An Economic Valuation and Assessment Analysis of the Pellicer Watershed

– Final Report

Prepared for the Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) Contacted by the Florida Department of Environmental Protection (FDEP)

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Executive Summary

Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) and the Pellicer Watershed Area

The Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) is one of 29 areas in the National Estuarine Research Reserve System in the United States. The GTM NERR site is administered through the Florida Department of Environmental Protection (FDEP). The GTM NERR focuses on the coastal stewardship, long-term research, training, and education, where topics covered include water quality monitoring, resilient communities, habitat restoration, and invasive species. The GTM NERR includes salt marsh and mangrove tidal wetlands, oyster bars, estuarine lagoons, upland habitat and offshore seas, and calving grounds for the endangered Right Whale. It stretches 30 miles north and 30 miles south of St. Augustine, Florida. The southern part of the GTM NERR intersects the Pellicer watershed area and its tributaries.

The Pellicer watershed area and its tributaries include four watersheds: Pellicer Creek, Pellicer Creek – Big Mulberry Branch Frontal, Pringle Branch, and Stevens Branch. These watersheds are located at the boundary of Flagler County and St. Johns County, covering 82,216.38 acres. At the end of the year 2015, the land use (LU)[1] in the Pellicer watershed area and its tributaries involve 66 classifications under 9 LU categories. The population is expected to continue to grow in Flagler County and St. Johns County, in addition to other factors such as sea level rise (SLR), in ensuring years. As such, the LU is changing over time, and these future LU scenarios will place substantial pressure on this area. Figure ES1 shows the GTM NERR and the Pellicer watershed and its tributaries.

[1] Land use (LU) classifications are defined by the Florida Department of Revenue (FDOR) County Property Appraiser (2016). Data source: http://floridarevenue.com/dor/property/appraisers.html

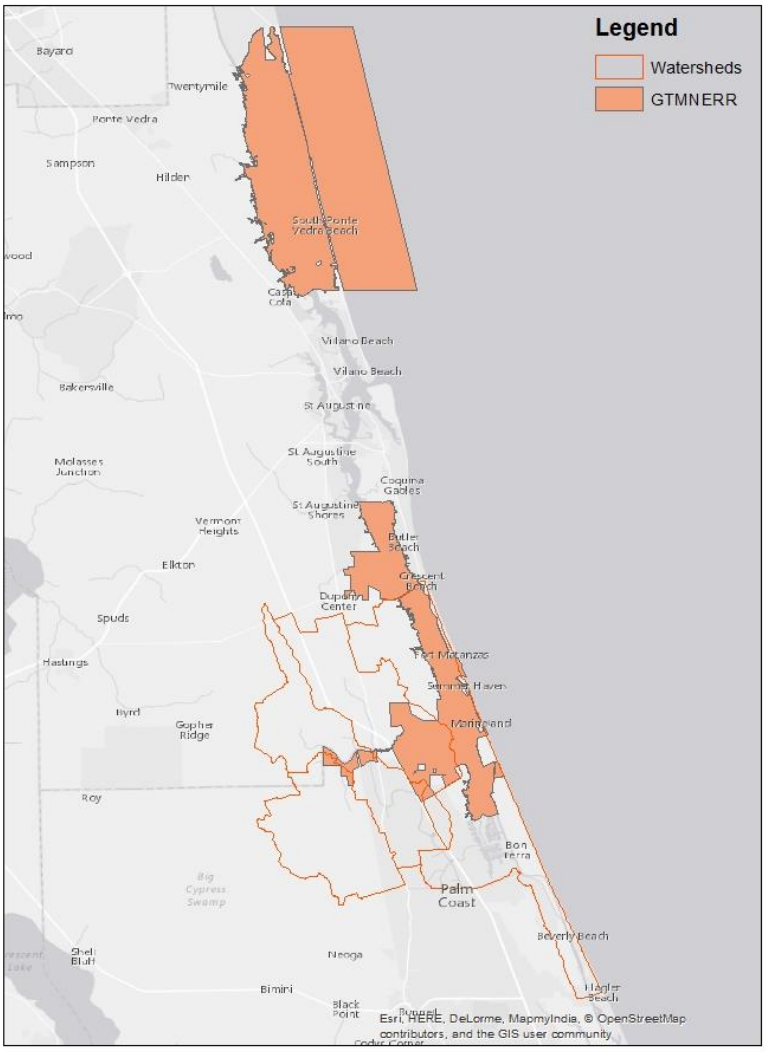


Figure ES1. The Guana Tolomato Matanzas National Estuarine Research Reserve (GTM NERR) and the Pellicer Watershed and Its Tributaries

In 2016, the FDEP GTM NERR commissioned the Florida State University Center for Economic Forecasting and Analysis (FSU CEFA) to conduct an economic valuation and assessment analysis study of the Pellicer watershed area and its tributaries in order to provide local planners and other stakeholders with information on the value of the Pellicer estuarine ecosystem.

FSU CEFA initially conducted an extensive literature review of the ecosystem services valuation software in order to determine, in concert with the GTM NERR, the model that would be most suitable for this study. Because of the complexity of LU, the model applied is comprehensive (with many individual

models) and dynamic[2] in functionality. The study team made a decision to use the Integrated Valuation of Ecosystem Services and Tradeoffs model (InVEST) developed by Natural Capital Project, a partnership of the Stanford University, the University of Minnesota, the Nature Conservancy and World Wildlife Fund. The InVEST model, consisting of 18 different models, is designed to analyze the effects of changes in the ecosystem's structure and function on the flows and values of the static and dynamic ecosystem. It includes assessments of a wide range of ecosystem service models for mapping and valuing ecosystem services at global, regional, and local scales. The multi-service system of InVEST allows for trade-off analysis, and the tiered design of InVEST allows for analysis based on data availability and levels of expertise. The simple models in InVEST system can also be combined with complementary ecosystem service models.

The study team examined the LU classifications by various categories of the Pellicer watershed area, by county, parcel number, acreage, just-value (JV), and the LU features of Flagler County and St. Johns County, in order to recommend suitable ecosystem valuation data for the InVEST model. The study team examined four models using InVEST based on the GTM NERR researchers' priority and the availability of data for the Pellicer watershed area. The four models were: Habitat Quality, Fisheries, Unobstructed Views: Scenic Quality Provision and Visitation: Recreation and Tourism.

Based on the input provided by the GTM NERR and the project team, and the preliminary results of the InVEST Model; FSU CEFA provided an on-site training to GTM NERR staff and other FDEP participants that demonstrated the functions of the InVEST model. The training was held in May 2017, at the FDEP office's computer lab in Tallahassee. The preliminary InVEST model results included the model output, a list of data gaps, and a sensitivity analysis of the models with respect to the data gaps. The training on the InVEST model included providing a training manual, two lectures of representative models (Habitat Quality and Visitation: Recreation, and Tourism), and organizing a practice/discussion session. The project team trainer collected and summarized comments and suggestions from GTM NERR researchers for further data refinement, and identification and ranking of priority conservation areas in the Pellicer watershed area.

The economic and vulnerability analysis was mainly conducted based on the inputs of the Habitat Quality model. Two items of the input were updated following the training session: 1) the habitat suitability score for LU parcels was calculated based on the LDI, instead of the binary approach. In addition, 2) the range of invasive species was narrowed down to Brazilian Peppertree, Cogongrass, Air-potato, and Chinese Tallow Tree, in order of importance. Table ES1 shows the ranking of priority conservation areas (parcels) and the main determinants of vulnerability, and their corresponding LU classifications, acreage, and JV's.

[2] Dynamic refers to the ability of InVEST to use projected LULC patterns to forecast the ecosystem changes in the future.

Table ES1. The Ranking of Priority Conservation Areas in the Pellicer Watershed Area and Its Tributaries

Invasive Plant	LU Classification	Ranking	Acreage	Just-value
Brazilian Peppertree	001: Single Family	1	3,845.88	$3,419,332,194
	004: Condominiums	2	0.00	$807,518,995
	000: Vacant Residential – with/without extra features	3	1,754.50	$350,852,324
Cogongrass	001: Single Family	1	1,082.26	$664,845,785
	004: Condominiums	2	0.00	$127,987,400
	000: Vacant Residential – with/without extra features	3	997.80	94,790,913
Air-potato	001: Single Family	1	857.20	$494,131,336
	087: State, other than military, forests, parks, recreational areas, colleges, hospitals	2	45,661.35	$84,806,426
	000: Vacant Residential – with/without extra features	3	304.40	$65,353,692
Chinese Tallow Tree	087: State, other than military, forests, parks, recreational areas, colleges, hospitals	1	37,365.00	$64,456,422
	001: Single Family	2	195.54	$26,269,470
	055: Timberland - site index 80 to 89	3	5,817.05	$11,485,145

For the species of Brazilian Peppertree and Cogongrass, LU classification “001: Single Family”, “004: Condominiums”, and “000: Vacant Residential – with/without extra features” in the “Residential” category comprise the top-three rankings, with the total JV $4,557,703,513. For the species of Air-potato and Chinese Tallow Tree, except LU classification “001: Single Family” and “000: Vacant Residential –

with/without extra features", the LU classification "055: Timberland - site index 80 to 89" in "Agricultural" category and "087: State, other than military, forests, parks, recreational areas, colleges, hospitals" in "Governmental" category are top-ranking in JVs as well.

Introduction

The Florida Department of Environmental Protection Guana Tolomato Matanzas National Estuarine Research Reserve (FDEP GTM NERR) is dedicated to the conservation of natural biodiversity and cultural resources through research and monitoring to guide science-based stewardship and education strategies.[3]

The GTM NERR provides conservation protection and oversight for 73,352 acres south of the City of Jacksonville (Duval County), in St. Johns County and Flagler County, on the northeast coast of Florida, one of the fastest growing regions in the state. The populations of St. Johns County and the adjacent Flagler, Putnam and Volusia counties have grown 20 percent since 1990, and was projected to grow an additional 20 percent by 2010. More than 1.3 million people live within 50 miles of the GTM NERR. These protected areas provide habitat for a wide variety of fish and wildlife. The southern component of GTM Research Reserve consists of Pellicer Creek Aquatic Preserve, Faver-Dykes State Park, Washington Oaks Gardens State Park, Moses Creek Conservation Area, Pellicer Creek Conservation Area, Fort Matanzas National Monument, Matanzas State Forest, Princess Place Preserve, the River to Sea Preserve at Marineland, Marsh View Preserve, and other state sovereign submerged lands adjacent to the Matanzas River within its boundary. The Pellicer watershed area is expected to almost double in population growth (89%) by the year 2040. Much of the expected growth in Flagler County and St Johns County will be in the lesser developed inland watersheds.

In 2016, the FDEP GTM NERR commissioned the Florida State University Center for Economic Forecasting and Analysis (FSU CEFA) to conduct an economic valuation and assessment analysis study of the Pellicer watershed area and its tributaries in order to provide local planners and other stakeholders with information on the value of the Pellicer estuarine ecosystem. FSU CEFA initially conducted an extensive literature review of valuation software, and then chose the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) as the main economic valuation and modeling software tool for this study.

The FSU CEFA study team examined the Land Use (LU) classifications by various categories of the Pellicer watershed area: by county, parcel number, acreage, just-value (JV), and LU features of Flagler County and

[3] See: http://www.dep.state.fl.us/coastal/sites/gtm/

St. Johns County, in order to recommend suitable ecosystem services valuation data for the InVEST model. According to the Florida Department of Revenue (FDOR) County Property Appraiser Data for 2016, the LU patterns are analyzed by separating the entire Pellicer watershed area and its tributaries into the Flagler county and the St. Johns county sections. Based on the DOR use codes, the LU patterns were investigated relating to the parcel number, acreage, and JV, by eight categories: "Residential", "Commercial", "Industrial", "Agricultural", "Institutional", "Governmental", "Miscellaneous", and "Non-Agricultural Acreage". "Residential" and "Commercial" categories comprise the majority of the parcel number and the JV's for both counties (96.98%, and 94.68%, respectively, for Flagler County, and 82.18%, and 78.15%, respectively, for St. Johns County). The "Agricultural" category encompasses large portions of the total acreages in both Flagler County and St. Johns County (37.43%, and 52.23%, respectively). The "Government" LU category, with the second top percentage relative to acreage, had the same pattern with "Agricultural" category for both counties. As the Pellicer watershed area is expected to almost double in population growth by year 2040, further LU decisions will place substantial pressure on this area. The larger average LU needs, by category (FDOR code), are expected to be in: "Residential" (000 – 009), "Commercial" (010 – 039), "Agricultural" (050 – 069), and "Governmental" (080 – 089). Four models in the InVEST were selected according to the GTM NERR researchers' priority, current LU features, and the availability of data. These models are: Habitat Quality, Fisheries, Unobstructed Views: Scenic Quality Provision, and Visitation: Recreation and Tourism.

