table 8). Individual results can be found in Appendix IV. Only Treehuggers and Little Haiti farms felt that economics and provisioning services respectively were the most important driving factor in their operation. Overall provisioning services were the second most significant factor influencing the operator's decisions in 6 of the sites, followed by supporting services, which was the most important in one residential site and third in 4 of the sites. Except for the farms mentioned above economic factors were given the least priority followed by regulating services.

Table 7: Example of Pair- wise matrix of Ecosystem Service Factors for a Farm

Little Haiti Community Garden						
	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	3	5	1	4	
Supporting	0.33	1	5	1	3	
Regulating	0.2	0.2	1	0.2	0.2	
Economic	1	1	5	1	1	
Cultural	0.25	0.33	5	1	1	
Sum Intensity	2.78	5.53	21	4.2	9.2	
			Factor Ratios			Weights
Provisioning	0.36	0.54	0.24	0.24	0.43	0.36
Supporting	0.12	0.18	0.24	0.24	0.33	0.22
Regulating	0.07	0.04	0.05	0.05	0.02	0.05
Economic	0.36	0.18	0.24	0.24	0.11	0.23
Cultural	0.09	0.06	0.24	0.24	0.11	0.15
						1.00

Table 8: Pair-Wise Matrix Average Weights

	Muni Farm	Guara Ki	Booker T	Gaia Ma	Treehug gers	Little Haiti	Twin Lakes	FGC U	Average Weights
Provisioning	0.26	0.09	0.25	0.24	0.26	0.36	0.22	0.29	0.25
Supporting	0.12	0.15	0.14	0.31	0.26	0.22	0.21	0.19	0.20
Regulating	0.12	0.17	0.10	0.14	0.11	0.05	0.13	0.12	0.12
Economic	0.19	0.11	0.08	0.06	0.28	0.23	0.05	0.07	0.13
Cultural	0.31	0.47	0.44	0.25	0.08	0.15	0.39	0.34	0.30
									1.00

4.4 Ranking according to PASS

Table 9 presents the ES indicator scores for the farm category where the cultural criteria received the highest scores overall, followed by provisioning and supporting. Table 10 shows the indicator scores for the residential category that had two of the highest scores overall, in the supporting and regulating categories. Table 11 shows the results for the public space category, which had the lowest scores overall. An example of how each Ranking score was formulated can be found in Appendix V.

Table 9: Farm Category Ranking based on PASS

	Muni Farms	**ECHO**	**Guara Ki**	**Treehuggers**	**Little Haiti**
Criteria					
Provisioning	2.98	3.88	3.96	4.14	3.43
Supporting	4.11	4.55	4.34	4.56	3.67
Regulating	3.94	4.36	3.77	4.45	3.04
Economic	2.00	2.50	3.75	3.50	4.50
Cultural	3.19	4.76	3.38	4.06	3.82
	3.30	4.23	3.84	4.20	3.72

Table 10: Residential Category Ranking based on PASS

Category	**Residential**		
	Gaia Ma	**Earth N Us**	**U Acres**
Criteria			
Provisioning	3.91	2.40	2.73
Supporting	4.60	4.12	3.88
Regulating	4.72	3.13	3.27
Economic	2.00	3.50	3.00
Cultural	3.74	3.66	3.30
	3.78	3.09	3.02

Table 11: Public Category Ranking based on PASS

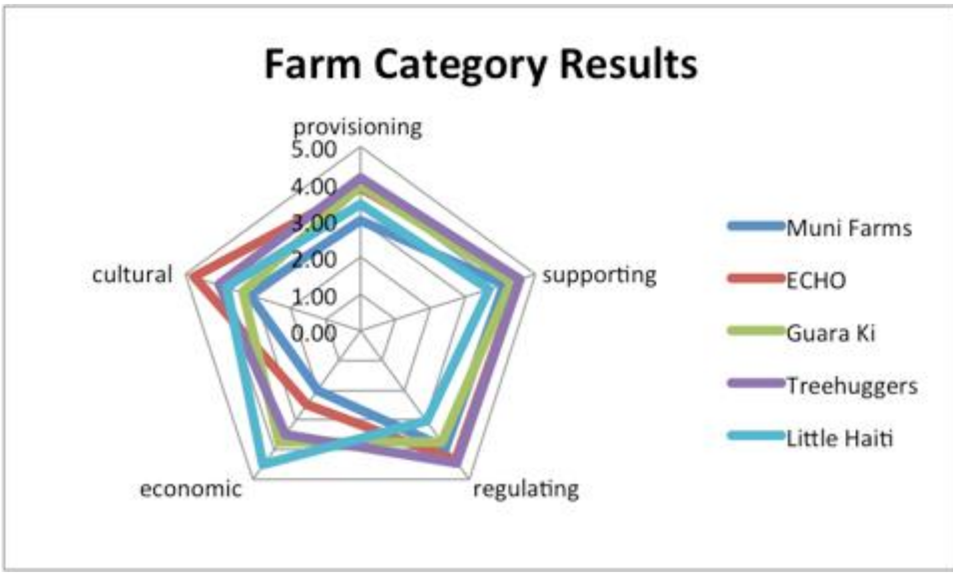
	FGCU	Mounts	Twin Lakes	Booker T.
Criteria				
Provisioning	3.50	2.29	3.45	3.36
Supporting	4.49	2.41	4.55	4.01
Regulating	4.46	2.76	4.02	3.56
Economic	3.50	2.25	3.25	3.25
Cultural	4.30	2.93	4.52	3.78
	4.11	2.32	3.70	3.67

ECHO Global Farms had the highest score overall (4.23) and the highest cultural score (4.76). Treehuggers Farm (4.20), and the FGCU Food Forest (4.11) were in second and third place respectively. Treehuggers had the highest score for provisioning services (4.14). Little Haiti Community Garden had the highest economic service score (4.50). Gaia Ma, a residence had both the highest supporting (4.60) and regulating score (4.72). Overall the scores in the Farm Category were higher than the residential and public category. The lowest score was for Mounts Botanical Edible Gardens (2.32) and Unbelievable Acres (3.02).

4.5 Farm Category

The farms are defined as an area of land whose primary function is growing crops or rearing animals for profit. There were five farms that were part of the study three in peri-urban areas of Florida City /Homestead and Davie, which included Muni Farms, Guara Ki Eco Farm, and Treehuggers, one in an urban part of Miami, Little Haiti Community Garden and one in a peri-urban area of Fort Myers, ECHO Global Farms. The diagram below compares the farms and their ES Scores. The sites in the farm category had the highest scores overall and two of the highest scores for cultural and provisioning services. On average supporting services scored highest in the farm category followed by regulating and cultural services. The radar chart in Figure 6 shows that Little Haiti Community Farm had the most well balanced approach to each of the categories, followed by Guara Ki and Treehuggers, with Muni Farms leaning more heavily towards the supporting and regulating services and ECHO towards cultural services.

Figure 6: Farm Category Radar Chart



4.5.1 Muni Farms

Muni Farms is a ten-acre family farm in the Redlands established in 2012. Their vision was to create a sustainable farm model that works with nature by using bio-mimicry in a self-maintained ecosystem. The land was previously a conventional farm with a rocky and marl soil. It is now certified organic by the USDA, therefore no herbicides or pesticides are used on the premises. Since this is a family farm they have counted on personal external sources of income to make the project a reality. Their primary source of income is a tropical plant nursery and landscape business. This project is in its beginning stages with a comprehensive permaculture design for all ten acres therefore individual areas are not developed to their full potential yet and the cost are high running at $100,000 a year for labor and materials. These two reasons could explain why it scored the lowest in the farm category (3.30); once in full production their score will probably change considerably. Special focus and attention was given to creating a native wind break and wildlife habitat surrounding the garden with over 25 species including Stoppers, Cocoplum, Milkweed, Gumbo Limbo, Wild Coffee, Silver Palms, Beautyberry, Necklace Pod, Coontie, Saw Palmetto and many more. Plants were grouped by genus in order to preserve seeds and stalk material for nursery. In addition, a large pond was dug out, and hammock like plantings including Everglades Palm, Cypress and Oak will line the outside edges protecting it from drift of pesticides sprayed in the adjacent farm and as a wind and fire break to create habitat and protect crops. Lower parts of the property have aquatic plants such as Cypress and others that are adapted to flooding conditions. The attention that was given to preserving and enhancing the natural heritage of the property as can be seen in Picture 1, as well as providing a space for educational activities such as permaculture workshops helps explain the cultural service score for this farm (3.19). All organic waste is composted and recycled on site mixed with the existing soil, in addition to chop and drop method used in banana circle, and mulch material brought in from other landscaping jobs. Planting beds are covered with organic mulch to keeps soil from eroding and perennial peanut is used as a groundcover throughout as seen in Picture 2. These practices earned the fourth highest score (4.11) for supporting services.

Picture 1: Aquatic system is enhanced when pond is dug out. Picture 2: Planting beds are covered with organic mulch keeping soil from eroding, paths are planted with perennial peanut as groundcover and nitrogen fixer.

4.5.2 Guara Ki Eco Farms

Guara Ki Eco is a 5-acre learning farm in Homestead, which is part of the local non-profit Earth Learning. It hosts a variety of workshops, classes and tours year round as well as selling products directly to restaurants and consumers. Before being acquired the farm was a Lychee and Mamey grove and since then many varieties of tropical fruits and vegetables such as Sugar Apple, Figs, Chirimoya, Sapodilla and Avocado have been added. Layers were integrated among the fruit trees of edible perennial and annual species following the permaculture and food forest model. Although the farm is not certified organic due to expenses associated with certification they do not use fertilizers or pesticides relying on organic mulch, horse manure, compost and chicken manure produced on site, worm castings. During the growing season many greens are planted such as Kale, Collards, and herbs that are sold directly to local restaurants. Guara Ki followed the trend of the farm category having the highest scores in the supporting (4.34), provisioning (3.96) and regulating services (0.87), respectively, followed by economic (3.75) and cultural (3.38). The standard deviation (SD) of the values here were also the lowest. Since the owners subscribe to permaculture principles and values, all ES were given thought in design and process accounting for the lower SD value.

Picture 3: The chicken tractor allows chickens to be integrated into the system utilizing their manure and scratching habits to improve the soil and control weeds. Picture 4: The bathroom facilities include a water-catchment, solar heated shower and a composting toilet.

4.5.3 Treehuggers Organic Farms

Treehuggers is a working farm and community established in 2012 on 4.6 acres of land that consisted primarily of weeds or invasive tree species. Their main focus is on feeding the soil rather than the plant, and enhancing diversity. They sell their produce at an internal market on the weekends and once a week at two different external markets. They are a key example of ways that a localized food production system can offer better prices for farmers. They received the highest provisioning score (4.14) of any site and the second highest score overall (4.20). In the farms category, this site gave the most importance to provisioning services (4.14) in the pair-wise matrix as well since one of their primary goals is to become a profitable enterprise and established farm. They devoted much of their land to perennial production about 80/20 ratio but since some of these species take 3 to 5 years to start producing much of their current sales and production comes from annuals (between November and April). Also contributing to the high provisioning score, the site was completely transformed with the introduction of a large pond, which now provides the majority of the water for irrigation on the property and the huge influx of topsoil and mulch brought in to raise the land by up to 6 ft. at certain points. This man made aquatic system is home to dozens of aquatic species, fish and other vegetation, it also helps to reduce flooding. Where rows of annual production are present, edges are planted with a variety of species including Holy Basil. The shift to perennial production has given the farm more profitability, for example sugar cane is planted in the edges of the farm and are labor free until harvesting, besides preventing soil erosion. Perennial polycultures around the farm include Lemon Bay Rum, Katuk, Mango, Bananas, Loquat, Jaboticaba, Figs, Dragon Fruit and Globe Artichoke. Adding fruit trees and perennial species has led to reduction in labor needs from five full time farmers to three, making the farm profitable. The farm had a high cultural value (4.06) with around 300 visitors per year including high school groups, customers. Customers buy directly from them, which helps them be economically viable. However they scored lowest in economics (3.50) due to the very high cost of establishment and high costs of maintenance in the first few years. This is a trend that we see in many of the sites in the study due to the length of establishing the supporting role of the soil and waiting for perennial plants to get established.

Picture 5: The pond that was dug out in the middle of the property is the primary source of irrigation, helps control flooding on the property and provides a diverse habitat. Picture 6: Community volunteers, workshops and a weekly market on the farm are all part of the cultural services provided on site.

4.5.4 ECHO Global Farm

The ECHO Global Farm is a part of the larger organization ECHO that acts as an information hub for development practitioners around the world. This is a work and training farm with many demonstration areas including an area for appropriate technologies. This farm holds one of the largest collections of edible tropical plants in the United States. The farms primary function is as a place for case studies and trials of seed varieties and appropriate technologies before they are sent overseas. Because of this many areas of the farm are not optimized for production as certain experiments are being conducted or environmental conditions are being mimicked. However the farm had the highest cultural rating of all the sites (4.76), with nearly 9,000 visitors each year, including visitors from schools, churches, garden clubs, foodies, and sustainable technology enthusiasts groups, who came for tours, workshops and volunteer opportunities. Besides the large number of visitors ECHO also hosts over 20 events and workshops a year, and has an active community volunteer base that is involved throughout the year. Monitoring and evaluating of the site takes place by interns and staff, these activities are included in the educational component of cultural services in the rubric. Also related to the cultural services the research and preservation of traditional farming practices, appropriate technologies and cultivars accounts for the high score in this area. The farm also acts as an in situ gene bank with over 33 varieties of Moringa. Since the site is used as a case study the performance of fruit bearing trees in understory of food forest is closely monitored and density and thinning of canopy is based on performance contributing to the provisioning service score of the site (3.88).

This farm scored high in regulating and supporting services as well (4.36 and 4.55). This in part due to their mission to apply conservation agricultural in order to produce the largest yields possible without comprising the health of the system. Animals are integrated throughout the garden including chickens, goats and ducks, this is unique of the sites visited but significant for nutrient cycling and productivity. Commercial inorganic fertilizers are also utilized in some areas producing crops such as maize, but primarily organic sources of nutrients such as county compost that is delivered and applied two to three times during the growing season. The regulating score (4.55) was the highest in the category since particular attention is given to improving soil and air quality and preventing erosion and flooding since this is an issue in many of the countries that benefit from the research on the site.

Picture 7: An in-situ collection of Moringa varieties is one of the ways ECHO preserves natural heritage and biodiversity. Picture 8: Several on site methods to produce compost, integrate manures, and worm farming for nutrient cycling on site.

4.5.5 Little Haiti Community Garden

This garden in the heart of the Little Haiti Community in Miami was founded in 2008 by a private owner in a derelict urban lot 13,500 sf. that had once been used as dump site. It took one year to clean up and rehabilitate the site and remove the lead out of the soil. What began as a community garden has turned into a micro business and urban farm over time. Although privately owned the farm itself is a non-profit organization and community garden that uses Permaculture techniques to grow fruits, vegetables and medicinal plants to be purchased by the community. Through donations from local foundations the garden was able to hire a full time gardener a Haitian native who fled after the hurricane, who is the primary caretaker of the operation. They sell produce directly to restaurants and customers in the neighborhood in a once a week on site market. About 95 % of the lot is planted out with a combination of perennial and annual species including Malanga , Bananas, Avocados, Yucca, Coconut Palm, Passion Fruit and Curry. Of the annuals primarily greens are grown for local restaurants including Arugula, Collards and Kale. This farm received the highest economic rating overall

(4.50) because it has achieved financial independence from external sources of funding, did not take a large financial investment to establish, hires a local employee and sells to the local market directly impacting the food security needs of the neighborhood. The owner stressed that making the site sustainable came from clearly defining roles vs. relying on donations or volunteers.

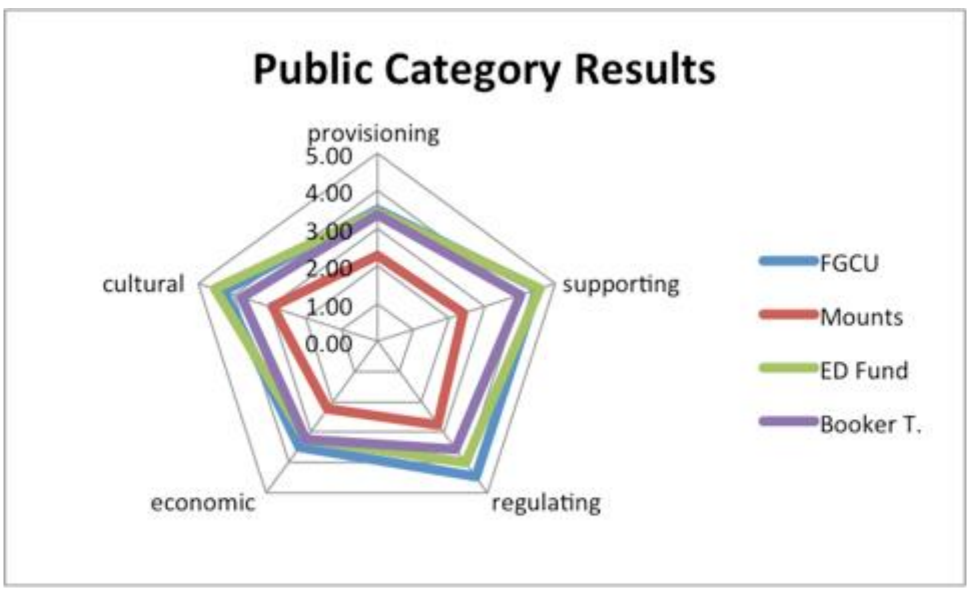
The second highest score within the site was for cultural services (3.82), with nearly 200 volunteers and visitors that come though the site each year from schools, universities and homeless shelters, as can be seen in Picture 10 below. Although not organically certified due to the high costs of certifications, no pesticides or herbicides are used on the vegetables, in the past if any crop showed significant weaknesses they ceased from growing it. All organic waste is recycled on site and turned into compost, cover crops such as sun hemp and buckwheat are used during the summer months contributing to the supporting service score (3.67).

Picture 9: Perennial plants are incorporated into annuals creating microclimates that allow the farm to extend the growing season for the lucrative greens sold to local restaurants. Picture 10: The garden has a full time employee and various school and community groups that volunteer from time to time.

4.6 Public Land Area Category

The public land categories are land areas that are held by central or local governments. A public university, high school, elementary school, as well as a county owned botanical garden are included in this category. The university food forest at FGCU was located in Fort Myers, the two public schools in urban Miami-Dade County and the Botanical Gardens in the city of West Palm Beach. The public category included the site with the lowest overall score and lowest scores at 0 in economics due primarily to how the projects are structured, with the primary goal being education and recreation within cultural services. As can be seen in Figure 7, overall the provisioning and economic services are less important than the cultural, supporting and regulating roles of these systems.

Figure 7: Public Land Category Radar Chart



4.6.1 Florida Gulf Coast University Food Forest

The FGCU Food Forest is a student run botanical garden with a large number of tropical and sub-tropical edible species arranged in a forest like environment. It was established in 2011 by a group of students funded by the student government, who designed, installed and maintain it to this day. The site received the third highest score overall (4.11) and the highest in the public category. A well thought out permaculture plan was designed by students, and many techniques and processes were implemented to build the soil, recycle nutrients on site and provide regulating services such as biological pest control and water flow regulation which accounts for the high scores in both supporting (4.49) and regulating services (4.46). Cultural services received the second highest score in this category (4.30), with initial and continuing participation by students and the community. A total of 148 individual students put in 1275 service hours, amounting to approximately $12,750.00 of labor to establish the garden over a four month period, including the laying down of compost material and earthworks. The garden relied on donations of both money and plants given by donors including local organization such as the Naples Botanical Garden and Home Depot. The site is an active part of the University and many students and professors utilize it as part of their classes and research. The Food Forest includes over 40 species of edible and native plants that produce fruit year round. As with the other public sites the economic role of the system is not as important as other ES but this site had the highest economic score in this category (3.50) since it was inexpensive to establish and was designed to not need intensive management or outside resources to sustain itself and also contributes indirectly to the local economy by providing free food to the student body and community who can harvest at no cost.

Picture 11: The garden was designed and implemented by students. Picture 12: Weekly tours to the general public and other special event make the garden an integral part of the culture of the university.

4.6.2 Booker T. Washington High School Food Forest

The edible forest garden was established in year 2015 as a demonstration and working garden at Booker T. Washington High School in Overtown, Miami. Although the garden is very new some of the trees were already on site and due to the microclimate created by the walls surrounding the courtyard there has seen substantial growth in the first year. The garden was established by a grant and with student participation. The primary function of the garden is to be used as outdoor classroom for both the culinary and environmental science programs at the school, which contribute to its high ratings in cultural services (3.78) primarily in education, the aesthetics and design process. This design process also accounts for the low standard deviation between the ES scores and a balance between the criteria since this was built in by design.

Picture 13: Before any planting a 1 to 2 ft. layer of organic mulch and horse manure mixture was poured over the site to build the soil and provide nutrients. Picture 14: The nutrient rich soil and microclimate created by the walls of the courtyard may explain the rates of growth in food forest.

4.6.3 Mount Botanical Edible Garden

Mounts Botanical was linked to agriculture from its inception serving the Palm Beach County Extension Service since 1964, early on 69 fruit trees were planted on site. In the 1990's a master plant was initiated by the University of Florida and completed in 2004. This public garden is a destination for thousands of visitors from the South Florida area. Housing meetings for over 10 associations including the Herb Society of Palm Beach County and the Palm Beach Rare Fruit Council. Once a month classes on, book discussions and art in the garden series are all part of the cultural services score (2.93), which is was the highest for this site. The property includes a variety of gardens including a tropical forest, rain garden and butterfly garden. For the sake of the study we concentrated on the edible landscape garden, which encompasses about 8000 sq. ft. of space. Tropical Fruit trees pruned to a small scale, some other perennials, and intercropped annual systems are the primary components of the garden. This site received the lowest score (2.32) of all the sites primarily because it does not utilize the space efficiently or integrate the perennial and annual plantings, relies on external inputs such as inorganic fertilizers, and due to regulations does not distribute or sell the crops that are produced on site. The garden is aesthetically pleasing and does provide examples for homeowners to explore in their own home gardens.

Picture 15: Annual and perennial mixture of plants less densely planted. Picture 16: Signage such as this helps to educate visitors about food crops they can grow in their home gardens.