The Habitat Quality model estimates the extent of habitat and vegetation types across the Pellicer watershed area and its tributaries, including their state of degradation, and identifies win-win areas (i.e. conservation can benefit both natural systems and human economies). It provides the habitat quality analysis based on the current LU patterns and threats from urbanization and other factors. Threats that can impact the habitat quality include the development of cities, transportation, invasive species (plants), and sea level rise (SLR).

The Fisheries model produces estimates of harvest volume and economic value of single-species fisheries and answers questions such as how changes in habitat or harvesting practices will impact the production of wild fish. It uses the "commercial landings of white shrimp" in Flagler and St. Johns counties as an example, generating useful implications on the impacts to the marine or aquatic ecosystems for decision makers. Scenic amenities play an important role in augmenting Florida economies by attracting visitors who support local businesses. The value of the Pellicer watershed and its tributaries, and other local properties is highly dependent on locational attributes. Scenic views are often correlated with increased property values.

The Unobstructed Views: Scenic Quality Provision Model analyzes two human use features, aquaculture and boat ramp(s), as examples to provide information about potential tradeoffs between nearshore and offshore development proposals and the visual impacts of those projects.

The Visitation: Recreation and Tourism Model quantifies the value of the tourism value of the Pellicer watershed area and its tributaries. It uses photo-user-days (PUD) as proxies for tourism development. Factors considered that can impact visitation include transportation (airports and roads), development

(parks and recreational facilities, hotels, and swimming beaches), and the natural environment (marsh habitat).

Vulnerability and economic analysis was conducted based on the inputs and results of the InVEST models and economic statistics of the DOR LU parcels. The analysis used the Vulnerability Hotspots tool (Kernel Density tool) in the Spatial Analysis in ArcGIS 10.3.1[4] to identify the vulnerable areas affected by invasive species Brazilian Peppertree, Cogongrass, Air-potato, and Chinese Tallow Tree. By answering the questions in the vulnerability assessment approach introduced by Hammill et al. (2013), the assessment specified the assessment approach and gave the vulnerability rankings based on LU parcels classification and their JVs.

The report is organized as follows: the "Literature Review" summarizes the studies relating to the theories of LU, the selection of the model, the individual models in the InVEST system, and the vulnerability assessment. The next section "Introduction to InVEST 3.3.2 Guideline Manual" provides the basic steps of model installation, selection of the model, data preparation, running the various models, and interpreting the model outcomes, or results. The next section "Land Use (LU) Data Report on the Pellicer Watershed Area" provides detail on the parcels, acres and just values of LU, using the Florida Department of Revenue (FDOR) parcel use codes, and further summarizes LU features and main differences associated with the LU patterns observed between Flagler County and St. Johns County. The following section "Description and Application of InVEST Models" provides empirical analysis for the Pellicer watershed area. Next, "Vulnerability and Economic Assessment" identifies the ranking of priority conservation areas in the Pellicer watershed area. The last section provides a discussion of results and conclusions.

[4] How the Kernel Density tool in ArcGIS 10.3.1 works: http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-kernel-density-works.htm.

Literature Review

The scope of this study examines the effects and tradeoffs of different upland land-use (LU) scenarios on the Pellicer estuarine ecosystem services. There are three main topical areas discussed in the literature.

Ecosystem Services, Land Development Intensity Index (LDI), and Introduction to InVEST

The first subject area discussed in the literature is relevant to the definition of ecosystem services, the use of the Land Development Intensity Index (LDI), and the introduction to InVEST modeling system.

Ecosystem services are the results of the biological, chemical, and physical processes associated with natural estuary environments that benefit human beings. Ecosystem services[5] provided by upland areas fall into four broad categories:

- Provision services which include provision of food, fresh water, building materials, medicinal plants and ornamental plants.
- Cultural (Spiritual and Information Services) services such as recreation, tourism and aesthetic landscapes.
- Regulatory services such as food regulation, climate regulation, soil stability, sediment supply, waste assimilation, disease control, waste dilution, flood attenuation, pest control, fire damage control, and coastal storm damage control.
- Supporting services such as habitat for wildlife and soil formation, and nutrient cycling.

It is recommended to quantify ecosystem functions with indicators that are able to describe the ecosystem process that provides the service (e.g. total water-storage capacity in m^3) and measure how much of the service that can be sustainably used (e.g. reduction of flood danger).

One may add an economic dimension by determining values for the ecosystem services, typically in monetary terms. The value of a service is evaluated by measuring the welfare created by the goods produced using these services. There are use values (for example, timber and fish extraction) and non-use values (for example, birdwatching). Use values can be direct or indirect. Direct uses can be divided into consumptive and non-consumptive. Non-use values can be divided into as existence value and bequest value. Existence value is the value that someone places on an ecosystem just because it exists even though that person has no intention to ever use it. Bequest value is that value that someone places on an ecosystem because it will be available for others and for future generations.[6]

[5] South African Water Research Commission, Introduction to Estuary Ecosystem Services.
[6] Forkink, A. (2015). Ecosystem Services Assessments as a Planning Tool in Florida.

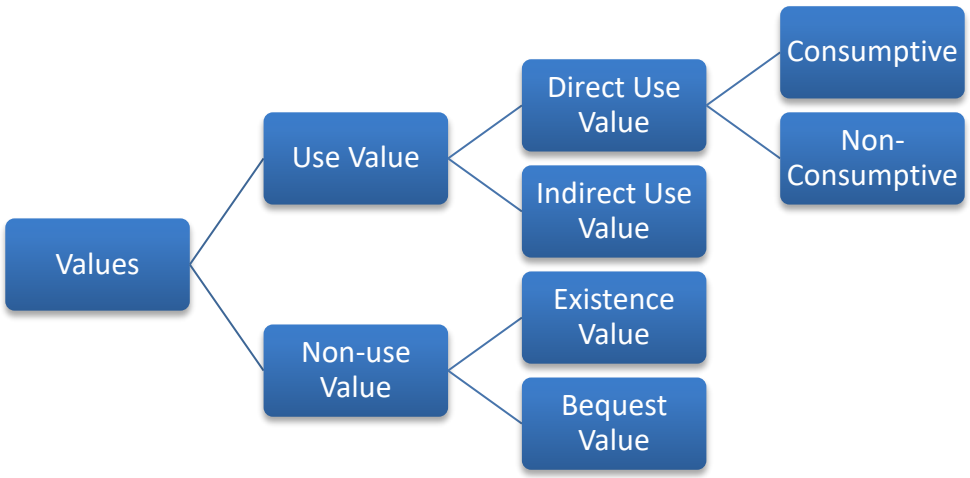


Figure 1. How Values are Categorized

Services can be valued using the market value, shadow pricing or benefit transfer. Market value can be used for services such as provision services where humans are paying for the goods such as food and timber that are obtained from the respective ecosystem service. Shadow pricing is used by measuring the investments made by public and private agencies to protect that ecosystem in order to maintain the ecosystem services from that area. Benefit transfer is done by using data from other studies to create an estimate of the value of the same ecosystem service that is in a different geographical area. Benefit transfer should only be used when: 1) the data in the original study 'are of sufficient quality', 2) the ecosystem services in the studies are very similar, and 3) the context is very similar.[7]

Literature focusing on the LDI includes Brown and Vivas (2005), Vivas (2007), Brown and Reiss (2010). LDI was originally developed by Mark T. Brown and M. Benjamin Vivas from the Center for Environmental Policy at the Department of Environmental Engineering Sciences at the University of Florida. LDI is a method of quantitatively evaluating the human disturbance gradient that is applicable to landscapes of varying scales, from watersheds to forest patches, or isolated wetlands. The human disturbance gradient is the effect of human land uses of on ecological processes of natural communities (or the quality of ecological communities) measured by the intensity of that human land use. LDI is measured on a scale of 1 to 10, with 1.0 being the LDI for natural lands and a LDI of 10.0 for the highest intensity land use, the Central Business District (CBD). [8] Vivas (2007) discussed how to calculate LDI for the Bayou Meto Watershed (BMW), located in eastern Arkansas, between the Arkansas River and the White River. In this paper, Vivas noted that at this point, one can't conclude that the LDI values for different land uses from one geographical locations can be transferred to another location. Brown and Reiss (2010) improved the calculation of LDI used by Vivas (2007), by proposing a new method for calculating the LDI of a landscape

[7] Forkink, A. (2015). Ecosystem Services Assessments as a Planning Tool in Florida.
[8] Appendix 1 presents the table of Land Uses and Definitions and Land Use Classification, Nonrenewable Empower Density, and Resulting LDI Coefficients in Brown and Vivas (2005).

unit based on a log_{10} scale of the ratio of the nonrenewable areal empower density of the landscape unit to an areal empower density of the environmental baseline of the landscape unit. In addition, the authors proposed a spatial averaged LDI for point source pollutants, especially those associated with pollutants such as nutrients, metals, and other toxins. In the Habitat Quality study, FSU CEFA mapped the LDI score in Brown and Vivas (2005) to a continuum suitability score on a scale 1 – 0 to represent the habitat suitability of various LUs.

InVEST is a suite of models developed by NatCap, a partnership of Stanford University, the University of Minnesota, the Nature Conservancy and World Wildlife Fund. It consists of 18 different models (under development) for mapping and valuing ecosystem services at global, regional, and local scales by using production functions to define how changes in the ecosystem's structure and function will likely affect the flows and values of ecosystem services. A user can choose to model only the ecosystems of interest using maps as information sources for input data. The models can be run independently or as a script tools in the ArcGIS Toolbox environment, but requires mapping software such as QGIS or ArcGIS, to view the results as InVEST produces maps as outputs. The following section, Introduction to InVEST 3.3.2 Guideline Manual, presents in detail how to prepare and apply InVEST models.

Models in InVEST

The second subject area in the literature is related to the individual InVEST Model applied in this study.

The representative literature concerning the application of the Habitat Quality model includes Terrado, Sabater, Chaplin-Kramer, Mandle, Guy Ziv, and Acuna (2016) and Terrado, Sabater, and Acuna (2016). Terrado, Sabater, Chaplin-Kramer, Mandle, Guy Ziv, and Acuna (2016) presented a straightforward model for the simultaneous assessment of terrestrial and aquatic habitat quality in river basins as a function of LU and anthropogenic threats to habitat that could be applied under different management scenarios to help understand the trade-offs of conservation actions. They authors modified the Habitat Quality model in the InVEST for the assessment of terrestrial habitat quality and extend it to freshwater habitats. Terrado, Sabater, and Acuna (2016) selected four European river basins across a gradient of water scarcity and irrigation agriculture. Buy employing the Habitat Quality model, the habitat quality in the basins was assessed as a function of habitat suitability and threats under current and future global change scenarios of irrigation. The relative impact and buffer distance of threats data are related to USGS's Conservation Buffer Distance Estimates for Greater Sage-Grouse—A Review (2014). The habitat suitability score of different LU classifications were calculated based on the LDI in Brown and Vivas (2005). Forman (1995), Noss (1997), and Lindenmayer et al (2008) stated that a habitat's sensitivity to threats should be based on general principles from landscape ecology for conserving biodiversity. We employed the Table A3 in the study of Terrado, Sabater, and Acuna (2016) to identify the parameters of LU's sensitivity to threats.