4.6.4 Twin Lakes Elementary School

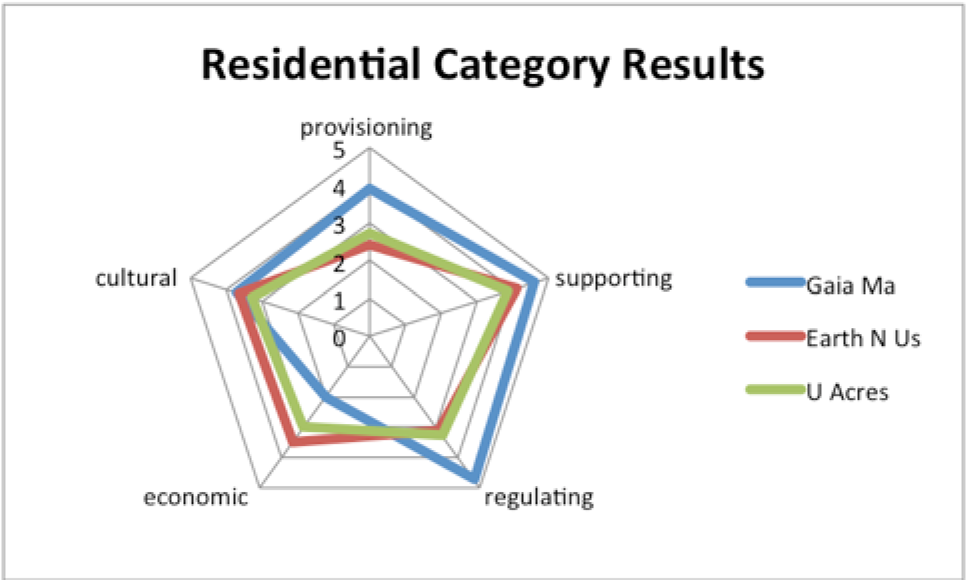
The Twin Lakes Elementary Food Forest is part of a growing movement of school gardens, sponsored by corporate or foundation donors whose purpose is to educate and engage youth around science, nutrition, and food production. This garden has evolved over the past five years from mostly annual raised garden beds to a designed and implemented food forest with many layers of complexity, moving from a 10/90 % ratio of annual to perennial to the opposite with almost 90 % of the plants on site being. This transition has translated to increase in biodiversity and the introduction of nectary and other beneficial species, a decrease in the need for external inputs, increase leaf litter and organic matter recycled on site, increase in soil water retention, decrease in pests and negative plant health indicators. This accounts for the highest score in the supporting ES in this category (4.55). As in other public sites and sites in general the cultural services are significant (4.52) with nearly 150 students utilizing the garden on a weekly basis for education, recreation and as a gathering focal point for the school community.

Picture 17 and 18: The garden made the transition over the years from annual garden beds to perennial polyculture food forest systems that mimic the home-garden agroforestry systems of the tropics.

4.7 Residential Category

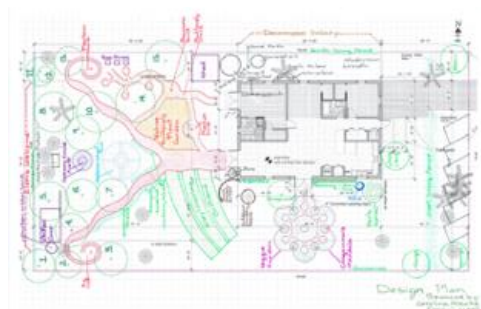
The residential category includes private homes that were landscaped primarily for private use, although the educational component and community engagement are much more present that in other private residences. Two of the residences, Gaia Ma and Earth n Us are located in urban Miami and one, Unbelievable Acres in peri-urban West Palm Beach. Although they are permanent residences they are each unique in that Earth n Us is comprised of several rental units and acts as a community of residents with shared common spaces, Gaia ma was built as a prototype and model for sustainable urban housing, and Unbelievable Acres has evolved into a private botanical garden and collection that is open for public tours at specific times. This category had the highest scores in the supporting, regulating and provisioning with cultural services close behind as seen in Figure 8 below.

Figure 8: Residential Category Radar Chart

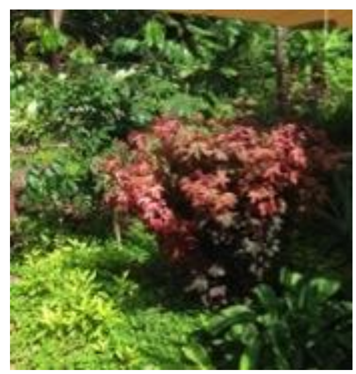


4.7.1 Gaia Ma by Urbanesco Development

This permaculture garden in a Biscayne Park residence was created as a prototype for Urbaneco Development, a green building and design company. Drawing on an abundance of private financial investment this project was planned right from the start. The lot of nearly 8,000 sq. ft. was prepared for a year before any planting was done through the addition of high quality compost and mulch. Components such as a 4,000 gallon water catchment system was installed to meet the water needs of the garden, a detailed permaculture design that utilized every part of the space with several elements layered in relative placement to each other made the project extremely effective in providing ES but also very expensive. This explains the low economic score (2.00) and the high supporting (4.60) and regulating services (4.72) provided, the last two, which were the highest in all of the sites. Practices such as the addition of organic matter to the soil, use of nitrogen fixers such as Pigeon pea and Perennial Peanut, use of mining plants, such as Comfrey, creation of pond habitat and butterfly garden, use of native nectary plants, restricted use of external inputs, use of windbreaks and creation of microclimates all contributed to these scores. Although this is a private residence several workshops and tours are held at the house on a monthly basis, which is a factor in the cultural contribution of the site (3.74).



Picture 19: Beginning with a detailed site analysis and design was part of the cultural score and could explain the high scores in the supporting and regulating categories.



Picture 20: Part of the supporting service is the formation of rich soil through the addition of mulch, manure and rich compost made on site for a year prior to planting. Picture 21: A 4,000 gallon rain catchment system was installed prior to planting and feeds the gardens irrigation system. Picture 22: A polyculture planting with a variety of species growing together.

4.7.2 Earth n Us Urban Ecovillage

Earth n US Urban Ecovilage is located in the Little Haiti neighborhood of Miami. Established in 1977 by the owner, over many years 11 parcels of land and houses were purchased until he had a two-acre lot in the heart of the city. From the beginning he established a garden, planted fruit trees and created an animal sanctuary with goats, chickens, bees, emus and a pig. Over the years the role of this urban ‘farm” in the community was established with ongoing field trips from schools, community dinners and courses. The primary income of the farm is the rent generated from the many single and multi family residences on the property. A green preschool, a bike cooperative, and as short-term rental accommodations have all been sources of income and community engagement on the site. Most recently the owner purchased an adjacent property where a food forest was planted. Members in and around the community are encouraged to compost on site, and this along with the manure produced from the animals, and vermin-culture system creates a rich soil amendment that is used wherever crops are grown. This accounts for the high supporting score (4.12), second only to the cultural piece (3.66), which is the driver for the project.

Picture 23: Composting for all the residents on site and for the neighbors is an important service this site provides. Picture 24: Animals present on site include the tortoises pictured here, goats, chickens, an ostrich and pig.

4.7.3 Unbelievable Acres

Unbelievable Acres was established in 1970 in West Palm Beach in what used to be an empty cow field. A combination of tropical vines, orchids, bromeliads, and tropical fruits are planted to mimic a tropical rainforest. The garden was established with one man's continued efforts and hundreds of volunteer hours throughout the years. Due to the minimal maintenance the canopy was not managed for optimal light, therefore production is minimal but the biodiversity, formation of soil, and climate regulation is significant. This is reflected in the scores, which are highest for supporting (3.88) and regulating 3.27 services but low overall (3.02). This is the oldest site in the study and although still productive similarly to a natural system is in a later stage of succession. With the canopy having almost at 100% cover with little productivity as far as food crops in the lower layers of the forest. However, its age and character make it a significant cultural contribution to the neighborhood housing dozens of rare species, and specimens such as the oldest Jaboticaba in the US. It is this kind of experience and learning opportunities that bring hundreds of visitors through the site each year during the once a month tours open to the public contributing to the cultural service score (3.30).


Picture 25: The food forest layers in the beginning stage of succession in a more recently planted part of the garden. Picture 26: At later stages of succession the canopy is denser and there is light available to understory plants making the food forest less productive overall.

The results show that all of the alternative agro-ecosystems in the study contribute in four or more areas to ES provided. Each site has unique attributes that either facilitate or hinder its ability to provide ES. The weight data affected the study results somewhat because overall most sites valued the cultural services more than the others, so more weight was given to this criterion. All of the sites had strong cultural components, with education, recreation, and volunteering elements being central goals and provisioning and economic considerations only used to support the cultural. Trends between the categories indicated that sites designated as farms, whether the purpose was education or production, had higher ES overall then residential and public. A detailed site analysis and design process was also related to the higher scores in all three categories as seen in Gaia Ma, FGCU and Treehuggers Farms.

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

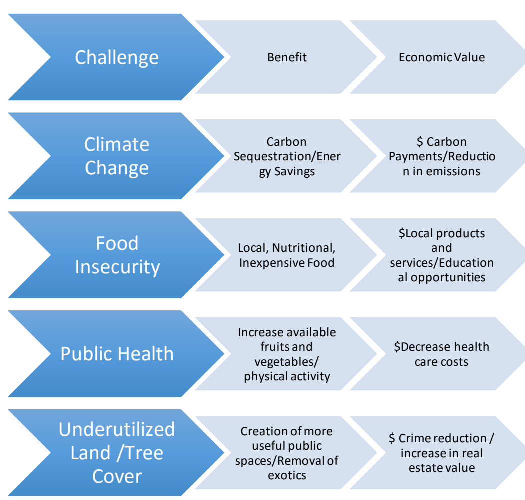
Alternative agro-ecosystems have evolved as a reaction to ecological and social issues related to industrial agriculture. Studies have shown a variety of practices and systems based on traditional knowledge and innovative technologies that are being put into practice at various degrees and scales. There is a growing interest in the assessment of ecosystem services and how they affect human well-being. However, there was no framework available to measure the sustainability of these systems and to help understand the challenges and opportunities they embody. The aim of this study was to build the PASS framework as an approach to assess the sustainability of alternative agro-ecosystems in urban areas. The scorecard was built upon prior Sustainability indicators integrating concepts of ES, SAFE, SITES, Permaculture principles and Agroecology Principles into a cohesive and case specific rubric that was tested in 12 sites in the South Florida region.

5.2 Existing alternative agro-ecosystems: challenges and opportunities

The alternative agro-ecosystems in the study demonstrated significant contributions in several ES. The assessment showed that their value is found to be greater in the supporting role that they provide rather than in the provision of food crops or economic contributions, which people tend to associate with agricultural projects. Practitioners recognize the need to establish supporting services such as soil formation, nutrient cycling and the exponential increase in biodiversity in order to sustain systems that do not require external inputs in the long run to sustain it. Cultural services are also given great importance and community engagement, education and preservation of natural and cultural heritage is a significant contribution made by each of these sites. They also provide a source of local food production which can have an impact on the local economy to a small degree, but this is less significant than the regulating role of ES expressed through erosion and flood control, climate regulation, water flow regulation and pollination services present on the site. Supporting services were followed by provisioning, supporting, regulating and economic services. These results followed the same order that the average farmer/operator indicated was most important according to the pair-wise matrix survey.

With so many potential benefits to the ES of urban areas the challenge becomes quantifying the same. Another challenge is giving economic incentives for their adoption whether this comes through better management practices that bring a greater return to farmers or outside incentives such as government grants and subsidies. Figure 9 below summarizes the challenges faced by the urban environment and the potential of alternative agro-ecosystem to help transform these challenges into opportunities.

Figure 9: Opportunities for Utilizing alternative agro-ecosystems in Urban Settings.



Alternative agro-ecosystems have a great potential to target specific urban challenges. For instance the carbon sequestration potential of these systems can fulfill the need to find climate change mitigation solutions and in the future could translate into carbon payments for farmers/operators. Within the context of food security and public health both the availability of fresh food in close proximity to communities and the educational and recreational potential of these systems can be used to address these issues. Vacant lands, which have a positive correlation with, increased crime, reduced property values and invasive species can be utilized in a way that creates resilience and support for the community (Sarah, 2010). There are many other benefits of utilizing alternative agro-ecosystems that need to be researched such as impacts on air quality, water pollution, temperature control, and social economic aspects such as job creation and neighborhood revitalization.