The FSU CEFA study team uses the "commercial landings of white shrimp" as an example in the InVEST model to show how changes in habitat or harvesting practices will impact the production of wild fish. Studies relating to the white shrimp in Florida include: The Florida Fish and Wildlife Conservation Commission FWRI (2014)[9] and Stock Assessment Update for White Shrimp (Litopenaeus setiferus) in the

[9] Also see: http://myfwc.com/research/saltwater/crustaceans/shrimp/faq/

U.S. Gulf of Mexico for 2014. Population parameters of white shrimp are cited from Baker et al. (2008) that studied the putative farnesoic acid O-methyltransferase (LvFAMeT) cDNA from white shrimp (Litopenaeus vannamei). The economic valuation analysis of white shrimp is based on the landings and pricing information provided by the Florida Fish and Wildlife Conservation Commission.[10] Data on habitat dependency is from the Gulf States Marine Fisheries Commission.[11]

The selection of human-use features in the scenic quality analysis is relevant to Perez, Telfer, and Ross (2005) that focused on the development of a standard methodology for selection of suitable sites for offshore (exposed) marine fish-cage farming (floating cages) of seabream and sea-bass in an island environment. It is also related to Sander and Polasky (2009) that examined how environmental amenities, particularly views and open space access, impact residential home sales prices in Ramsey County, MN using a hedonic pricing model. Sander and Polasky concluded that home sale prices increase with closer proximity to parks, trails, lakes, and streams. FSU CEFA team analyzes two human use features, aquaculture and boat ramp(s), as examples to provide information about potential tradeoffs between nearshore and offshore development proposals and the visual impacts of those projects.

The recreation and tourism analysis are conducted based on the research frequent ask questions from the Visit Florida, the official tourism marketing corporation for the State of Florida.[12] Research questions interested are:

- Do most visitors come to Florida by car or plane?
- How many nature parks are in Florida?
- What activities do Florida visitors participate in the most?
- How many hotel rooms are in Florida?

Based on those questions, the FSU CEFA study team selected predictors affecting the visitation in the Pellicer watershed area: main highways, airports, the number of parks and recreational facilities, number of hotels, marsh habitat, and swimming beach.

Vulnerability Assessment

The third subject area of the literature is related to the vulnerability assessment.

This portion of the literature review draws extensively from Comparative Analysis of Climate Change Vulnerability Assessments: Lessons from Tunisia and Indonesia which was written by Anne Hammill, Livia Bizikovia, Julie, Dekens and Matthew McCandless from the International Institute for Sustainable Development (Hammill et al., 2013). Although the paper was primarily about vulnerability assessments

[10] https://publictemp.myfwc.com/FWRI/PFDM/

[11] Summary Table of White Shrimp (Penaeus Setiferus) Life History Information for the Gulf of Mexico (Associations and interactions with environmental and habitat variables are listed with citations). See: http://www.gsmfc.org/pubs/Habitat/tables/whiteshrimp.pdf

[12] www.visitflorida.org

relating to climate change, the content could and has been adapted to a more general format so that it is applicable to performing vulnerability assessments to ecosystem services.

A vulnerability assessment is an approach that is used to identify the nature and extent of possible threats to humans or ecological systems. They help to create an understanding of how socio-ecological systems may be affected by a source of harm (hazard) in order to devise measures that can reduce or eliminate that harm. There are various purposes for conducting a vulnerability assessment: to set mitigation targets, to allocate resources effectively, to design adaption policies, to monitor adaption policies, to raise awareness about the hazard and its effects, and to conduct scientific research. A vulnerability assessment remains a very broad concept until the following questions can be answered to make it more specific: Which system: What is the social/socio/ecological system being threatened?

- Feature of concern: What is the valued feature within the vulnerable system that is potentially threatened (e.g. specific crop, human health)?
- Type of hazard: What it the potentially damaging influence, which may adversely affect the valued feature of the system (e.g. changes in precipitation and temperature and its consequences like droughts or floods)?
- Temporal reference: What is the time period of interest? Is the assessment considering current vulnerability of future vulnerability?

Table 1 summarizes the typology of vulnerability assessment according to modeling approaches and respective inputs.

Table 1. The Typology of Vulnerability Assessment

Vulnerability Approach	Modeling Approach	Targets	Data	Methods	Time and Effort Required
Risk hazard	Quantitative model	Modeling the system	Field data	Modeling	High
Risk hazard	Impact chain	Deriving a qualitative model of the system	Can go potentially without data	Expert judgement, or quantitative modeling	From low to high
Risk hazard	Indicator	Representing a system based on proxy-indicators	Field data	Literature review and/or statistical analysis	From medium to high
Political economy	Bottom - up	Describing the broader development context/ stressors	Field data	Participative and qualitative (e.g. consultations or focus group)	From low to high

The FSU CEFA research team accepted the combination of the risk hazard approach (with proxy indicators) and the political economy approach for the vulnerability assessment in this report.

Introduction to InVEST 3.3.2 Guideline Manual

Description

This manual was designed for a two-day training program for FDEP GTM NERR in May 2017. FSU CEFA provided a comprehensive training in the installation and application of InVEST and the framework and methods utilized to develop ecosystem services analysis to GTM NERR staffs interested in using the InVEST. Data sets and potential indicators as well as the preliminary results of four individual models were assembled and evaluated in the workshop. The workshop's primary focus was on the steps needed to perform ecosystem services analysis by using InVEST.

The workshop was intended for FDEP GTM NERR staff who are broadly familiar with a variety of geospatial data formats, and who regularly manage Environmental Science, Biology, or Engineering data sets. Mapping software such as QGIS or ArcGIS was required in order to manage data and view map results produced by InVEST. The workshop was divided into the following modules showing in Figure 2, which are addressed in greater detail in the manual that follows.

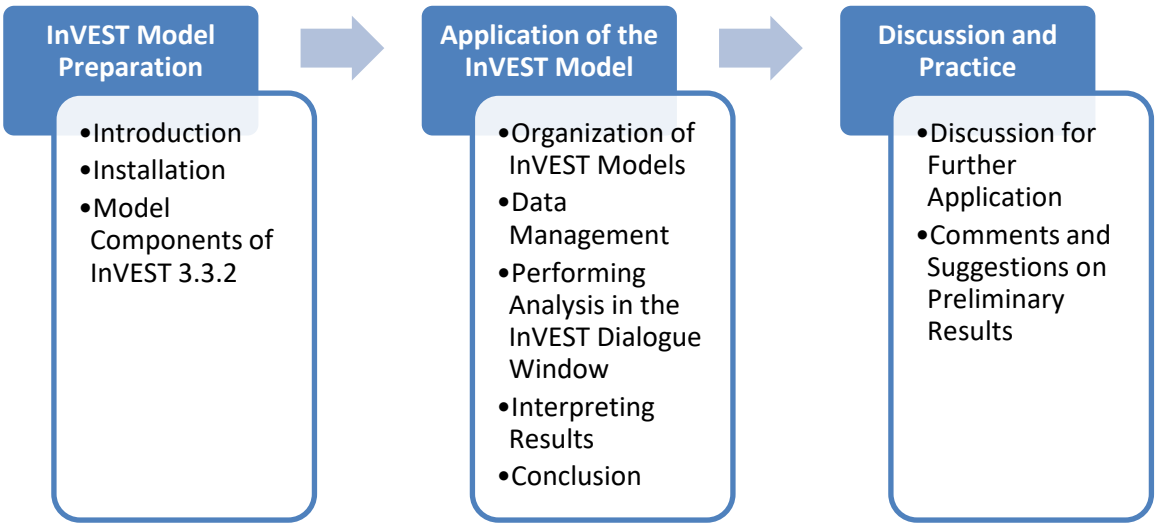


Figure 2. Introduction to InVEST 3.3.2

InVEST Model Preparation

Introduction

The InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) is a powerful tool used for quantifying and mapping the values of ecosystem services, exploring how changes in ecosystems are likely to lead to changes in benefits that flow to people. InVEST employs a production function approach with a framework delineating "supply, service, and value".

For this training workshop, the project team used InVEST 3.3.2 software developed by the Natural Capital Project (NCP). This workshop is meant to teach some fundamentals of InVEST operations.

InVEST is an open source software. The newest version and user's guide can be downloaded at:

http://www.naturalcapitalproject.org/invest/

Installation

Download the InVEST software. The executable will be called "InVEST_3.3.2_Setup.exe".[13] Double-click on this .exe to run the installer.

After clicking through the first screen and agreeing to the License Agreement, the "Choose Components" screen will appear. The installer will always install the InVEST Tools, ArcGIS toolbox and HTML and PDF versions of the InVEST User's Guide. Optionally, sample datasets may also be installed, and by default they are all selected.

Next, choose the folder where the InVEST toolsets and sample data will be installed. The installer shows how much space is available on the selected drive. Click Install to begin the installation.[14]

Model Components of InVEST 3.3.2

InVEST 3.3.2 includes 19 models of ecosystem services, and tools to facilitate and support ecosystem service analyses. Table 2 shows models in InVEST 3.3.2 and model discrepancies for the project "An Economic Valuation and Assessment Analysis of the Pellicer Watershed" conducted by FSU CEFA.[15] For further information, visit: http://www.naturalcapitalproject.org/contact-us/.

[13] The latest version is InVEST 3.3.3.
[14] InVEST is a GIS based software. Most data needs are standard GIS shapefiles. Any GIS tool including ArcGIS and others are necessary supporting applications.
[15] Since InVEST software is still under development, there are possible models discrepancies during the process of any comprehensive analysis projects. For details see the online documentation: http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/index.html

Table 2. Model Discrepancies for the Project "An Economic Valuation and Assessment Analysis of the Pellicer Watershed"

Number	InVEST 3.3.2 x86	InVEST Models in Online Documentation	Models in InVEST Data Matrix	Researchers' Priority
1	Carbon	Carbon Storage and Sequestration: Climate Regulation	Carbon	1
2	Coastal Vulnerability	Coastal Vulnerability	Coastal Vulnerability	4
3	Coastal Blue Carbon	Coastal Blue Carbon	Coastal Blue Carbon	2
4	Crop Production (Unstable)	Crop Production		
5	Finfish Aquaculture	Marine Finfish Aqua-cultural Production	Marine Finfish Aquaculture Production	Not incl. in survey
6	Fisheries	Fisheries	Fisheries	2
7	Forest Carbon Edge Effect	Forest Carbon Edge Effect		
8	Habitat Quality	Habitat Quality	Habitat Quality	7
9	Habitat Risk Assessment	Habitat Risk Assessment	Habitat Risk Assessment	6
10	Marine Water Quality	Marine Water Quality	Marine Water Quality	4
11	Pollination	Pollination Abundance: Crop Pollination	Pollination	1
12	Recreation	Visitation: Recreation and Tourism	Visitation: Recreation and Tourism	2
13	Scenic Quality (Unstable)	Unobstructed Views: Scenic Quality Provision	Unobstructed Views: Scenic Quality	1
14	Seasonal Water Yield	Seasonal Water Yield	Annual Water Yield	1
15	Water Yield	Water Yield: Reservoir Hydropower Production		
16	Wave Energy	Wave Energy Production	Wave Energy Production	0
17	Wind Energy	Offshore Wind Energy Production	Offshore Wind Energy Production	0
18	NDR	Nutrient Delivery Ratio	Nutrient Retention	1
19	SDR	Sediment Delivery Ratio	Sediment Retention	3
20	Missing Models		Managed Timber Production	4

	Wave Attenuation & Erosion Reduction: Coastal Protection	Nearshore Waves and Erosion	3

Application of the InVEST Model

Organization of the InVEST Models

Each InVEST ecosystem service model in the online documentation follows the basic structure:

- Summary
- Introduction: introduces questions InVEST can solve, which allows you to choose the fit model depending on your research field.
- Mathematical Model: explains the theoretical mechanism how InVEST works, helping you organize data which needed for analysis.
- Data Needs: provides requirements for inputs (both required and optional), including workspace, data format, and data units setup. You could use the sample dataset as a guide for formatting the data. We shall discuss how to find, organize, and use data in detail in the section Data Management.
- Running the Model: to begin, click the model you wish to run from the "Start" or installation file. Then complete the required inputs in the dialogue box that appears.
- Interpreting Results: provides the instruction for interpreting your results.