5.3 Factors that influence the adoption of alternative agro-ecosystems in urban landscapes

In general the driving factor behind these projects was the desire to establish a place of natural and cultural value that educated the public and added to the ecosystem of the area. A few exceptions were some of the farms that in addition wanted to create a livelihood from the selling of food crops produced in the system. The main issues identified from the study for their adoption and sustainability are the following:

1) Funding - The adoption of these practices depends on their economic feasibility, availability of external resources and on the presence of a market for diversified products.

a) Dependency on external finances: Other economic incentives from environmental benefits provided need to be present to incentivize their adoption. Implementing these types of projects can be challenging and require constant communication with the public and larger donors for continued support.

b) Connection to food security and public health: Making the connection to these issues facing urban environments in the developed world could be an opportunity for funding from health organizations and other agencies and foundations dealing with poverty. Vacant lands, which have a positive correlation with, increased crime, reduced property values and invasive species can be utilized in a way that creates resilience and support for the community and produce job creation and neighborhood revitalization (Sarah, 2010).

c) Market for diversified products: New distribution networks and a market that allows diversified products is needed to sell these products. Farmers/ operators have a difficult time distributing their goods because they have such a variety and our current system requires large quantities of uniform fruits and vegetables to be sold at markets. Having farmer co-operatives, farmers markets, community supported agriculture and other distribution networks that are direct from site to consumer would insure they have a market.

d) Funding from the United States Department of Agriculture (USDA): The largest source of funding for programs related to agriculture and forestry is the USDA, whose strategic goals are consistent with the goals in many of the sites in this study. In fact since the majority of USDA spending is to insure that people have nutritious food to eat, it seems like a logical next step to fund projects that feed people directly while creating jobs and many other benefits. Discretionary funding (about $23 billion in 2015) from the Farm Bill could be redirected to fund permanent comprehensive community- based alternative agro-ecosystems initiatives to simultaneously address food security, climate change, economic and ecosystem service challenges facing urban environments. More recently the Urban Agriculture Act of 2016 to create new economic opportunities and give families greater access to healthy food. This act specifically targets expanding urban agriculture initiatives by providing loans, mentorship, education and risk management tools to farmers.

2) Complexity and lack of measurable data –

   a) Measuring systems and practices: Having ways to measure and develop a set of reference values for each indicator formulated either by established scientific values or by comparison of the systems needs to be established. In this way both specific targeted values or threshold values can be established. For example, by monitoring the yield (kg/sq. m) of each system a target or threshold value can be established. By knowing what needs to be measured and how to measure it operators could keep more detailed records.

   b) Mainstreaming the use of these ecosystem indicators: This will have the effect of making the business case for ES more self-evident. Once entry points are identified such as extension offices, non-profit organizations and urban forestry organizations, tools such as PASS can be distributed to be implemented.

3) Policy –

   a) Regulatory codes and zoning: In many regions laws currently prohibit growing food crops and/or gathering on public lands. This institutional framework assumes that citizens should be separate from nature ignoring the potential for food and medicine to be supplied by these spaces. Urban gatherers exist and their practices can be implemented and utilized in this context as a part of the management plan.

   b) Carbon sequestration: Although carbon sequestration is the most popular ES studied in the literature (Nair et al., 2009; Tang et al., 2016), the regulating services involved in this study were given the least importance as a strategy. This would certainly change if there were an economic incentive such as carbon credits or property tax breaks established to incentivize the adoption of carbon farming methods. National strategies such as low interest loans to help farmers transition to sustainable agriculture, or requiring a certain percentage of trees be planted by law in farming systems have proven to be effective ways to incentivize carbon sequestration. Many countries have started using Payment for Environmental Service (PES), which is basically a way to pay farmers for the other ES they provide through the use of sustainable and carbon sequestering practices. In Australia the Carbon Farming Initiative (CFI), which is funded through a cap-and-trade system provides financial rewards to farmers who implement specific practices (Toensmeier, 2016). In the United States the USDA is implementing tools to help farmers calculate the carbon sequestration potential of different practices but economic incentives are found by the IPCC to be the most effective way in incentivizing farmers. In the urban context even greater financial incentives can be awarded given the extent of the impact these systems have on highly urbanized environments.

4) Best practices –
   a) Design: A presentation of indicators without a clear strategy of how to integrate it can result in a fragmented and erroneous understanding of the system under analysis (Lopez-Ridaura et al., 2005). With clear indication of criteria to select soil building techniques, plants, water management the adoption of these system will become more approachable.
   b) Maintenance: Even after implementation having clear maintenance schedules is important including plans of potential volunteer and urban foraging groups that can help in managing the project.
5) Scaling Up –
   a) Master Planning - As with most projects scale can have a great impact on the costs involved with installation and maintenance. By implementing a master planning process at a city wide to regional scale elements such as nurseries to produce plant stock, composting facilities, equipment for harvesting and maintaining gardens, and distribution centers for local food could be shared by smaller gardens optimizing efficiency and reducing costs of implementation and maintenance.
   b) Dispersing Information – On a local and broad scale the implementation of productive landscapes in the form of alternative agro-ecosystems needs to be compiled as case studies to be shared among practitioners. Through the establishment of conferences on the subject, online resources for practitioners and

tools such as PASS being available for use during the planning process. Educating the public through extension services for residential implementation can also be an effective way to encourage the implementation of these systems.

LIST OF REFERENCES

Adams WM (2006) The future of sustainability: re-thinking environment and development in the twenty-first century. Report of the IUCN renowned thinkers meeting, 29-31 January, 2006.

Ahern, J. (2013). Urban landscape sustainability and resilience: The promise and challenges of integrating ecology with urban planning and design. Landscape Ecology, 28(6), 1203.

Ajayi, J. O. (2014). Comparative economic study of mixed and sole cassava cropping systems in nigeria. Agris on-Line Papers in Economics & Informatics, 6(4), 15-23.

Albert, C., Galler, C., Hermes, J., Neuendorf, F., von Haaren, C., & Lovett, A. (2016). Applying ecosystem services indicators in landscape planning and management: The ES-in-planning framework. Ecological Indicators, 61, Part 1, 100-113. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolind.2015.03.029

Algert, S., Diekmann, L., Renvall, M., & Gray, L. (2016). Community and home gardens increase vegetable intake and food security of residents in san jose, california. California Agriculture, 70(2), 77-82.

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. Agriculture, Ecosystems & Environment, 74(1), 19-31.

Altieri, M. A. (2002). Agroecology: The science of natural resource management for poor farmers in marginal environments. Agriculture, Ecosystems & Environment, 93(1–3), 1-24. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/S0167-8809(02)00085-3

Altieri, M. A. (2011). The agroecological revolution in latin america: Rescuing nature, ensuring food sovereignty and empowering peasants. The Journal of Peasant Studies, 38(3), 587; 587-612; 612.

Altieri, M. A. (2011). Multifunctional biodiversity in Latin America traditional agriculture. LEISA Magazine, 15 (3-4).

Anderson, E. K. (2012). Seeing the trees for the carbon: Agroforestry for development and carbon mitigation. Climatic Change, 115(3-4), 741; 741-757; 757.

Andrew J. Macnab, Professor Donald,Professor. (2014). School food gardens: Fertile ground for education. Health Education (Bradford, West Yorkshire, England), 114(4), 281; 281-292; 292.

Araujo, Q. R., Loureiro, Guilherme A. H. A., Santana, S. O., & Baligar, V. C.Soil classification and carbon storage in cacao agroforestry farming systems of bahia, brazil Taylor & Francis.

Asdrubali, F. (2015). A comparison between environmental sustainability rating systems LEED and ITACA for residential buildings. Building and Environment, 86, 98; 98-108; 108.

Aubry, C. (2012). Urban agriculture and land use in cities: An approach with the multi-functionality and sustainability concepts in the case of antananarivo (madagascar).(report). Land use Policy, 29(2), 429.

Auclair, D., Barczi, J., Borne, F., & Étienne, M.Assessing the visual impact of agroforestry management with landscape design software. Landscape Research, 26(4), 397.

Babcicky, P. (2013). Rethinking the foundations of sustainability measurement: The limitations of the environmental sustainability index (ESI). Social Indicators Research, 113(1), 133; 133-157; 157.

Banai, R.The metropolitan region: From concepts to indicators of urban sustainability. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 6(1), 1.

Bangwayo-Skeete, P., Bezabih, M., & Zikhali, P. (2012). Crop biodiversity, productivity and production risk: Panel data micro-evidence from ethiopia. Natural Resources Forum, 36(4), 263-273. doi:10.1111/1477-8947.12000

Beck, T., Quigley, M., & Martin, J. (2001). Emergy evaluation of food production in urban residential landscapes. Urban Ecosystems, 5(3), 187.

Berardi, U. (2013). Sustainability assessment of urban communities through rating systems. Environment, Development and Sustainability, 15(6), 1573; 1573-1591; 1591.

Berendsen, R. L. (2012). The rhizosphere microbiome and plant health. Trends in Plant Science, 17(8), 478; 478-486; 486.

Bergez, J. -., & C. (1301). An open platform to build, evaluate and simulate integrated models of farming and agro-ecosystems. Environmental Modelling and Software, 39, 39.

Bianchi, F. J. J. A., Mikos, V., Brussaard, L., Delbaere, B., & Pulleman, M. M. (2013). Opportunities and limitations for functional agrobiodiversity in the european context. Environmental Science & Policy, 27(0), 223-231. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.envsci.2012.12.014

Blair, J. M., & Mcsherry, L. (1996). Sustainable agriculture in the southwest united states and its relationship to landscape planning. Journal of Soil and Water Conservation, 51(4), 280.

Bockstaller, C., Guichard, L., Keichinger, O., Girardin, P., Galan, M., & Gaillard, G. (2009). Comparison of methods to assess the sustainability of agricultural systems. A review. Agronomy for Sustainable Development (EDP Sciences), 29(1), 223-235.

Bodenstab, A. (2006). The seed goes on. Earth Island Journal, 21(4), 43-44.

Boody, G., Vondracek, B., Andow, D. A., Zimmerman, J., Krinke, M., Westra, J., & Welle, P. (2005). Multifunctional agriculture in the united states. Bioscience, 55(1), 27-38.

Bregendahl, C. and Enderton, A. 2013. 2012 Economic Impacts of Iowa's Regional Food Systems Working Group. Leopold Center for Sustainable Agriculture, Ames, IA.

Brown, C., Reyers, B., Ingwall-King, L., Mapendembe, A., Nel, J., O'Farrell, P., Dixon, M. & Bowles-Newark, N.J. (2014). Measuring ecosystem services: Guidance on developing ecosystem service indicators. UNEP-WCMC, Cambridge, UK.
Caldwell, R., & Hansen, J. (1993). Simulation of multiple cropping systems with CropSys. Systems approaches for agricultural development (pp. 397-412) Springer.

Carlisle, L. (2016). Factors influencing farmer adoption of soil health practices in the united states: A narrative review. Agroecology and Sustainable Food Systems, 40(6), 583; 583-613; 613.

Clark, K., & Nicholas, K. (2013). Introducing urban food forestry: A multifunctional approach to increase food security and provide ecosystem services. Landscape Ecology, 28(9), 1649.

Cleveland, D. A., & Soleri, D. (1994). Do folk crop varieties have a role in sustainable agriculture? Bioscience, 44(11), 740-751.

Cohen, J. I., Williams, J. T., Plucknett, D. L., & Shands, H. (1991). Ex situ conservation of plant genetic resources: Global development and environmental concerns. Science, 253(5022), 866.

Coiner, C., Wu, J., & Polasky, S. (2001). Economic and environmental implications of alternative landscape designs in the walnut creek watershed of iowa. Ecological Economics, 38(1), 119-139. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/S0921-8009(01)00147-1

Crop diversity for yield increase. (2009). Plos One, 4(11), 1-6.

Cuanalo de la Cerda, H. (2008). Homegarden production and productivity in a mayan community of yucatan. Human Ecology : An Interdisciplinary Journal, 36(3), 423; 423-433; 433.

de Vries, F. P., Teng, P., & Metselaar, K. (1993). Systems approaches for agricultural development: Proceedings of the international symposium on systems approaches for agricultural development, 2-6 december 1991, bangkok, thailand Springer.

Delbaere, B., Mikos, V., & Pulleman, M. (2014). European policy review: Functional agrobiodiversity supporting sustainable agriculture. Journal for Nature Conservation, 22(3), 193-194. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.jnc.2014.01.003

Demuzere, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management, 146, 107.