Data Management

Finding, organizing, and using data is at the center of application of any InVEST models. Table 3 shows common InVEST data types. All inputs must be in the same projected coordinate system as the Area of Interest (AOI). All distance, length, and area calculations use the same units as the AOI coordinate system.[16] Users can format data needed based on chapters describing how to prepare input data for each model.

Table 3. Data Types Used in InVEST Models

Type	Description or Extension
Workspace	Path/Folder
GIS Raster	TIFF and/or IMG
GIS Vector	Points, Polylines, and/or Polygons (.shp, .shx, .dbf, and/or .lyr)
Tables	Excel.csv
Parameters	Numbers (integer or fraction)

[16] ArcMap > Catalog > Toolboxes > System Toolboxes > Management Tools > Projections and Transformations

Given the models in the InVEST package typically involve various subjects, the project team recommends collecting data model by model, especially for users who plan to run just a few of models in InVEST. Users can preview data and clear data using GIS software. There are some useful tools in the ArcGIS system toolboxes that can help transform data formats.[17] For Florida users, following are some useful links to download geographic data:

- Florida Climate Center: http://climatecenter.fsu.edu/
- Florida Geographic Data Library (FGDL): http://www.fgdl.org/metadataexplorer/explorer.jsp
- Florida Department of Environmental Protection Geospatial Open Data: http://geodata.dep.state.fl.us/
- Florida Department of Revenue: http://floridarevenue.com/taxes/Pages/distributions.aspx
- Florida Fish and Wildlife Conservation Commission (FWCC): http://geodata.myfwc.com/
- National Estuarine Research Reserve System: http://cdmo.baruch.sc.edu
- St Johns River Water Management District's (SJRWMD) Geospatial Open Data: http://data-floridaswater.opendata.arcgis.com/
- The Home of the U.S. Government's Open Data: https://www.data.gov/
- N.O.A.A Sea Level Rise Data Download: https://coast.noaa.gov/slrdata/
- U.S.D.A. Web Soil Survey: https://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx
- U.S.D.A. Forest Service: https://apps.fs.usda.gov/fia/datamart/
- U.S.D.A. Geospatial Data Gateway: https://datagateway.nrcs.usda.gov/
- U.S. Geological Survey (USGS) Watershed Boundary Dataset: https://nhd.usgs.gov/wbd.html

Performing Analysis in the InVEST Dialogue Window

Not only can users format data based on chapters describing how to prepare input data for each model, they can start to prepare data by understanding the dialogue window of each model in InVEST. Figure 3 uses the Habitat Quality model as an example to show how to format data. The first column lists the title and the format of data needed, displaying whether the input is required or optional for the analysis. Users click the "file" button to select the path that transfer the prepared data. When the format of data matches the requirement, a green checkmark is displayed in the front of each row.

Click the Run button on the interface to run the model.

Interpreting Results

The model generally creates two folders in the workspace created: "intermediate" and "output." After the script completes successfully, users can view the results by adding them from the folders to the ArcGIS document using the "connect folder" and "adding data" functions. Figure 4 shows the structure of the

[17] ArcMap > Catalog > Toolboxes > System Toolboxes: here you can find tools to convert data formats (Table and Excel, GIS Vector and Raster, etc.)

output. Usually there are three types of the InVEST output: GIS raster data, GIS vector data, and Microsoft CSV table.

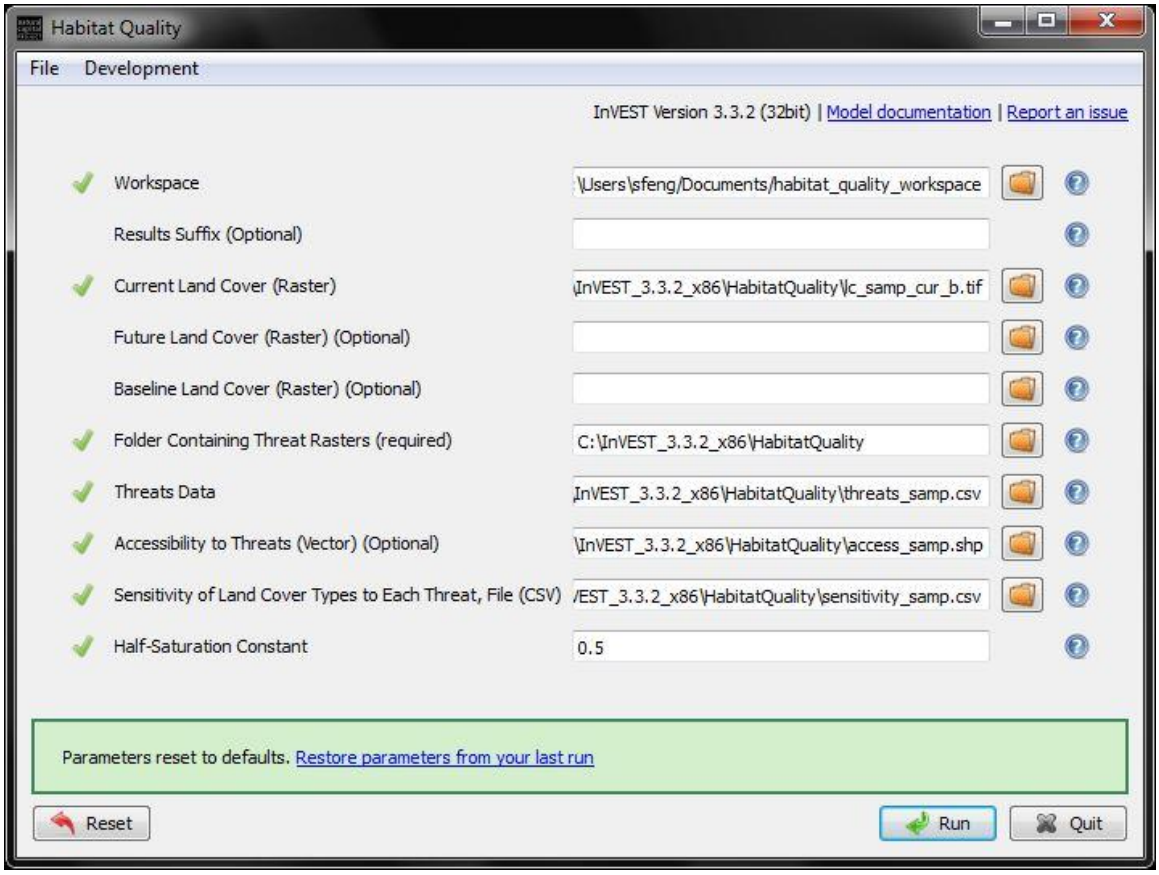


Figure 3. The Dialogue Window in Habitat Quality Model

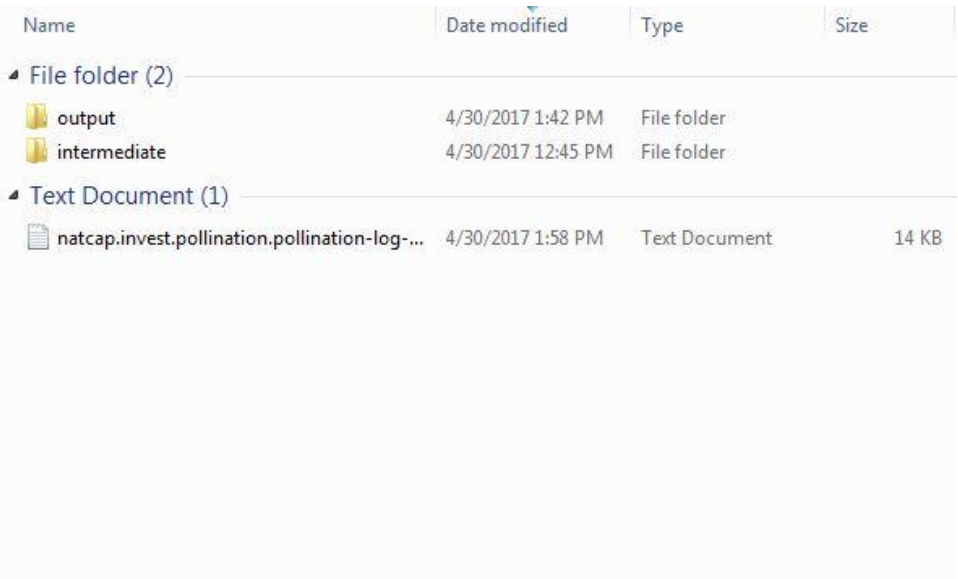


Figure 4. The Structure of the Output Folder

Conclusions

The project team demonstrated how to use InVEST 3.3.2 to analyze data in various models. We introduced how to install InVEST, to collect and format data on the variables, and how to run the model. Based on the data format requirements, we cleared the data and followed the steps in the dialogue window to choose the right data path. The output is in the form of GIS raster, GIS vector, and CSV tables. Useful data download links and technical tips are provided.

Practice and Discussion

The training was held May 2017 at the FDEP office in Tallahassee. Preliminary results included modeling output, a list of data gaps, and the sensitivity of models relating to the data gaps. The CEFA-based trainer collected and summarized comments and suggestions from GTM NERR researchers for further data refinement, and identification and ranking of priority conservation areas in the Pellicer watershed area.

Two presentations of representative models, Habitat Quality and Visitation: Recreation and Tourism, were given in the first session.

The discussion conclusions underscored that the sensitivity of the Habitat Quality model to the data quality is high. One data processing method was improved when new data on local LDI were available: the habitat suitability score for LU parcels was calculated based on the LDI, instead of the binary approach. Data on the threat of invasive plant species were narrowed down to: Brazilian Peppertree, Cogongrass, Air-potato, and Chinese Tallow Tree.

Participants and the CEFA-based trainer discussed the further application of the Visitation: Recreation and Tourism model. Questions included:

- Where do you plan to apply this model?
    - Area of interest (AOI) can be narrowed down.
- What other predictor variables do you think are important?
    - Local roads, location of various attractions, among others.
- What are the key policy questions?

One limitation of the Visitation: Recreation and Tourism Model was also discussed: whether the website flickr is a good sample site to be representative of the visitation data.

The practice and discussion of the Fisheries model and the Unobstructed Views: Scenic Quality Provision model were provided in the second session. Participants from the FDEP GTM NERR practiced on how to use the InVEST software with the sample data provided by FSU CEFA. Discussion included questions on how to format raw data and the availability of data needed in the Fisheries model.

Land Use (LU) Data and Information on the Pellicer Watershed Area

Description of the Area of Interest (AOI)

The project "An Economic Valuation and Assessment Analysis of the Pellicer Watershed" provides local planners and other stakeholders with information on the ecosystem services or values of the Pellicer estuarine ecosystem to better enable them to accurately access the benefits and costs related to future land-use (LU) decisions.

The scope of the area of interest (AOI) is the Pellicer Watershed Area and its tributaries. As shown in Figure 5, the AOI includes four watersheds: Pellicer Creek, Pellicer Creek – Big Mulberry Branch Frontal, Pringle Branch, and Stevens Branch. Figure 1 displays the Pellicer Watershed Area and its tributaries.