De Schutter, Oliver. (2014). Report of the Special Rapporteur on the right to food. United Nations General Assembly: Human Rights Council. Agenda item 3.

Dobbs, C., Kendal, D., & Nitschke, C. R. (2014). Multiple ecosystem services and disservices of the urban forest establishing their connections with landscape structure and sociodemographics. Ecological Indicators, 43, 44-55. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolind.2014.02.007

Dominati, E., Mackay, A., Green, S., & Patterson, M. (2014). A soil change-based methodology for the quantification and valuation of ecosystem services from agro-ecosystems: A case study of pastoral agriculture in new zealand. Ecological Economics, 100, 119-129. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2014.02.008

Duany Plater-Zyberk & Company, LLC (2009). Transect-Based Agriculture.

Dunmall, G. (2009). How to ... create your own edible landscape.(horticulture)(on food up front, adopt-A-garden, garden share, and landshare schemes). The Ecologist (1979), 39(3), 56.

Dwyer, John F., et al. "Assessing the benefits and costs of the urban forest." *Journal of Arboriculture* 18 (1992): 227-227.

Edwards, F., & Mercer, D.Meals in metropolis: Mapping the urban foodscape in melbourne, australia. Local Environment, 15(2), 153.

Egoh, Benis, Drakou, Evangelia G., Dunbar, Martha B., Maes, Joachim & Willemen, Louise. (2012). Indicators for mapping ecosystem services: a review. European Commission Joint Research Centre.

Engels, J., & E. (2006). Centres of crop diversity and/or origin, genetically modified crops and implications for plant genetic resources conservation. Genetic Resources and Crop Evolution, 53(8), 1675.

Erskine, P. D., Lamb, D., & Bristow, M. (2006). Tree species diversity and ecosystem function: Can tropical multi-species plantations generate greater productivity? Forest Ecology and Management, 233(2), 205-210.

Ewel, J. J. (1999). Natural systems as models for the design of sustainable systems of land use. Agroforestry Systems, 45(1-3), 1-21.

Fageria, N. (2012). Role of soil organic matter in maintaining sustainability of cropping systems. Communications in Soil Science and Plant Analysis, 43(16), 2063; 2063-2113; 2113.

Falk, Ben. (2013). The resilient farm and homestead: an innovative permaculture and whole systems design approach. White River Junction: Chelsea Green Publishing.

Fentahun, M., & Hager, H. (2010). Integration of indigenous wild woody perennial edible fruit bearing species in the agricultural landscapes of amhara region, ethiopia. Agroforestry Systems, 78(1), 79.

Ferguson, R., & Lovell, S. (2014). Permaculture for agroecology: Design, movement, practice, and worldview. A review. Agronomy for Sustainable Development, 34(2), 251.

Fernandes, Lúcio André de O., & Woodhouse, P. J. (2008). Family farm sustainability in southern brazil: An application of agri-environmental indicators. Ecological Economics, 66(2), 243.

FERNANDEZ, M., GOODALL, K., OLSON, M., & ERNESTO MÉNDEZ, ,V. (2013). Agroecology and alternative agri-food movements in the united states: Toward a sustainable agri-food system. Agroecology & Sustainable Food Systems, 37(1), 115-126. doi:10.1080/10440046.2012.735633

Ferreira, J., Pardini, R., Metzger, J. P., Fonseca, C. R., Pompeu, P. S., Sparovek, G., & Louzada, J. (2012). Towards environmentally sustainable agriculture in brazil: Challenges and opportunities for applied ecological research. Journal of Applied Ecology, 49(3), 535-541.

Francis, C. , LIeblein, G., Gliessman, S., Breland, T.A., Creamer, N., Harwood, L….& Wiedenhoeft, M. (2003). Agroecology: the ecology of food systems. Journal of sustainable agriculture, 22(3), 99-118.

Frausin, V., Fraser, J., Narmah, W., Lahai, M., Winnebah, T., Fairhead, J., & Leach, M. (2014). 'God made the soil, but we made it fertile': Gender, knowledge, and practice in the formation and use of african dark earths in liberia and sierra leone. Human Ecology: An Interdisciplinary Journal, 42(5), 695-710. doi:10.1007/s10745-014-9686-0

George, S. J., & H. (2012). A sustainable agricultural landscape for australia: A review of interlacing carbon sequestration, biodiversity and salinity management in agroforestry systems

Ghisellini, P., Zucaro, A., Viglia, S., & Ulgiati, S. (2014). Monitoring and evaluating the sustainability of italian agricultural system. an emergy decomposition analysis. Ecological Modelling, 271, 132-148. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolmodel.2013.02.014

Gliessman, S. (2011). Transforming food systems to sustainability with agroecology. Journal of Sustainable Agriculture, 35(8), 823; 823-825; 825.

Gliessman, S. (2007). Agroecology: The Ecology of Sustainable Food Systems. Boca Raton: CRC Press.

Grimm, Nancy; Faeth, Stanley; Glubiewski, Nancy; Redman, Charles; W, Jianguo; Bai, Xuemel and Briggs, John. (2008). Global change and the Ecology of Cities. *Science, 8(319), 756.*

Harrop, S. R. (2007). Traditional agricultural landscapes as protected areas in international law and policy. Agriculture, Ecosystems & Environment, 121(3), 296; 296-307; 307.

Henderson, H. (1994). Paths to sustainable development: The role of social indicators. Futures, 26(2), 125.

Hemenway, Toby. (2009). Gaia’s Garden: A guide to home-scale permaculture. White River Junction, VT: Chelsea Green Publishing.

Hezri, A. A. (2006). Sustainability indicators, policy and governance: Issues for ecological economics. Ecological Economics, 60(1), 86; 86-99; 99.

Hiremath, R. B., Balachandra, P., Kumar, B., Bansode, S. S., & Murali, J. (2013). Indicator-based urban sustainability—A review. Energy for Sustainable Development, 17(6), 555-563. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.esd.2013.08.004

Hodgkin, T., & Bordoni, P.Climate change and the conservation of plant genetic resources. Journal of Crop Improvement, 26(3), 329.

Holdsworth, B. (2005). Continuous productive urban landscapes: Designing urban agriculture for sustainable cities. Refocus (Oxford), 6(4), 13; 13-13; 13.

Huang, L. (2015). Defining and measuring urban sustainability: A review of indicators. Landscape Ecology, 30(7), 1175; 1175-1193; 1193.

Huvio, T., & Sidibé, A. (2003). Strengthening farmers' capacities for plant genetic resources conservation in mali. Plant Genetic Resources: Characterization and Utilization, 1(1), 31.

Iles, A. (2012). Nurturing diversified farming systems in industrialized countries: How public policy can contribute. Ecology and Society, 17(4), 178; 178-196; 196.

Ingram, J., Maye, D., Kirwan, J., Curry, N., & Kubinakova, K. (2014). Learning in the permaculture community of practice in england: An analysis of the relationship between core practices and boundary processes. Journal of Agricultural Education and Extension, 20(3), 275.

Islam, M., Dey, A., & Rahman, M. (2015). Effect of tree diversity on soil organic carbon content in the homegarden agroforestry system of north-eastern bangladesh. Small-Scale Forestry, 14(1), 91.

Jacke, Dave and Toensmeier, Eric. (2005). Edible Forest Gardens: Ecological vision and theory of temperate climate permaculture. White River Junction, VT: Chelsea Green Publishing.
James, S. (2016). Planning for peri-urban agriculture: A geographically-specific, evidence-based approach from sydney. Australian Geographer, 47(2), 179; 179-194; 194.

Jansson, Å. (2013). Reaching for a sustainable, resilient urban future using the lens of ecosystem services. Ecological Economics, 86, 285-291. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2012.06.013

Johnston, M.a brief history of urban forestry in the united states. Arboricultural Journal, 20(3), 257.

Jones-Walters, L., & Čivić, K. (2013). European protected areas: Past, present and future. Journal for Nature Conservation, 21(2), 122-124. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.jnc.2012.11.006

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview.(report). Agroforestry Systems, 76(1), 1.

Kate H Brown, & Andrew, L. J. (2000). Public health implications of urban agriculture. Journal of Public Health Policy, 21(1), 20.

Kattel, G. R., Elkadi, H., & Meikle, H. (2013). Developing a complementary framework for urban ecology. Urban Forestry & Urban Greening, 12(4), 498.

Koont, S. (2008). A cuban success story: Urban agriculture. Review of Radical Political Economics, 40(3), 285.

Kopali, A. (2013). Analysis of the sustainability of agricultural farms through agri-environmental indicators at the level of biodiversity and landscape. Albanian Journal of Agricultural Sciences, 12(4), 539.

Kremen, C., Iles, A., & Bacon, C. (2012). Diversified farming systems: An agroecological, systems-based alternative to modern industrial agriculture. Ecology & Society, 17(4), 288-306. doi:10.5751/ES-05103-170444

Kulak, M., Graves, A., & Chatterton, J. (2013). Reducing greenhouse gas emissions with urban agriculture: A life cycle assessment perspective. Landscape and Urban Planning, 111(0), 68-78. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.landurbplan.2012.11.007

Lafontaine-Messier, M., Gélinas, N., & Olivier, A. (2016). Profitability of food trees planted in urban public green areas. Urban Forestry & Urban Greening, 16, 197-207. doi:10.1016/j.ufug.2016.02.013

Lang, T. A., Oladeji, O., Josan, M., & Daroub, S. (2010). Environmental and management factors that influence drainage water P loads from everglades agricultural area farms of south florida. Agriculture, Ecosystems and Environment, 138(3), 170.

Layke, C., Mapendembe, A., Brown, C., Walpole, M., & Winn, J. (2012). Indicators from the global and sub-global millennium ecosystem assessments: An analysis and next steps. Ecological Indicators, 17, 77-87. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolind.2011.04.025

Lebacq, T., Baret, P., & Stilmant, D. (2013). Sustainability indicators for livestock farming. A review. Agronomy for Sustainable Development, 33(2), 311.

Lin, B. B., Philpott, S. M., & Jha, S.(2015). The future of urban agriculture and biodiversity-ecosystem services: Challenges and next steps. Basic and Applied Ecology, 16(3), 189.

Linger, E. (2014). Agro-ecosystem and socio-economic role of homegarden agroforestry in jabithenan district, north-western ethiopia: Implication for climate change adaptation. Springerplus, 3(1), 1.

Lovell, S. T., DeSantis, S., Nathan, C. A., Olson, M. B., Ernesto Méndez, V., Kominami, H. C., . . . Morris, W. B. (2010). Integrating agroecology and landscape multifunctionality in vermont: An evolving framework to evaluate the design of agroecosystems. Agricultural Systems, 103(5), 327.

Lynch, K., Maconachie, R., Binns, T., Tengbe, P., & Bangura, K. (2013). Meeting the urban challenge? urban agriculture and food security in post-conflict freetown, sierra leone. Applied Geography, 36(0), 31-39. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.apgeog.2012.06.007

Ma, Y., Chen, L., Zhao, X., Zheng, H., & Yihe Lü. (2009). What motivates farmers to participate in sustainable agriculture? evidence and policy implications. International Journal of Sustainable Development & World Ecology, 16(6), 374-380. doi:10.1080/13504500903319047

Machum, S.The persistence of family farming in the wake of agribusiness: A new brunswick, canada case study. Journal of Comparative Family Studies, 36(3), 377.

Mackenzie, D. (1991). Plant breeders plan strategy for resilient crops. (preservation of the genetic diversity of crop species). New Scientist, 131(1776), 17.

Maes, J., Liquete, C., Teller, A., Erhard, M., Paracchini, M. L., Barredo, J. I.' Lavalle, C. (2016). An indicator framework for assessing ecosystem services in support of the EU biodiversity strategy to 2020. Ecosystem Services, 17, 14-23. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecoser.2015.10.023

Malézieux, E. (2012). Designing cropping systems from nature. Agronomy for Sustainable Development, 32(1), 15.

Manna, M. C., & S. (2001). Long-term effects of intercropping and bio-litter recycling on soil biological activity and fertility status of sub-tropical soils. Bioresource Technology, 76(2), 143.

Matisoff, D. C. (2014). Performance or marketing benefits? the case of LEED certification. Environmental Science & Technology, 48(3), 2001; 2001-2007; 2007.

Matsushita, K., Yamane, F., & Asano, K. (2016). Linkage between crop diversity and agro-ecosystem resilience: Nonmonotonic agricultural response under alternate regimes. Ecological Economics, 126, 23-31. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2016.03.006

Mattison, E. H. A., & Norris, K. (2005). Bridging the gaps between agricultural policy, land-use and biodiversity. Trends in Ecology & Evolution, 20(11), 610.

Mbow, C., Van Noordwijk, M., Luedeling, E., Neufeldt, H., Minang, P. A., & Kowero, G. (2014). Agroforestry solutions to address food security and climate change challenges in africa. Current Opinion in Environmental Sustainability, 6(0), 61-67. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.cosust.2013.10.014

McClintock, N., Cooper, J., & Khandeshi, S. (2013). Assessing the potential contribution of vacant land to urban vegetable production and consumption in oakland, california. Landscape and Urban Planning, 111(0), 46-58. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.landurbplan.2012.12.009

Mclain, R. J., Hurley, P. T., Emery, M. R., & Poe, M. R.Gathering “wild” food in the city: Rethinking the role of foraging in urban ecosystem planning and management. Local Environment, 19(2), 220.

McLain, R., Poe, M., Hurley, P. T., Lecompte-Mastenbrook, J., & Emery, M.Producing edible landscapes in seattle's urban forest. Urban Forestry & Urban Greening,

Mitchell, J., Harben, R., Sposito, G., Shrestha, A., Munk, D., Miyao, G., . . . Six, J. (2016). Conservation agriculture: Systems thinking for sustainable farming. California Agriculture, 70(2), 53-56.

Mollison, Bill (2012). Permaculture: A Designers Manual. Tasmania: Tagari Publications.

Mononen, L.; AP Auviene, AL Ahokumpu, M. Ronka, N. Aaras, H. Tolvanen, M. Kamppinen, E. Virret, T. Kumpula, P. Vihervaara (2016). National ecosystem service indicators: Measures of social-ecological sustainability. Ecological Indicators, 61(1), 27-37.

Montagnini, F. (2004). Carbon sequestration: An underexploited environmental benefit of agroforestry systems. Agroforestry Systems, 61-62(1-3), 281; 281-295; 295.

Moon, W., & Griffith, J. W. (2011). Assessing holistic economic value for multifunctional agriculture in the US. Food Policy, 36(4), 455-465. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.foodpol.2011.05.003

Morrow, Rosemary. (2006). Earth User’s guide to permaculture. White River Junction: Chelsea Green Publishing.

Morse, S., & Fraser, E. D. G. (2005). Making ‘dirty’ nations look clean? the nation state and the problem of selecting and weighting indices as tools for measuring progress towards sustainability. Geoforum, 36(5), 625-640. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.geoforum.2004.10.005

Motzke, I., Tscharntke, T., Wanger, T. C., & Klein, A. (2015). Pollination mitigates cucumber yield gaps more than pesticide and fertilizer use in tropical smallholder gardens. Journal of Applied Ecology, 52(1), 261-269. doi:10.1111/1365-2664.12357

Nair, P. K. R. (2011). Agroforestry systems and environmental quality: Introduction. Journal of Environmental Quality, 40(3), 784.

Nair, P. (1985). Classification of agroforestry systems. Agroforestry Systems, 3(2), 97.

Nair, P. (2012). Carbon sequestration studies in agroforestry systems: A reality-check. Agroforestry Systems, 86(2), 243.

Nair, P. K. R., Nair, V. D., Kumar, B. M., & Haile, S. G. (2009). Soil carbon sequestration in tropical agroforestry systems: A feasibility appraisal. Environmental Science & Policy, 12(8), 1099-1111. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.envsci.2009.01.010

Napawan, N. C.Complexity in urban agriculture: The role of landscape typologies in promoting urban agriculture's growth. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, , 1.

Narloch, U., Drucker, A. G., & Pascual, U. (2011). Payments for agrobiodiversity conservation services for sustained on-farm utilization of plant and animal genetic resources. Ecological Economics, 70(11), 1837.

Nelson, E., Scott, S., Cukier, J., & Galan, A. L. (2009). Institutionalizing agroecology: Successes and challenges in cuba.(report). Agriculture and Human Values, 26(3), 233.

Noponen, M. R. A., Healey, J. R., Soto, G., & Haggar, J. P. (2013). Sink or source—The potential of coffee agroforestry systems to sequester atmospheric CO2 into soil organic carbon. Agriculture, Ecosystems and Environment, 175, 60.

Odion, E. C., Ahmadu, I. S., Aminu, A. R., Luka, G. L., Isah, S. A., & Arunah, U. L. (2015). Determination of production efficiency of crop mixtures: The relevance of the agronomic efficiency method. Agricultura Tropica Et Subtropica, 48(3), 59-66. doi:10.1515/ats-2015-0009

Oelbermann, M., Paul Voroney, R., & Gordon, A. M. (2004). Carbon sequestration in tropical and temperate agroforestry systems: A review with examples from costa rica and southern canada. Agriculture, Ecosystems and Environment, 104(3), 359.

Omer, A., Pascual, U., & Russell, N. (2010). A theoretical model of agrobiodiversity as a supporting service for sustainable agricultural intensification. Ecological Economics, 69(10), 1926-1933. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2010.04.025

Palm, Cheryl Ann. "Contribution of agroforestry trees to nutrient requirements of intercropped plants." *Agroforestry: Science, Policy and Practice*. Springer Netherlands, 1995. 105-124.

Pearson, C. J. (2007). Regenerative, semiclosed systems: A priority for twenty-first-century agriculture. Bioscience, 57(5), 409.

Pearson, L. J. (2010). Sustainable urban agriculture: Stocktake and opportunities. International Journal of Agricultural Sustainability, 8(1/2), 7; 7-19; 19.

Pissourios, I. A. (2013). An interdisciplinary study on indicators: A comparative review of quality-of-life, macroeconomic, environmental, welfare and sustainability indicators. Ecological Indicators, 34, 420; 420-427; 427.

Poe, M. R., LeCompte, J., McLain, R., & Hurley, P. (2014). Urban foraging and the relational ecologies of belonging Routledge. doi:10.1080/14649365.2014.908232

Poe, M., McLain, R., Emery, M., & Hurley, P. (2013). Urban forest justice and the rights to wild foods, medicines, and materials in the city. Human Ecology: An Interdisciplinary Journal, 41(3), 409-422. doi:10.1007/s10745-013-9572-1

Port, C. M., & Moos, M.Growing food in the suburbs: Estimating the land potential for sub-urban agriculture in waterloo, ontario. Planning Practice and Research, 29(2), 152.

PORTER, E. (2015). B.C.-grown "agricultural urbanism" turns ten. Landscapes/paysages, 17(2), 34-37.

Potteiger, M. (2013). Eating places: Food systems, narratives, networks, and spaces. Landscape Journal: Design, Planning, and Management of the Land, 32(2), 261.

Praetorius, P. (2006). A permaculture school garden. applying the principles of permaculture in schoolyard projects reinforces values of resourcefulness, stewardship, and sustainability. Green Teacher, (78), 6.

Reimer, A., & Prokopy, L. (2014). One federal policy, four different policy contexts: An examination of agri-environmental policy implementation in the midwestern united states. Land use Policy, 38(0), 605-614. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.landusepol.2014.01.008

Rhodes, C. J. (2012). Feeding and healing the world: Through regenerative agriculture and permaculture. Science Progress, 95, 345.

Rizzo, D., & M.Farming systems designing landscapes: Land management units at the interface between agronomy and geography. Geografisk Tidsskrift-Danish Journal of Geography, 113(2), 71.

Rodrigo P. Tayobong. (2013). Edible landscaping in the philippines: Maximizing the use of small spaces for aesthetics and crop production. Journal of Developments in Sustainable Agriculture, 8(2), 91-99.

Roncken, P., Stremke, S., & Paulissen, M. C. P.Landscape machines: Productive nature and the future sublime. Journal of Landscape Architecture, 6(1), 68.

Rowley, H. V. (2012). Aggregating sustainability indicators: Beyond the weighted sum. Journal of Environmental Management, 111, 24; 24-33; 33.

Roy, R. (2012). An assessment of agricultural sustainability indicators in bangladesh: Review and synthesis. The Environmentalist, 32(1), 99; 99-110; 110.

Russell, A. E. (2002). Relationships between crop-species diversity and soil characteristics in southwest indian agroecosystems. Agriculture, Ecosystems and Environment, 92(2), 235.

Samuel-Fitwi, B., Wuertz, S., Schroeder, J. P., & Schulz, C. (2012). Sustainability assessment tools to support aquaculture development. Journal of Cleaner Production, 32, 183-192. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.jclepro.2012.03.037

Santiago-Meléndez, S., González, S., & Goenaga, R. (2012). Evaluation of an agricultural experiment station as a case study site for the establishment of a multi-use urban forest. Urban Forestry & Urban Greening, 11(4), 406.

Sarah, T. L. (2010). Multifunctional urban agriculture for sustainable land use planning in the united states. Sustainability (Basel, Switzerland), 2(8), 2499.

Scherr, Sara; Shames, S; Friedman, R (2013). Defining integrated landscape management for policy markers. Ecoagriculture Policy Focus (10)

Scherr, Sara and McNeely, Jeffrey (2011). Reconciling Agriculture and Biodiversity: policy and research challenges of "Ecoagriculture." UNDP World Summit on Sustainable Development, Equator Initiative, 2002, pp 2-3.

Scheromm, P.Motivations and practices of gardeners in urban collective gardens: The case of montpellier. Urban Forestry & Urban Greening,

Scholte, S. S. K., van Teeffelen, A. J. A., & Verburg, P. H. (2015). Integrating socio-cultural perspectives into ecosystem service valuation: A review of concepts and methods. Ecological Economics, 114, 67-78. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2015.03.007

Scialabba, Nadia; Pacini, C; Moller, S (2014). Smallholder ecologies. UN Food and Agriculture Organization. Rome, 2014.

Sharghi, T., Sedighi, H., & Eftekhari, A. R. (2010). Effective factors in achieving sustainable agriculture. American Journal of Agricultural & Biological Science, 5(2), 235-241.

Shen, L., Jorge Ochoa, J., Shah, M. N., & Zhang, X. (2011). The application of urban sustainability indicators – A comparison between various practices. Habitat International, 35(1), 17-29. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.habitatint.2010.03.006

Shi, T. (2005). Developing effective policies for the sustainable development of ecological agriculture in china: The case study of jinshan county with a systems dynamics model. Ecological Economics, 53(2), 223; 223-246; 246.

Sinclair, F. (1999). A general classification of agroforestry practice. Agroforestry Systems, 46(2), 161.

Singh, R. (2009). An overview of sustainability assessment methodologies. Ecological Indicators, 9(2), 189; 189-212; 212.

Smit, W., Hancock, T., Kumaresen, J., Santos-Burgoa, C., Sánchez-Kobashi Meneses, R., & Friel, S. (2011). Toward a research and action agenda on urban Planning/Design and health equity in cities in low and middle-income countries. Journal of Urban Health, 88(5), 875.

Smith, P. (2013). REVIEW: The role of ecosystems and their management in regulating climate, and soil, water and air quality. The Journal of Applied Ecology, 50(4), 812; 812-829; 829.

Sortino, O. (2014). Benefits for agriculture and the environment from urban waste. The Science of the Total Environment, 487, 443.

Steiner, F. (2011). Landscape ecological urbanism: Origins and trajectories. Landscape and Urban Planning, 100(4), 333; 333-337; 337.

Sustainable Sites Initiative. (2015). SITES v2 Rating System + Reference Guide.