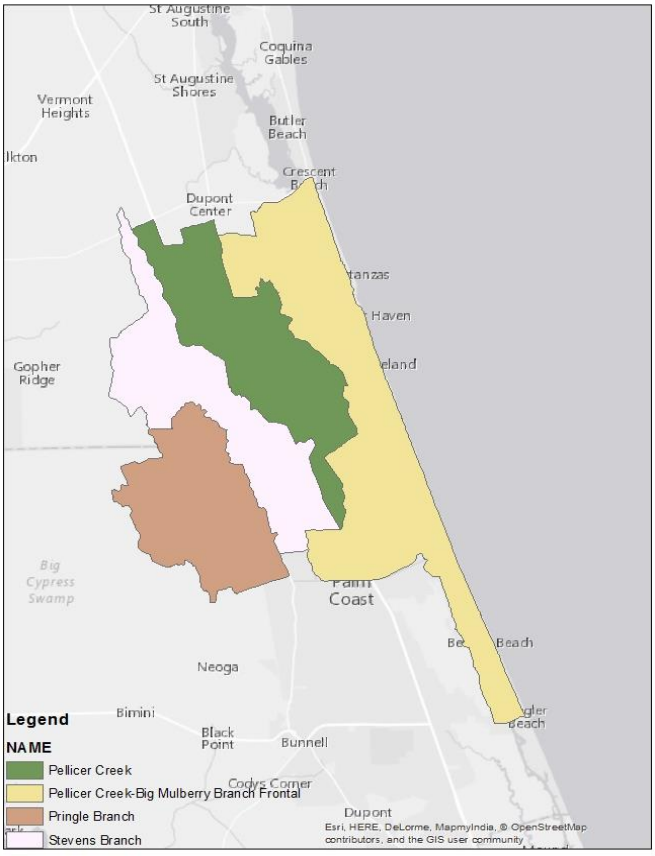


Figure 5. The Pellicer Watershed Area Including Its Tributaries

Features of Land Use Parcels

Empirical data on Land Use (LU) was collected from the Florida Department of Revenue (DOR) County Property Appraiser (2016). The LU parcels were selected based on the AOI. Figure 6 shows the available parcels in Flagler County and St. Johns County, which are in, or intersect with, the AOI. The parcels in light green belong to Flagler County, the parcels in dark green belong to St. Johns County, and the red lines show the boundaries of watersheds. It was also suggested by the FDEP GTM NERR to include an extra whole parcel in St. Johns County (highlighted by a star), which is added to the LU data.

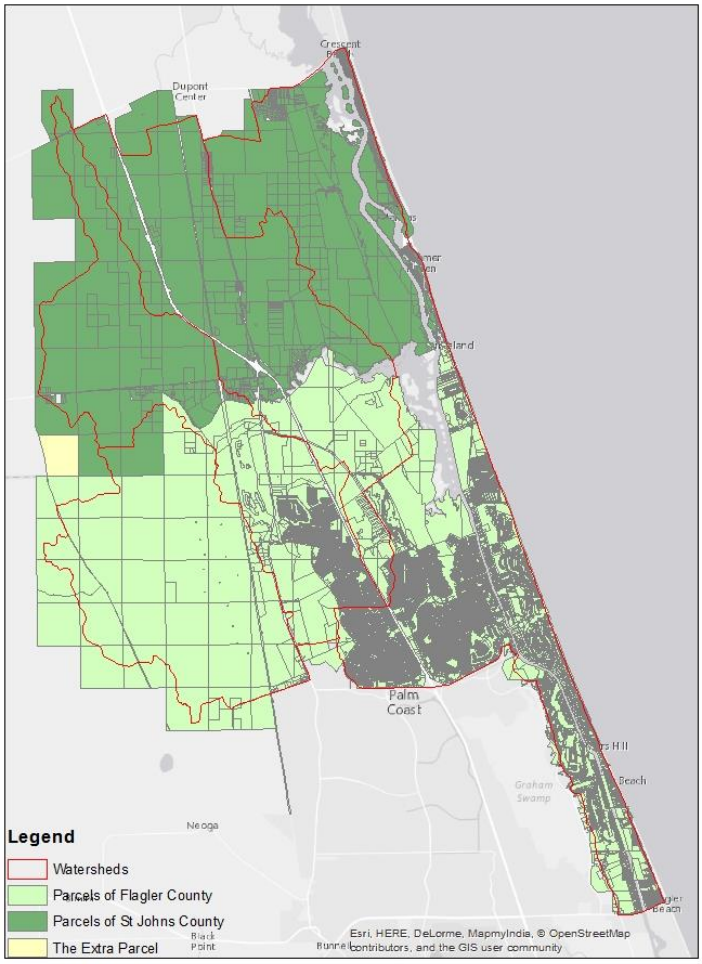
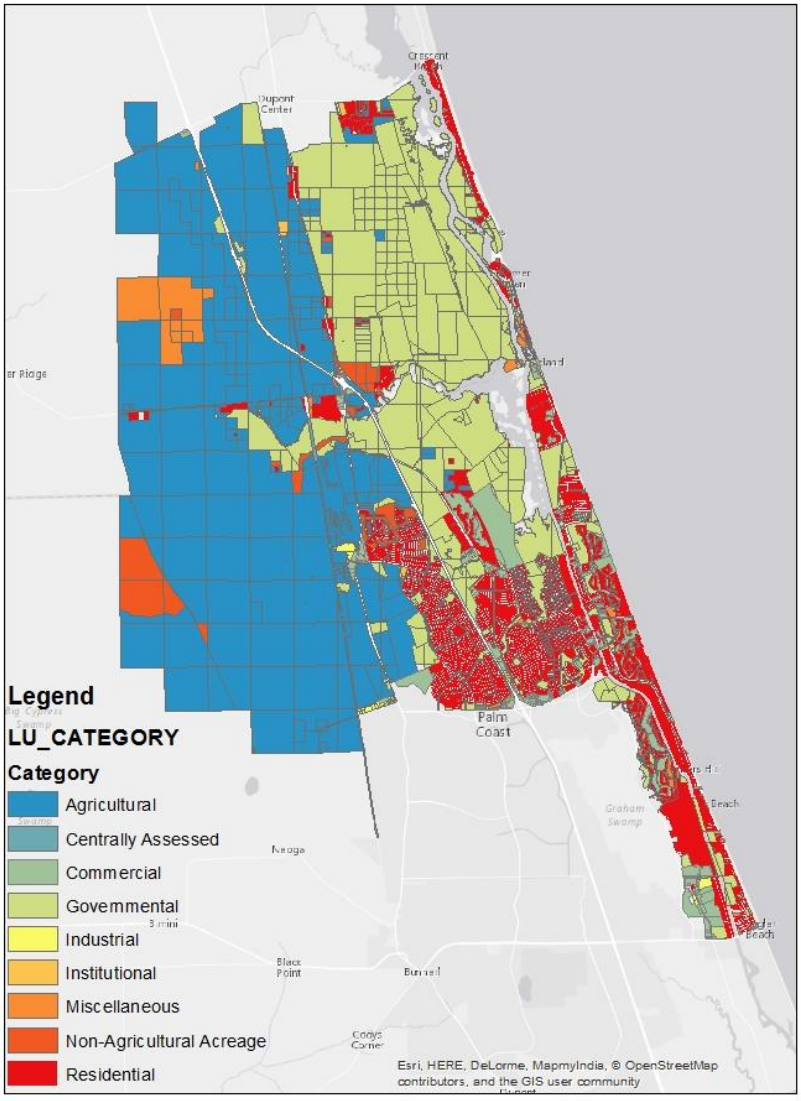


Figure 6. Pellicer Watershed Parcels in the Pellicer Watershed Area, Flagler County, and St. Johns County

Details on the parcels, acres and just values of land use (LU) using the Florida Department of Revenue (FDOR) parcel use codes are provided in Appendix 1.[18] As reflected in the table, parcels in the Flagler County fall in the categories “Residential”, “Commercial”, “Industrial” , “Agricultural”, “Institutional”, “Governmental”, “Miscellaneous”, “Centrally Assessed”, and “Non-Agricultural Acreage”. The available parcels and acres in the St. Johns County are found in the same use categories, except “Centrally Assessed”. Figure 7 displays the LU parcels by category.



[18] Appendix 1: Table A2. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area.

Figure 7. The Distribution of Land Use (LU) Parcels by Category

Table 4 summarizes the amount of parcels, acres, and just values of LU categories in the Flagler and St. Johns counties, and includes the corresponding percentages.

Table 4. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area, Flagler County and St. Johns County Sections of the Pellicer Watershed Area, by DOR Use Code (Category) and Percentage

Use Code	Use Description	Flagler County			St. Johns County		
		Number of Parcels	Total Acres by Use	Total Just-Value by Use ($)	Number of Parcels	Total Acres by Use	Total Just-Value by Use ($)
000 - 009	Residential	29,534	7,771.0	$ 4,822,799,543	1,225	1,496.6	$ 369,955,506
	Percentage of the County Total	*95.26%*	*20.13%*	*91.21%*	*79.08%*	*3.92%*	*75.38%*
010 - 039	Commercial	532	3,057.3	$ 183,496,728	48	110.8	$ 13,572,137
	Percentage of the County Total	*1.72%*	*7.92%*	*3.47%*	*3.10%*	*0.29%*	*2.77%*
040 - 049	Industrial	33	206.1	$ 17,711,836	1	5.0	$ 230,225
	Percentage of the County Total	*0.11%*	*0.53%*	*0.33%*	*0.06%*	*0.01%*	*0.05%*
050 - 069	Agricultural	104	14,448.1	$ 67,619,224	111	19,920.9	$ 44,792,068
	Percentage of the County Total	*0.34%*	*37.43%*	*1.28%*	*7.17%*	*52.23%*	*9.13%*
070 -079	Institutional	37	129.2	$ 29,713,210	3	80.5	$ 1,802,852
	Percentage of the County Total	*0.12%*	*0.33%*	*0.56%*	*0.19%*	*0.21%*	*0.37%*
080 - 089	Governmental	519	10,718.6	$ 133,391,396	110	14,128.3	$ 54,377,451
	Percentage of the County Total	*1.67%*	*27.77%*	*2.52%*	*7.10%*	*37.04%*	*11.08%*
090 - 097	Miscellaneous	231	589.6	$ 25,148,756	43	1,994.5	$ 2,788,622
	Percentage of the County Total	*0.75%*	*1.53%*	*0.48%*	*2.78%*	*5.23%*	*0.57%*
098	Centrally Assessed	1	-	$ 5,061,098	-	-	-
	Percentage of the County Total	*0.00%*	-	*0.10%*	-	-	-
099	Non-Agricultural Acreage	11	1,682.1	$ 2,919,287	8	403.7	$ 3,254,872
	Percentage of the County Total	*0.04%*	*4.36%*	*0.06%*	*0.52%*	*1.06%*	*0.66%*
	Total	31,002	38,601.9	$ 5,287,861,078	1,549	38,140.3	$ 490,773,733

The last row presents the aggregate number of parcels, the total acres, and the total just value (JV). The total number of acres is 76,742.2; 38,601.9 acres for Flagler County and 38,140.3 acres for St. Johns County. Although the total acreage of the two counties are approximately equivalent, the number of parcels and their associated LU categories reflect substantially different LU patterns.

The first difference between the two counties arises from the total parcel numbers and the associated total just values (JV). The total number of parcels for Flagler County is 31,002, which is about 20 times greater than that of St. Johns County (i.e., 1,549). Among these parcels, 95.26% is in the category "Residential", which occupies 20.13% of the total acres and 91.21% of the total JV, which is $5,287,861,078. Conversely, the number of acres in the "Residential" category in St. Johns County is only 3.92% of the total acres, which is only one-fifth of the number of acres in "Residential" in Flagler County, even though the corresponding parcel number and the JV have high percentages (79.08% and 75.38%, respectively). As depicted in Figure 7, the higher density of parcels (shown in red) in Flagler County centers around Palm Coast, Painters Hill, Beverly Beach, and Flagler Beach, and indicates higher densities of population.

The LU category of "Commercial" mirrors that of the "Residential" category for both counties. The commercial acreage, and the corresponding JV of Flagler County, are 27 times, and 13 times, greater than those of St. Johns County, respectively.

The second significant difference between the LU patterns of the two counties comes from the category "Agricultural" (shown in dark blue in Figure 7). Flagler County comprises 14,448.1 acres, which accounts for 37.43 % of its total acres, and St. Johns encompasses 19,920.9 acres, which accounts for more than half, 52.23%, of its total LU acres. Relating to the JV, agriculture accounts for 9.13% of its total JV of St. Johns County, whereas agriculture only accounts for 1.28% of the total JV of Flagler County.

The third important difference in LU patterns relates to the "Governmental" LU category. Parcels in olive in Figure7 present the total available parcels in the "Governmental" category.

Compared with Flagler County, St. Johns County has more acres of Governmental LU: 14,128.3, which comprises 37.04% of its total acreage. Though this number is less in Flagler County, 10,718.6, it encompasses 27.77% of its total acreage. However, the Governmental JV in St. Johns County is 11.08% of its total LU JV, while this number is only 2.52% for Flagler County. Specifically, for Flagler County, the classifications of "public county schools" and "colleges" account for 49.29% of the Governmental JV. However, these two LU classifications only account for 0.01% in St. Johns County.[19]

Figure(s) 8 (a), 8 (b) and 8 (c) summarize the common and different LU patterns by the percentages of parcels, by acreages, and JV's. For Flagler County, 95.26% of parcels and 91.21% of JVs are represented by "Residential", and 65.20% of the acreage is occupied by the "Agricultural" and "Governmental" categories. However, for St. Johns County, although the "Residential" has the top percentages according to number of parcels and JV's (79.08%, and 75.38%, respectively), the numbers of "Agricultural" and "Governmental" are significantly higher (14.27%, and 20.21%, respectively). The "Agricultural" and "Governmental" LU acreages comprise 89.27% for St. Johns County.

[19] Appendix 1: Table A2. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area.

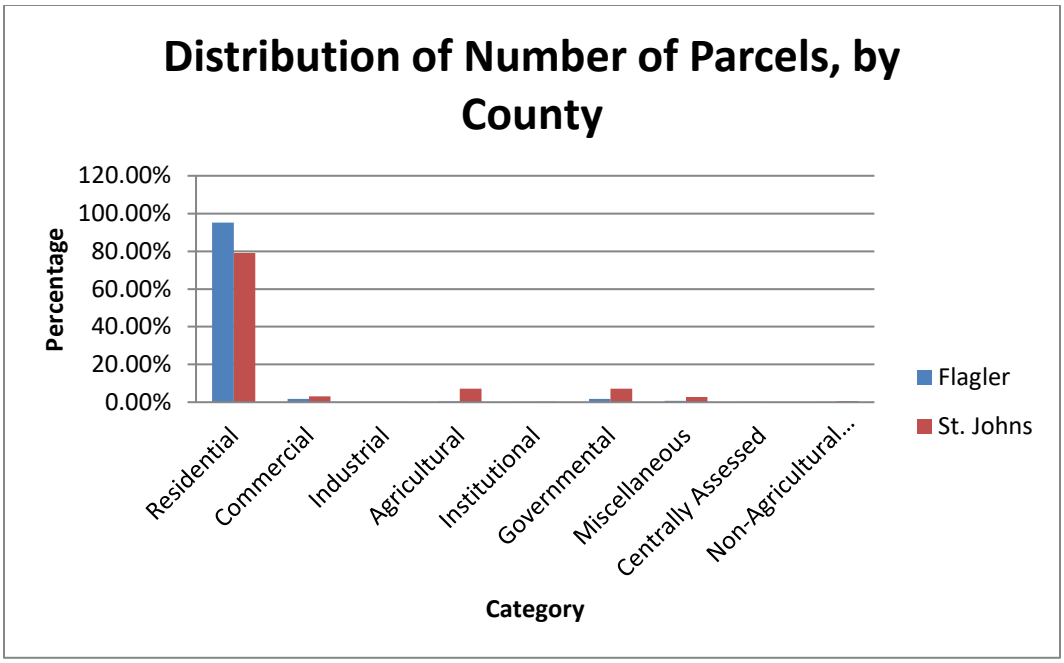


Figure 8 (a). Distribution of Number of Parcels by County

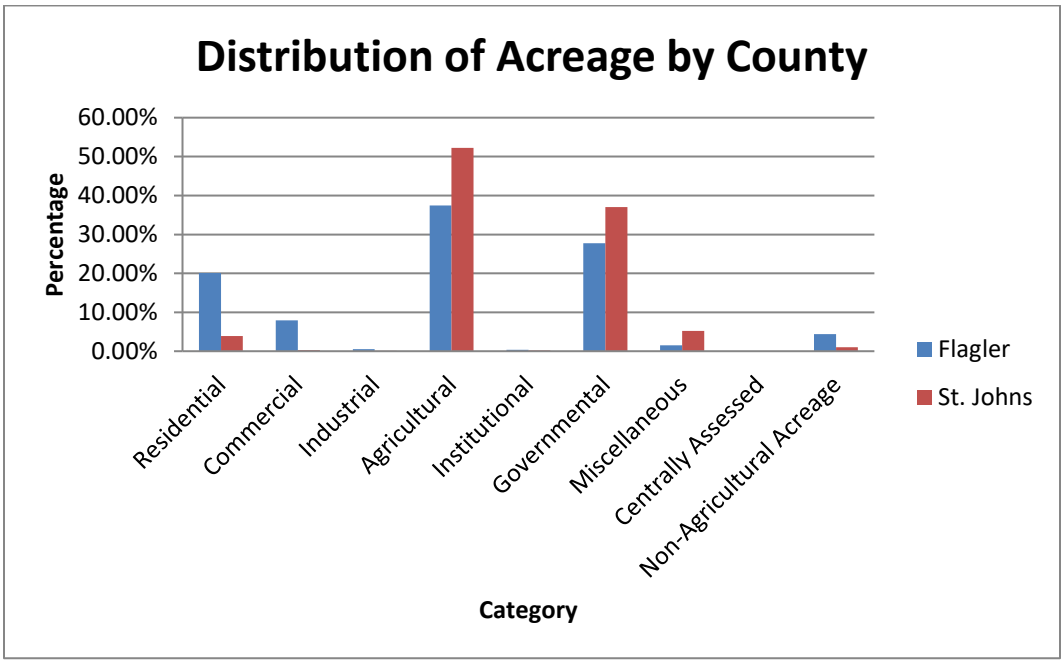


Figure 8 (b). Distribution of Acreage by County

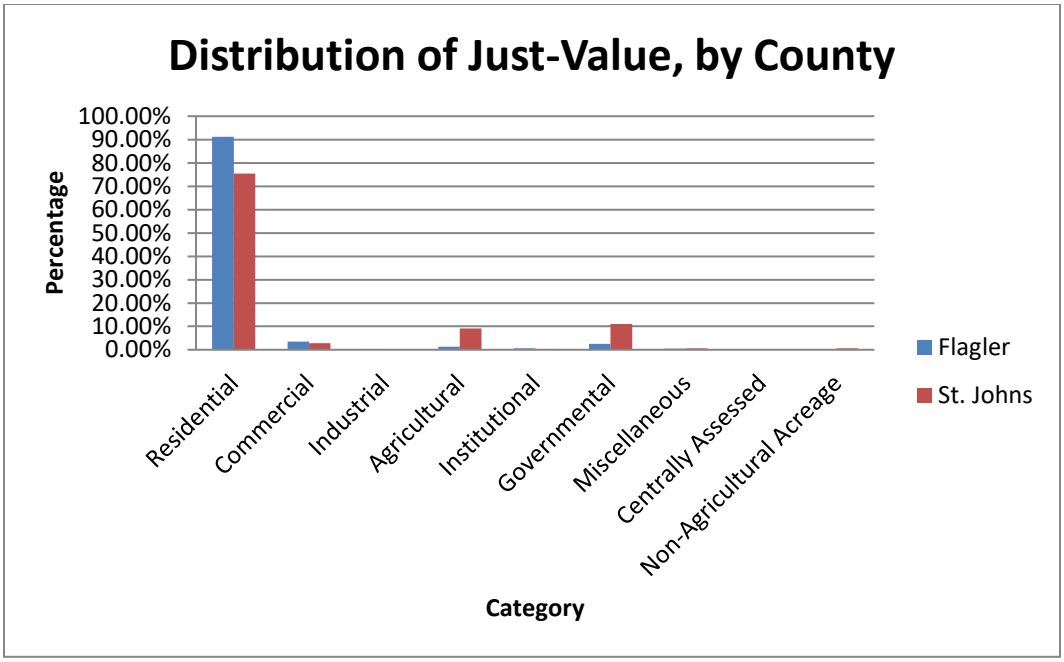


Figure 8 (c). Distribution of Just-Value by County

Summary

This data report analyzes the LU patterns in the Pellicer watershed area and its tributaries, which intersect parts of Flagler county and St. Johns county. Data on LU is collected from the Florida Department of Revenue (DOR) County Property Appraiser (2016).

Based on the DOR use codes, this report investigates the parcel number, the acreage, and the just value by eight categories. They are "Residential", "Commercial", "Industrial", "Agricultural", "Institutional", "Governmental", "Miscellaneous", and "Non-Agricultural Acreage". LU patterns are analyzed by separating the entire Pellicer watershed area and its tributaries into the Flagler county sections and St. Johns county sections.

"Residential" and "Commercial" categories comprise the majority of the parcel number and the JV's for both counties (96.98%, and 94.68%, respectively, for Flagler county, and 82.18%, and 78.15%, respectively, for St. Johns county).

The following main differences associated with the LU patterns are observed between Flagler county and St. Johns county:[20]

- The number of parcels and the JVs are higher in Flagler County, which is attributed to its high ratio in the "Residential" category.
- The "Agricultural" category encompasses large portions of the total acreages in both Flagler county and St. Johns county (37.43%, and 52.23%, respectively). However, the corresponding JV's percentage in St. Johns County is around 6 times higher.
- The "Government" LU category, with the second top percentage relative to acreage, has the same pattern with "Agricultural" category for both counties. But the LU classification structure under this category of both counties differs from each other: public county schools and colleges comprise 49.29% of Governmental JV in Flagler County, while this number is only 0.01% for St. Johns County.

[20] Further data detail can be found based on Table A2 in Appendix 1. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area, Flagler County and St. Johns County Sections of the Pellicer Watershed Area, by Department of Revenue Use Code.

Description and Application of InVEST Models

The General Description of the InVEST Model

Four models in InVEST were selected for this study according to the GTM NERR researchers' priority, current LU features, and the availability of data. These models are: Habitat Quality, Fisheries, Unobstructed Views: Scenic Quality Provision, and Visitation: Recreation and Tourism. FSU CEFA provides a general analysis template for further selections of other models in InVEST. The application of models in InVEST follows the process depicted in Figure 9.

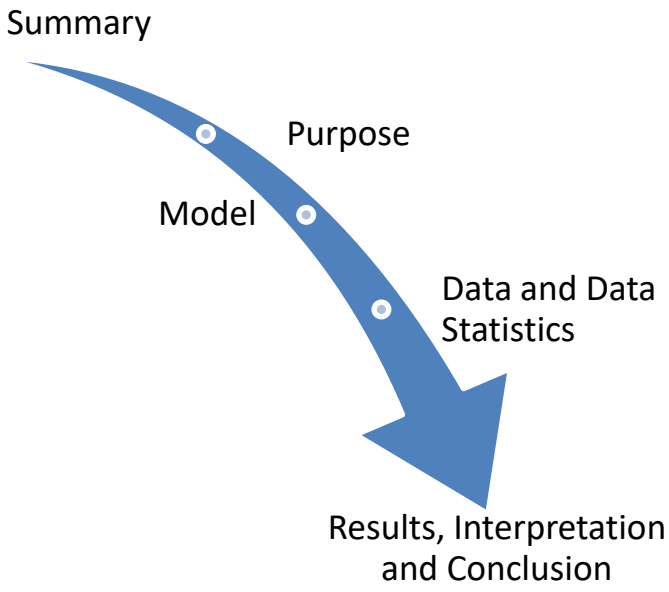


Figure 9. The Steps to Apply Individual Models of InVEST

- Summary: introduces how the model is related to the study topic, the specific question that will be solved, and the targets/variables selected and analyzed.
- Purpose: introduces general questions that the individual model can solve.
- Model: explains the theoretical mechanism how the model works, helping match variables and required data.
- Data and Data Statistics: summarizes data sources and data statistics, as well as required workspace, data format, and data unit setup.
- Results, Interpretation, and Conclusion: shows the results in the format of map and table and provides interpretation of results, following the "supply, service, and value" framework.

Habitat Quality Model

Summary

Biodiversity is strongly associated or linked to ecosystem services production. Patterns in biodiversity can be estimated by analyzing maps of land use and land cover (LULC) in conjunction with threats. This study provides the habitat quality analysis of the Pellicer watershed area and its tributaries based on the current LU and the threats from urbanization and other factors. Threats that can impact the habitat quality include the development of cities, transportation, invasive species (plants), and sea level rise (SLR).