Swift, M. J., Izac, A. -. N., & van Noordwijk, M. (2004). Biodiversity and ecosystem services in agricultural landscapes—are we asking the right questions? Agriculture, Ecosystems & Environment, 104(1), 113-134. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.agee.2004.01.013

Takimoto, A., Nair, P. K. R., & Nair, V. D. (2008). Carbon stock and sequestration potential of traditional and improved agroforestry systems in the west african sahel. Agriculture, Ecosystems and Environment, 125(1), 159.

Tang, K., Kragt, M. E., Hailu, A., & Ma, C. (2016). Carbon farming economics: What have we learned? Journal of Environmental Management, 172, 49-57. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.jenvman.2016.02.008

Thangata, P. H., & H. (2012). Carbon stock and sequestration potential of agroforestry systems in smallholder agroecosystems of sub-saharan africa: Mechanisms for 'reducing emissions from deforestation and forest degradation' (REDD+)

Toensmeier, Eric. (2016). The Carbon Farming Solution: A global toolkit of perennial crops and regenerative agriculture practices for climate change mitigation and food security. White River Junction, VT: Chelsea Green Publishing.

Torquebiau, E. F. (2000). A renewed perspective on agroforestry concepts and classification. Comptes Rendus De l'Academie Des Sciences Series III Sciences De La Vie, 323(11), 1009.

United Nations, Geneva (1987) World Commission on Environment and Development (WCED) Report of the World Commission on Environment and Development: Our Common Future

United Nations. (2014). The Millennium Development Goals Report. *United Nations.*

University of California, Division of Agriculture and Natural Resources (2016). Calculating Rainwater available for collection.

Udawatta, R., & Jose, S. (2012). Agroforestry strategies to sequester carbon in temperate north america. Agroforestry Systems, 86(2), 225.

Van Cauwenbergh, N. (2007). SAFE—A hierarchical framework for assessing the sustainability of agricultural systems. Agriculture, Ecosystems & Environment, 120(2-4), 229; 229-242; 242.

Van de Werf & Petit. (2002). Evaluation of environmental impact of agriculture at farm level: a comparison and analysis of 12 indicators based methods. *Agriculture, Ecosystems and Environment, 93, 131.*

Van der Werf, W., Keesman, K., Burgess, P., Graves, A., Pilbeam, D., Incoll, L. D., . . . Dupraz, C. (2007). Yield-SAFE: A parameter-sparse, process-based dynamic model for predicting resource capture, growth, and production in agroforestry systems. Ecological Engineering, 29(4), 419-433. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecoleng.2006.09.017

Vásquez-Moreno, L. (2013). A conceptual framework to assess urban agriculture's potential contributions to urban sustainability: An application to san cristobal de las casas, mexico. International Journal of Urban Sustainable Development, 5(2), 200; 200-224; 224.

Veteto, J. R., & Lockyer, J. (2008). Environmental anthropology engaging permaculture: Moving theory and practice toward sustainability. Culture & Agriculture, 30(1), 47-58. doi:10.1111/j.1556-486X.2008.00007.x

WEBB, E. L., & KABIR, E. (2009). Home gardening for tropical biodiversity conservation. Conservation Biology, 23(6), 1641-1644. doi:10.1111/j.1523-1739.2009.01267.x

Weber, C.L. and Matthews, H.S. 2008. Food-miles and the relative climate impacts of food choices in the United States. Environmental Science and Technology 42(10):3508–3513.

Wezel, A., Bellon, S., Dore, T., Francis, C., Vallod, D. & David, C. (2009). Agroecology as a science, a movement and a practice. A review. Agronomy for sustainable development, 29(4), 503-515.

Wilmart, O. (2015). Measuring the general phytosanitary situation: Development of a plant health barometer. European Journal of Plant Pathology, 141(2), 349; 349-360; 360.

Winfree, R., Gross, B. J., & Kremen, C. (2011). Valuing pollination services to agriculture. Ecological Economics, 71, 80-88. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.ecolecon.2011.08.001

Wojtkowski, P. (1993). Toward an understanding of tropical home gardens. Agroforestry Systems, 24(2), 215.

Yang, Z., Hao, P., Liu, W., & Cai, J. (2016). Peri-urban agricultural development in beijing: Varied forms, innovative practices and policy implications. Habitat International, 56, 222-234. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.habitatint.2016.06.004

Zasada, I. (2011). Multifunctional peri-urban agriculture—A review of societal demands and the provision of goods and services by farming. Land use Policy, 28(4), 639-648. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.landusepol.2011.01.008

Zezza, A., & Tasciotti, L. (2010). Urban agriculture, poverty, and food security: Empirical evidence from a sample of developing countries. Food Policy, 35(4), 265-273. doi:http://dx.doi.org.ezproxy.fiu.edu/10.1016/j.foodpol.2010.04.007

Zhang, Y. (2011). Potential of perennial crop on environmental sustainability of agriculture. Procedia Environmental Sciences, 10, 1141; 1141-1147; 1147.

APPENDICES

Appendix I: Questionnaire

Site Name: ______________________________
Land Area: ______________________________
Date: ______________________________

Provisioning -

1) Food

What are the main crops grown on site?
Do you keep records of the yield for each of these crops?
Do you provide for internal needs? Market? Restaurants ?
What percentage is used or sold locally vs. sold to distributers/exported ?
Do you produce food year round? What percentages?
Are the seven layers of permaculture utilized on site:

Does your system implement the ideal seven components of permaculture? Fill in all that apply)

- Food for consumption (fruits, vegetables, legumes, nuts, fats, animals)
- Food for the soil
- Climbers
- Supporters
- Miners or diggers
- Ground covers
- Protectors

Fresh Water

Is water captured or held on site? If so how?
Is water recycled on site?
Were aquatic systems present enhanced or restored ?
Are adequate amounts of surface, ground and soil water supplied?
Is micro irrigation used ? In what percentage of the property

Raw materials

Do you grow any other materials such as mushrooms, wood for biomass or construction, medicinal plants ? what amounts ?
Is the canopy structure managed for optimal rates of light transmission ? If so how often?
Are trees utilize to shade structure and minimize building energy use?

Supporting

1) Quality of soil

See visual soil assessment.

2) Soil Formation

Do you till the soil ? If so how regularly? What tilling methods do you use?
Do you utilize any of the following methods to build soil?

- Chop and drop coppicing?
- Mulching
- Green manures
- Cover crops
- Organic mulch
- Sheet mulching

3) Use of Space and Biodiversity

How many species were introduced to the site ? native? Non-native?
Were wild areas or non-productive areas preserved or restored?
Was genetic diversity increased on site? How many species ?
Was functional diversity increased on site ? How many species ?

4) Nutrient Cycling

Do you use synthetic fertilizer? If so, how often? What kind?
Do you compost? How much in comparison to your use of synthetic fertilizers?
Is all of the organic material recycled on site ?
Do you compost following the recommended 30:1 Carbon Nitrogen ratio? How do you maintain your compost pile? (i.e. regular turning, adding moisture)
Do you utilize manures
Were disturbed soils enhanced or maintained with organic material and other amended materials ?
Are nitrogen fixing species utilized ? at what rate? What species?

5) Plant Health

Do you notice a lot of pest damage? How do you deal with it?
Do you notice stunted growth amongst your plants?
Do any of your plants have diseases?

Do all of your plants flower and fruit?
Are there specific plants that were planted in order to attract beneficial insects and pollinators? If so what species and what percentage ?

Regulating

1) Carbon Sequestration

What percentage of the site is planted with long-lived perennial plants? Approximately how many seasons do they last?

Is one of your guild's central species a carbon-sequestering plant? (i.e. a large tree)

Do your perennial and carbon-sequestering plants also serve another purpose? Do they assist in water, air purification, and flood control?

2) Pest Control

What methods of pest-control do you use? What is your primary method? Do you use artificial pesticide, organic methods, or a combination?

If it is a combination, which method do you use more of?

Have you ever used artificial pesticide for your system?

How effective are the used pest-control methods? Is pest damage still prevalent and observed?

3) Water Usage

Does your system implement these seven components? Fill in all those that apply.

- Use of grey water
- Use of small ponds
- Rain barrels
- Micro-sprinkler system
- Drip-liners connected to a timer
- Water filtration system
- Water Management Scheme

4) Erosion /Flood Control

Is the soil mass flux is controlled and buffered through mounds, swales and buffers?

Is vegetation always present to hold soil in place ?

Cultural

1) Human Interactions

How many visitors do you have on a yearly basis? What type of visitors?

How many volunteers ? school groups? Others?

How many workshops or classes do you hold per year?

Do you have educational programs, displays and tools for visitors to learn about the site?

What recreational and volunteer opportunities do you provide?

Is the site used as a case study ? is the site monitored for performance ?

Are cultural and historic features enhanced or maintained ?

Are natural value features enhanced or maintained?

Economic

Do you have any workers or volunteers?
What benefits do you provide for them?
Approximately, what was cost of establishing your system?

How long did it take to establish your system?

How many workers or volunteers did you use for establishing? Approximately, how many days did you need the workers?

Were plants purchased or propagated on site ?

Approximately, what is your average cost of maintaining an 8,000 sq ft portion of your site? This cost should include labor, fertilizer, and water (exclude cost of rent or mortgage).

Appendix II: Literature Review of Ecosystem Services Indicators

Ecosystem Services (ES)	SAFE (n. Van Cauwenbergh, et al, 2007)	SITES (University of Texas at Austin, 2014)	Permaculture Indicators (Holgrem 2002, Morrow, 2006)	Agroecology Sustainability Indicators (Gliessman 2007, Altieri, 2002)
Provisioning Services				
Food Production (fruit, crops)	production capacity is compatible with society's demand for food	provide on site food production	create small scale intensive systems	maximize yield without sacrificing the long term productive capacity of entire system
			select very well adapted species	
	quality and quantity of food is increased	addresses food security/ food desert issues	maximize the use of space by stacking functions	food self-sufficiency on the farm
	adequate amount of agricultural land is maintained		utilize a great diversity of perennial and annual species	
Fresh Water	surface water of adequate quality is supplied	reduce water use for landscape irrigation	capture, hold and recycle water	adjust distribution, intensity and variability of rainfall
	soil water of adequate quality is supplied	reduce outdoor water use	plant using contours that slows flow of water	harvest water by collecting and concentrating rainfall runoff
	groundwater of adequate quality is supplied	restore aquatic ecosystems	utilize ponds, paddies, swales and mounds	
	adequate amounts of surface, ground and soil water is supplied		have two or more sources of water available	
Raw Materials	adequate amounts of energy is supplied	optimize biomass	utilize a variety of materials for firewood, medicine, mushrooms	canopy structure is managed for optimal relative rate of light transmission
	energy flow is adequately	use vegetation to	Utilize fertility building plants	maintain environmental

	buffered	minimize building energy use		conditions at an optimum rate for photosynthetic efficiency
	diversity of raw materials is increased			
Regulating Services				
Mediation of waste and toxins		minimize pesticide and fertilizer use	all surpluses of put into use in the system	leaching of nutrients and pesticides is limited
Climate Regulation	Wind speed is adequately buffered	reduce urban heat island effects	use of windbreaks	
Air Quality	Air quality is maintained or enhanced	protect air quality		
Soil Quality		use plants to hold soil in place	Build soil organic matter with composts, mulches and cover crops	soil fertility is enhanced with cover crops, green manures, mulching, compost, etc.
Nitrogen Uptake			utilize nitrogen fixers	
Noise Reduction			utilize hedges and breaks	
Biological Control /Pollination Services		control and manage invasive plants	create habitat (food, shelter and water) in order to attract insects	pest regulation is enhanced with crop diversity, cultural practices, microbial insecticides and habit modification
			use of a diversity of herbs, shrubs and trees to attract wildlife	
Water Retention /Flood Control	flooding and runoff regulation is maintained or enhanced	manage precipitation on site	use water as many times as possible	use farming practices that reduce evaporation and increase the flow through transpiration such as mulching, fallow cropping and reduce tillage
		design functional storm water features	maximize water stored in soil	