Purpose

The Habitat Quality model estimates the extent of habitat and vegetation types across a landscape, and their state of degradation, and to identify win-win areas (i.e. conservation can benefit both natural systems and human economies). This model will attempt to respond to the questions: 1. How and where do biodiversity and ecosystem services align in space? 2. How do LU management actions affect both? The model uses habitat quality and rarity as proxies for biodiversity.

Model

The Habitat Quality model is most relevant to "coarse filter", or habitat-based approaches. It assumes the legal protection of land is effective and all threats to a landscape are additive. There are two blocks in the Habitat Quality model: Habitat Quality analysis and Habitat Rarity analysis. This study focuses on the Habitat Quality analysis.[21]

The Habitat Quality analysis identifies areas where biodiversity is likely to be most intact or imperiled. It generates a map of the habitat degradation score which is used to calculate the habitat quality index.

As defined in Hall et al. (1997), Habitat is the resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism. Habitat quality is the ability of the ecosystem to provide conditions appropriate for individual and population persistence. It is represented by a continuous variable in the model, ranging from *low to medium to high*, based on resources available for survival, reproduction, and population persistence, respectively. Habitat quality depends on a habitat's proximity to human LUs and the intensity of these LUs.

Firstly, LULC types that can provide habitat for the conservation objective are defined.

- Which LULC types should be considered habitat?

[21] The Habitat rarity block evaluates the relative rarity of habitats on the landscape regardless of quality.

There are two approaches to define the habitat suitability of each LULC types: a binary approach, $\{0, 1\}$, or a continuous habitat suitability score, $[0, 1]$. H_j is denoted as the habitat suitability of LULC type j.

Secondly, the model requires data on habitat threat density and its impacts on habitat quality. Threat sources are human modified LULC types that cause habitat fragmentation, edge, and degradation in neighboring habitat threats.

- What threats or threat sources should be considered? Are they for general biodiversity or applied in reference to a particular species guild of group?[22]

Denote o_{ry} as the threat r's "score" in raster cell y, $o_{ry} \in \{0, 1\}$. The impact of threats is mediated by four factors:

1) The weight relative impact of each threat w_r

2) The distance between habitat and the threat source and the impact of the threat across space. The researcher can choose either a linear or exponential distance-decay function to describe how a threat decays over space.

$$i_{rxy} = 1 - \left(\frac{d_{xy}}{d_{r\,max}}\right) \qquad \text{if linear}$$

$$i_{rxy} = e^{-\left(\frac{2.99}{d_{r\,max}}\right)d_{xy}} \quad \text{if exponential}$$

i_{rxy}: the impact of threat r originates in cell y on cell x

d_{xy}: the linear distance between cell y and cell x

$d_{r\,max}$: the maximum effective distance of threat r, used for threats outside of the AOI

3) The level of legal / institutional / social / physical protection from disturbance in each cell (access)

$\beta_x \in [0, 1]$: zero to complete accessibility to cell x

The model assumes $\beta_x = 1$ by default.

[22] In the model, the edge effects are considered. And all mapped threats should be measured in the same scale and metric. Edge effects: changes in the biological and physical conditions that occur at a patch boundary and within adjacent patches.

4) The total degradation in a cell with habitat

$$\mathrm{D}_{xj} = \sum_{r=1}^{R} \sum_{y=1}^{Y_r} \left(\frac{w_r}{\sum_{r=1}^{R} w_r} \right) \mathrm{r}_y i_{rxy} \beta_x S_{jr}$$

$S_{jr} \in [0, 1]$: the sensitivity of LULC type j to threat r

Y_r: the set of grid cells on r's raster map

Finally, the model uses the Habitat Quality formula, with the degradation score and values of a set of parameters, to calculate the habitat quality values Q_{xj} (parameters $z = 2.5, k = 0.5$ by default).

- How to measure the habitat quality?

$$Q_{xj} = H_j \left(1 - \left(\frac{D_{xj}^z}{D_{xj}^z + k^z} \right) \right)$$

Data and Data Statistics

Empirical data on LU:

The empirical data on current LU types is from the Florida Department of Revenue (DOR) County Property Appraiser (2016). Details have been illustrated in the previous section "Land Use (LU) Data and Information on the Pellicer Watershed Area". The DOR defined LU has 99 classifications,[23] belonging to nine categories. The LU parcels intersecting with Pellicer watershed area include 64 classifications. The LU polygon data was conversed to raster data with the cell size equaling to 30, following the InVEST online example. Figure 10 displays the raster map of current LU parcels. The details of raster values are shown in Appendix 1.[24]

[23] See: Appendix 1. Table A2.
[24] See: Appendix 1. Table A3.

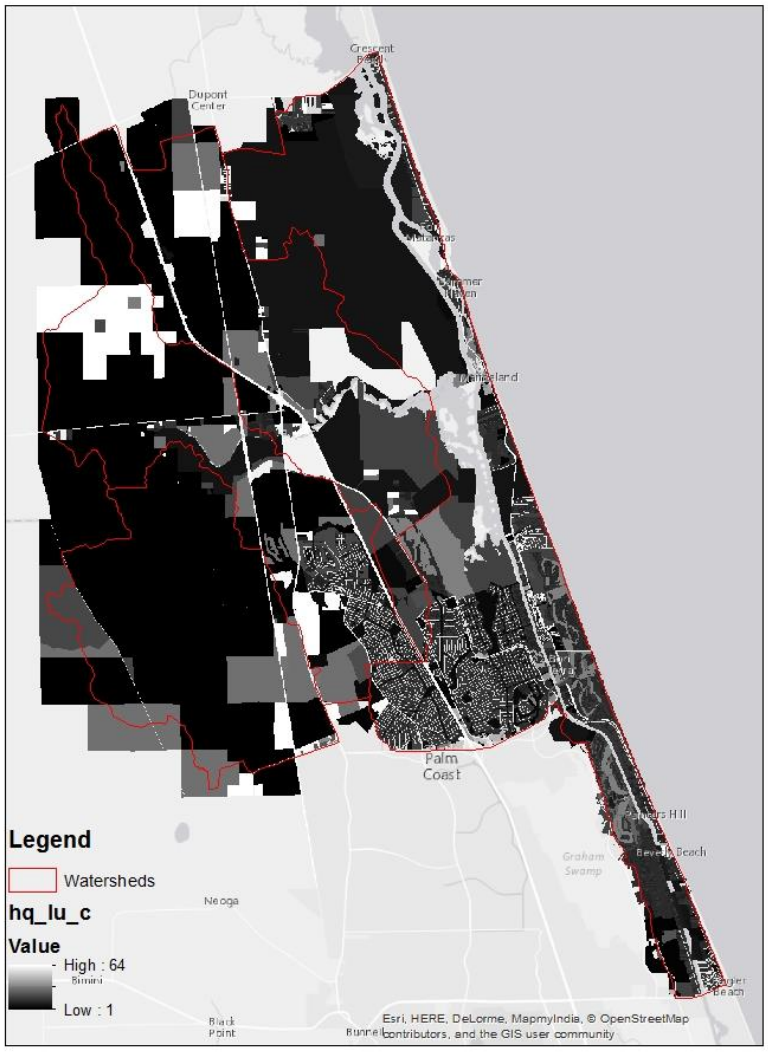


Figure 10. The Raster Map of Current Land Use (LU) Parcels

Threats Data:

The project team chose threats relating to human activities because of the stress of population growth in Flagler and St. Johns counties. Other possible degradation sources are chosen based on the causes of endangerment for American species classified as threatened or endangered by the US Fish and Wildlife

Service.[25] They are: urbanization ("Residential" and "Commercial" categories in DOR LU classifications), road presence and traffic related air pollution (Roads - Main Highways), and other factors such as invasive species (Brazilian Peppertree, Cogongrass, Air-potato, and Chinese Tallow Tree) and sea level rise (Erosion Coast). These factors are measured by cities, roads, invasive plants, and coastal erosion respectively.[26] Figure 11 displays the spatial relationships of these threats with the Pellicer watershed area.

[25]InVEST online document: http://data.naturalcapitalproject.org/nightly-build/invest-users-guide/html/habitat_quality.html#id3

[26]Data Source:
Urbanization: Florida Department of Revenue (DOR) County Property Appraiser (2016)
Roads: FLORIDA DEPARTMENT OF TRANSPORTATION - RCI DERIVED MAJOR HIGHWAYS – 2016, Florida Geographic Data Library (FGDL)
Invasive Plants: Early Detection and Distribution Mapping System
Florida Coastal Erosion: CRITICAL COASTAL (BEACH) EROSION IN FLORIDA – 2014, Florida Geographic Data Library (FGDL)

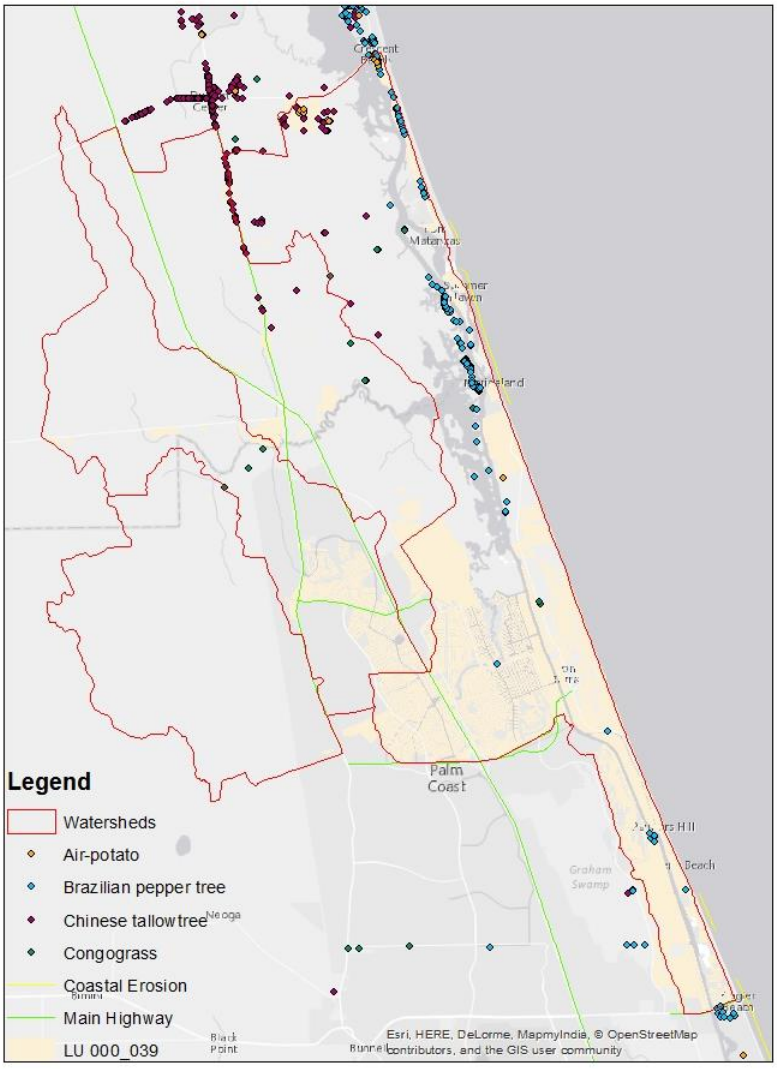


Figure 11. Threats and the Pellicer Watershed Area

Table 5 summarizes the value of variables w_r and $d_{r\,max}$ in the first two factors of the threats. Weights of relative impact are calculated based on the estimated number of endangered species derived by extrapolation of a 5% sample from the Federal Register. Data of maximum distance (buffer distance) is cited from the USGS's Conservation Buffer Distance Estimates for Greater Sage-Grouse—A Review (2014). According to the InVEST online manual, the decay function, which is user-defined, can be either linear or exponential. This study applied the linear functional form for all threats.