		protect floodplain functions	maximize water stored in biomass (swales, perennial roots)	
Water Filtration			slow down water flow and filters it through mulches and soils	
Erosion Control	Soil mass flux is adequately buffered	conserve healthy soils and appropriate vegetation		cover cropping, and no tillage systems are used to prevent erosion
Supporting Services				
Soil Formation	soil loss is minimized	recycle organic matter	catch and hold resources	maintain constant inputs of organic matter from crop residues, cover crops, manure and composts
	soil chemical quality is maintained	restore soils disturbed during construction	utilize nitrogen fixers, nutrient accumulators(deep rooted plants) and mulch plants	reduce the use of tillage practices
	soil physical quality is maintained		use top-down (leaf litter, mulch) and bottom-up techniques (plants that pull nutrients)	
Nutrient Cycling		recycles organic matter	design closed system that meet own nutrient needs internally	emphasizes the recycling of nutrients
Biodiversity	Planned biodiversity is maintained or increased	conserve aquatic systems	design diverse habitats in the garden	conserve biological diversity
	Functional and heritage part of spontaneous biodiversity is maintained or increased	conserve habitat for threatened and endangered species	preserve and restore nearby wild places	maintains spatial and temporal diversity and continuity
	diversity of habitat is maintained or increased		design polycultures	maintains functional diversity (interactions, energy flows, etc.)
	functional quality of habitats is maintained or increased			
Economic Services				
Economic	farm income is insured	redevelop degraded	include externalities (cradle to	relatively independent of

		sites	grave) costs when assessing enterprises from system	external economic factors
	dependency of subsidies is minimized	location of project is within developed areas	assist self-reliance among marginalized and disadvantaged people	bring farmers and consumers together
	dependency on external finance is optimal	site is connected to transit networks	work and keep money circulating within your bioregion	bring "localness" back into agriculture
	agricultural activities are economically and technically efficient	use salvaged and recycled materials	Produce a short term and long term yield	keep the shortest supply chain possible
	market activities are optimal	use regional materials	Create alternative distribution networks	create alternative local food networks
	farmers professional training is optimal	support local economy	Diversify flows of income	Focus on specialized crops
	inter-generational continuation of farming activity is ensured		Plant high value crops	Process or make value-added products
	adaptability of the farm is sufficient		Create regenerative enterprises	
	land tenure arrangements are optimal		Re-invest surplus into regenerative projects	
	labor conditions are optimal			
Cultural Services				
Recreational		support physical activity	Organize ‘perma-blitzes’	Incorporate agro-tourism as a source of income
		support social connection	social participatory gatherings	
Science and education	educational and scientific value features are maintained or increased	promote sustainability awareness and education	Sharing information in networks	keep information exchange democratic
		develop and communicate a case study	Communities of practice, learning by doing and sharing	
		Monitor and report site	Kinesthetic learning activities	

		performance		
Natural Heritage		limit development of farmland C98	diversify crop species, varietal composition within species, resistant mechanisms within varieties	relies on local crop varieties and often incorporates
Cultural Heritage	health of the farming community is acceptable	protect and maintain cultural and historic places	Preserve heritage of food plants and traditional practices where relevant	build on the knowledge and culture of local inhabitants
	cultural spiritual and aesthetic heritage value features are maintained or increased			
Design		use an integrative design process	design with relative placement in mind	design with multiple uses and functions in mind
Aesthetic Landscapes		conduct pre design site assessment	Design spaces with people in mind / kinesthetic	
		engage and use stakeholders		

Appendix III: Multi-Criteria Analysis Survey for Farmers

	Provisioning	**Supporting**	**Regulating**	**Economic**	**Cultural**
Provisioning					
Supporting					
Regulating					
Economic					
Cultural					

Intensity of Importance	**Definition**
1	Equal importance
2 or 1/2	Somewhat more important
3 or 1/3	Much more important
4 or 1/4	Very much more important
5 or 1/5	Absolutely more important

Please pick the intensity of importance from 1-5 or 1/2 to 1/5 as described below for each category in column 1 as it relates to each of the other categories. For example: Provisioning is of equal importance to the supporting role of ecosystem services (place a 1 in column 3 row 2)

Criteria Definitions:

Provisioning- Includes all products obtained from the ecosystem including food, raw materials, water, minerals, medicine, ornamentals and energy.
Supporting-are the services necessary to produce all the other ecosystem services such as soil formation and quality, biodiversity present in the site, the cylcing of nutrients and overall plant health.
Regulating-includes benefits obtained from the regulation of ecosystem services processes, such as carbon sequestration and climate regulation, purification of air and water, and pest and disease control
Economic- the economic value of the ecosystem and ability to be profitable over time.
Cultural -includes all the non-material benefits obtained from ecosystems through aesthetic, educational, recreational, historical and cultural experiences.

Appendix IV: Multi-criteria Analysis Survey Results for Individual Sites

Guara Ki

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	0.5	0.5	1	0.2	
Supporting	2	1	1	2	0.2	
Regulating	2	2	1	2	0.2	
Economic	1	0.5	0.5	1	0.5	
Cultural	5	5	5	2	1	
Sum Intensity	11	9	8	8	2.1	
			Factor Ratios			Weights
Provisioning	0.09	0.06	0.06	0.13	0.10	0.09
Supporting	0.18	0.11	0.13	0.25	0.10	0.15
Regulating	0.18	0.22	0.13	0.25	0.10	0.17
Economic	0.09	0.06	0.06	0.13	0.24	0.11
Cultural	0.45	0.56	0.63	0.25	0.48	0.47
						1.00

Little Haiti Community Garden

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	3	5	1	4	
Supporting	0.33	1	5	1	3	
Regulating	0.2	0.2	1	0.2	0.2	
Economic	1	1	5	1	1	
Cultural	0.25	0.33	5	1	1	
Sum Intensity	2.78	5.53	21	4.2	9.2	
			Factor Ratios			Weights
Provisioning	0.36	0.54	0.24	0.24	0.43	0.36
Supporting	0.12	0.18	0.24	0.24	0.33	0.22
Regulating	0.07	0.04	0.05	0.05	0.02	0.05
Economic	0.36	0.18	0.24	0.24	0.11	0.23
Cultural	0.09	0.06	0.24	0.24	0.11	0.15
						1.00

Booker T, Washington Food Forest

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	2	2	5	0.5	
Supporting	0.5	1	1	4	0.2	
Regulating	0.5	1	1	1	0.2	
Economic	0.2	0.25	1	1	0.33	
Cultural	2	5	5	3	1	
Sum Intensity	4.2	9.25	10	14	2.23	
			Factor Ratios			Weights
Provisioning	0.24	0.22	0.20	0.36	0.22	0.25
Supporting	0.12	0.11	0.10	0.29	0.09	0.14
Regulating	0.12	0.11	0.10	0.07	0.09	0.10
Economic	0.05	0.03	0.10	0.07	0.15	0.08
Cultural	0.48	0.54	0.50	0.21	0.45	0.44
						1.00

Gaia Ma

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	1	2	5	1	
Supporting	1	1	3	5	2	
Regulating	0.5	0.33	1	5	0.5	
Economic	0.2	0.2	0.2	1	0.5	
Cultural	1	2	2	2	1	
Sum Intensity	3.7	4.53	8.2	18	5	
			Factor Ratios			Weights
Provisioning	0.27	0.22	0.24	0.28	0.20	0.24
Supporting	0.27	0.22	0.37	0.28	0.40	0.31
Regulating	0.14	0.07	0.12	0.28	0.10	0.14
Economic	0.05	0.04	0.02	0.06	0.10	0.06
Cultural	0.27	0.44	0.24	0.11	0.20	0.25
						1.00

Treehuggers

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	1	3	1	3	
Supporting	1	1	3	1	3	
Regulating	0.33	0.33	1	0.5	2	
Economic	1	2	2	1	3	
Cultural	0.33	0.5	0.5	0.33	1	
Sum Intensity	3.66	4.83	9.5	3.83	12	
Factor Ratios						Weights
Provisioning	0.27	0.21	0.32	0.26	0.25	0.26
Supporting	0.27	0.21	0.32	0.26	0.25	0.26
Regulating	0.09	0.07	0.11	0.13	0.17	0.11
Economic	0.27	0.41	0.21	0.26	0.25	0.28
Cultural	0.09	0.10	0.05	0.09	0.08	0.08
						1.00

Twin Lakes Food Forest

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	1	3	5	0.25	
Supporting	1	1	2	4	0.5	
Regulating	0.33	0.5	1	3	0.5	
Economic	0.2	0.25	0.33	1	0.2	
Cultural	4	2	2	5	1	
Sum Intensity	6.53	4.75	8.33	18	2.45	
Factor Ratios						Weights
Provisioning	0.15	0.21	0.36	0.28	0.10	0.22
Supporting	0.15	0.21	0.24	0.22	0.20	0.21
Regulating	0.05	0.11	0.12	0.17	0.20	0.13
Economic	0.03	0.05	0.04	0.06	0.08	0.05
Cultural	0.61	0.42	0.24	0.28	0.41	0.39
						1.00

Muni Farms

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	2	2	1	2	
Supporting	0.5	1	1	2	0.2	
Regulating	0.5	0.5	1	2	0.2	
Economic	1	5	0.5	1	0.5	
Cultural	0.5	5	5	2	1	
Sum Intensity	3.5	13.5	9.5	8	3.9	
Factor Ratios						Weights
Provisioning	0.29	0.15	0.21	0.13	0.51	0.26
Supporting	0.14	0.07	0.11	0.25	0.05	0.12
Regulating	0.14	0.04	0.11	0.25	0.05	0.12
Economic	0.29	0.37	0.05	0.13	0.13	0.19
Cultural	0.14	0.37	0.53	0.25	0.26	0.31

1.00

FGCU Food Forest

	Provisioning	Supporting	Regulating	Economic	Cultural	
Provisioning	1	2	2	4	1	
Supporting	0.5	1	2	3	0.2	
Regulating	0.33	0.5	1	2	0.5	
Economic	0.25	0.33	0.5	1	0.5	
Cultural	5	2	2	2	1	
Sum Intensity	7.08	5.83	7.5	12	3.2	
Factor Ratios						Weights
Provisioning	0.14	0.28	0.28	0.56	0.14	0.28
Supporting	0.07	0.14	0.28	0.42	0.03	0.19
Regulating	0.05	0.07	0.14	0.28	0.07	0.12
Economic	0.04	0.05	0.07	0.14	0.07	0.07
Cultural	0.71	0.28	0.28	0.28	0.14	0.34

1.01

Appendix V: PASS Score Formulation Example

Criteria	**Indicator**	**ES WEIGHTS**	**MUNI FARMS**				
		Weights	Actual value	Weighted Value	ES Totals	ES Weights	Weighted values
Provisioning	Food Provision	0.5	2.5	1.25			
	Fresh Water Provision	0.3	3.75	1.13			
	Raw Materials	0.2	3	0.60	2.98	0.25	0.74
Supporting	Soil Formation	0.25	4.5	1.13			
	Biodiversity	0.5	3.8	1.90			
	Nutrient Cycling	0.25	4.33	1.08	4.11	0.2	0.82
Regulating	Climate Regulation	0.4	4.33	1.73			
	Air/Soil Quality	0.1	4.33	0.43			
	Biological Control	0.1	5	0.50			
	Water Regulation	0.3	3.25	0.98			
	Erosion/Flood Control	0.1	3	0.30	3.94	0.12	0.47
Economic	Economic	1	2	2.00	2.00	0.12	0.24
Cultural	Physical/Social Activity	0.2	1	0.20			
	Educational Activities	0.4	3	1.20			
	Cultural/Historic Value	0.2	4.33	0.87			
	Design	0.2	4.6	0.92	3.19	0.32	1.02
	Farm Score						3.30