Table 5. Threats, Weight of Relative Impact, Buffer Distance, and Decay Function

Threats	Est. # of species endangered, derived by extrapolation of 5% sample from *Federal Register*	Weight of relative impact w_r	Buffer distance (km) $d_{r\,max}$	Decay Function
Urbanization	340	1	11.6	Linear
Roads	100	0.3	5.1	Linear
Invasive Plants	340	1	20	Linear
Florida Coastal Erosion	240	0.7	18	Linear

Habitat suitability, H_j, is derived from the Land Development Intensity (LDI) Index of the Pellicer area. There are two ways to calculate habitat suitability: the continuum suitability across LULC types and the binary approach (natural or unnatural) by considering biodiversity in general . The project team measured the habitat suitability using the LDI studied in Brown and Vivas (2005). In their study, the authors assigned LDI on a scale of 1 – 10 to different LU classifications. FSU CEFA mapped this LDI score to a continuum suitability score on a scale 1 – 0 (1 means perfect suitability and 0 means non-suitability) by the following equation:

$$H_j = 1 - \frac{LDI - 1}{9}$$

The corresponding habitat suitability for LU classifications in Brown and Vivas (2005) is summarized in Table 6.

Table 6. Habitat Suitability for LU Classifications and LDI in Brown and Vivas (2005)

LU Classification and LDI in Brown, M.T. & Vivas, B. M. (2005)		
Land Use	LDI (on a scale 1 - 10)	Habitat Suitability (on a scale 1 - 0)
Natural system	1.00	1.00
Natural open water	1.00	1.00
Pine/tree plantation	1.58	0.94
Recreational/open space - low intensity	1.83	0.91
Woodland pasture (with livestock)	2.02	0.89
Improved pasture (without livestock)	2.77	0.80
Improved pasture - low intensity (with livestock)	3.41	0.73
Citrus	3.68	0.70
Improved pasture - high intensity (with livestock)	3.74	0.70
Row crops	4.54	0.61
Single family residential - low density	6.90	0.34
Recreational/open space - high intensity	6.92	0.34
Agricultural - high intensity	7.00	0.33
Single family residential - medium density	7.47	0.28
Single family residential - high density	7.55	0.27
Mobile home - medium density	7.70	0.26
Highway - 2 lanes	7.81	0.24
Low intensity commercial	8.00	0.22
Institutional	8.07	0.21
Highway - 4 lanes	8.28	0.19
Mobile home - high density	8.29	0.19
Industrial	8.32	0.19
Multi-family residential - low rise	8.66	0.15
High intensity commercial	9.18	0.09
Multi-family residential - high rise	9.19	0.09
CBD - average 2 stories	9.42	0.06
CBD - average 4 stories	10.00	0.00

Because discrepancies exist between the LU classifications in different studies, or for different study purposes, a relative habitat suitability score between 0 and 1 can be customized based on the demand of, or input from, InVEST users.

Figure 12 shows the distribution of the LDI values for land-cover (LU) analysis in the Pellicer watershed area and its tributaries.[27] There are sixteen values of LDI in this area. From low to high, they are: 1, 1.6, 1.9, 2.1, 3.5, 4.1, 4.6, 5.2, 6.8, 6.9, 7.6, 8, 8.1, 8.3, 8.7, and 10. The project team compared this LDI map

[27]Data source: Florida Department of Environmental Protection (FDEP) Geospatial Open Data http://geodata.dep.state.fl.us/

with the geographic data on LU parcels collected from the FDOR, and calculated the average value of LDI polygons which intersect each LU classification, termed "the LDI for individual LU classifications". Table 7 summarizes the LU classification, the representative LDI value, and the Habitat Suitability Score derived from the LDI.

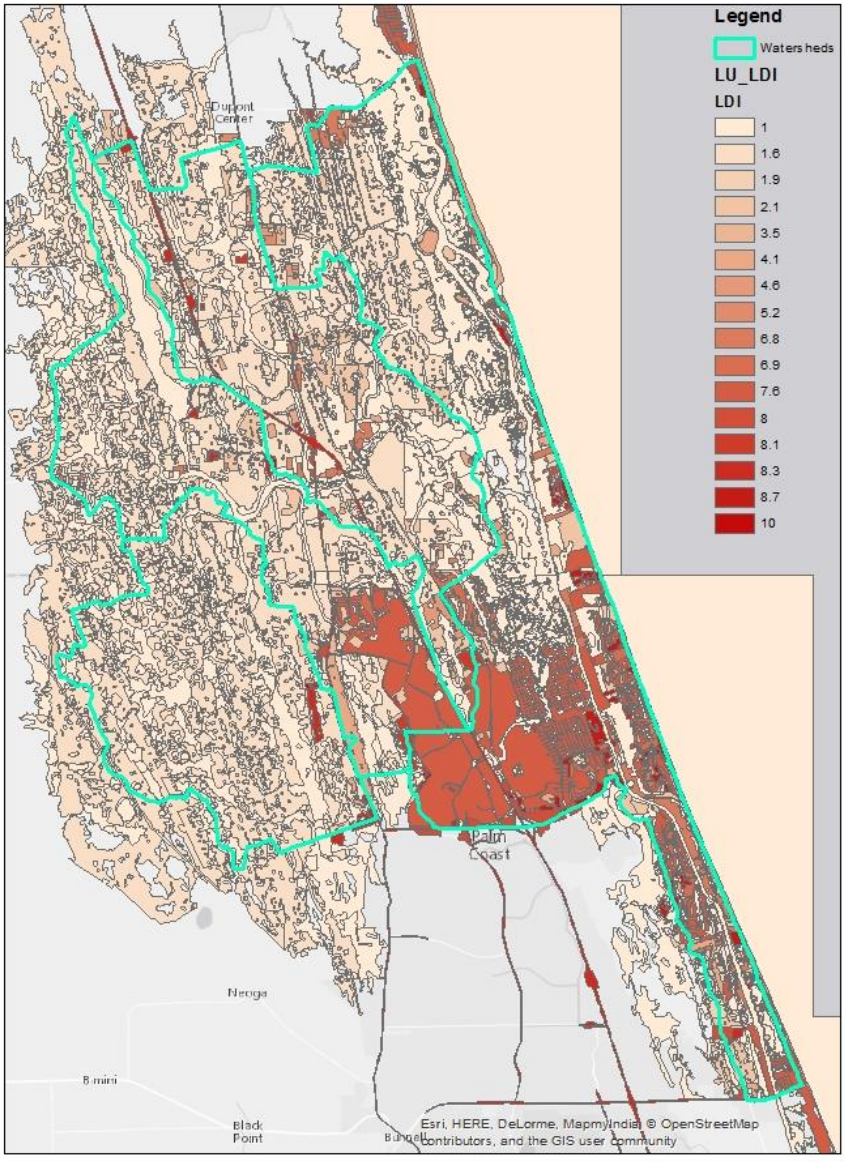


Figure 12. The Distribution of the LDI Values in the Pellicer Watershed Area and Its Tributaries

Table 7. Land Use (LU) Classification, LDI, and Habitat Suitability Score of the Pallicer Watershed Area

Use Code	Land Use Description	LDI (on a scale 1 - 10)	Habitat Suitability (on a scale 1 - 0)
000	Vacant Residential – with/without extra features	3.75	0.69
001	Single Family	3.83	0.69
002	Mobile Homes	3.55	0.72
003	Multi-family - 10 units or more	4.93	0.56
004	Condominiums	7.10	0.32
005	Cooperatives	4.98	0.56
007	Miscellaneous Residential (migrant camps, boarding homes, etc.)	4.34	0.63
008	Multi-family - fewer than 10 units	3.10	0.77
009	Residential Common Elements/Areas	4.26	0.64
010	Vacant Commercial - with/without extra features	3.54	0.72
011	Stores, one story	5.28	0.52
012	Mixed use - store and office or store and residential combination	4.64	0.60
016	Community Shopping Centers	6.27	0.41
017	Office buildings, non-professional service buildings, one story	6.30	0.41
018	Office buildings, non-professional service buildings, multi-story	6.56	0.38
019	Professional service buildings	6.51	0.39
020	Airports (private or commercial), bus terminals, marine terminals, piers, marinas	4.76	0.58
021	Restaurants, cafeterias	6.66	0.37
022	Drive-in Restaurants	5.43	0.51
023	Financial institutions (banks, saving and loan companies, mortgage companies, credit services)	6.66	0.37
025	Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats	4.37	0.63
026	Service stations	4.50	0.61
027	Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment,	6.18	0.42

	mobile home sales, motorcycles, construction vehicle sales		
Use Code	**Land Use Description**	**LDI (on a scale 1 - 10)**	**Habitat Suitability (on a scale 1 - 0)**
028	Parking lots (commercial or patron), mobile home parks	5.33	0.52
030	Florists, greenhouses	7.60	0.27
033	Nightclubs, cocktail lounges, bars	7.73	0.25
034	Bowling alleys, skating rinks, pool halls, enclosed arenas	4.95	0.56
035	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)	5.19	0.53
038	Golf courses, driving ranges	3.42	0.73
039	Hotels, motels	4.40	0.62
040	Vacant Industrial -with/without extra features	2.80	0.80
041	Light manufacturing, small equipment manufacturing plants, small machine shops, instrument manufacturing, printing plants	2.81	0.80
042	Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants	4.44	0.62
044	Packing plants, fruit and vegetable packing plants, meat packing plants	3.97	0.67
048	Warehousing, distribution terminals, trucking terminals, van and storage warehousing	3.28	0.75
050	Improved agricultural	3.21	0.75
055	Timberland - site index 80 to 89	1.35	0.96
056	Timberland - site index 70 to 79	1.61	0.93
059	Timberland not classified by site index to Pines	1.57	0.94
060	Grazing land soil capability Class I	2.82	0.80
062	Orchard Groves, citrus, etc.	4.05	0.66
067	Poultry, bees, tropical fish, rabbits, etc.	2.55	0.83
069	Ornamentals, miscellaneous agricultural	4.23	0.64
070	Vacant Institutional, with or without extra features	3.77	0.69
071	Churches	5.01	0.55
072	Private schools and colleges	4.92	0.56
074	Homes for the aged	7.69	0.26
075	Orphanages, other non-profit or charitable services	2.38	0.85

Use Code	Land Use Description	LDI (on a scale 1 - 10)	Habitat Suitability (on a scale 1 - 0)
076	Mortuaries, cemeteries, crematoriums	1.74	0.92
077	Clubs, lodges, union halls	4.06	0.66
082	Forest, parks, recreational areas	1.68	0.92
083	Public county schools - including all property of Board of Public Instruction	4.03	0.66
084	Colleges (non-private)	5.10	0.54
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	2.37	0.85
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	1.50	0.94
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	2.05	0.88
089	Municipal, other than parks, recreational areas, colleges, hospitals	3.27	0.75
091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	4.91	0.57
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	3.68	0.70
095	Rivers and lakes, submerged lands	4.52	0.61
096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	3.33	0.74
097	Outdoor recreational or parkland, or high-water recharge subject to classified use assessment	1.21	0.98
098	Centrally assessed	1.88	0.90
099	Acreage not zoned agricultural - with/without extra features	2.25	0.86

A habitat's sensitivity to threats, S_{jr}, should be based on general principles from landscape ecology for conserving biodiversity (e.g., Forman (1995); Noss (1997); Lindenmayer et al (2008)). The project team used Table A3 from the study of Terrado, Sabater, and Acuna (2016) "Identifying Regions Vulnerable to Habitat Degradation under Future Irrigation Scenarios." We assumed that all LU classifications under the same LU category defined by FDOR have the same relative sensitivity to the same threat. This general measurement of relative sensitivities is also employed by the InVEST development team. "Residential", "Commercial", "Industrial", "Governmental", except Classification 82, "Institutional", "Miscellaneous", except Classification 95 and 97, "Centrally Assessed", and "Non-agricultural Acreage" use the parameters for "Urban" in Terrado, Sabater, and Acuna (2016). "Agricultural", excluding Classification 55, 56, and 59 for "Timberland", uses the parameters for "Agric-NI" and "Agric." Classification 55, 56, 59, and 82 use the

parameters for "Forest." Lastly, Classification 95 and 97 use the parameters for "Stream". Table 8 summarizes the sensitivity parameters.

Table 8. Relative Sensitivity Table for Perfect Habitat Suitability LU

LU Category	Threats			
	Urbanization	Roads	Invasive Plants	Florida Coast Erosion
Residential	0.01	0.10	0.16	-
Commercial	0.01	0.10	0.16	-
Industrial	0.01	0.10	0.16	-
Agricultural	0.71	0.59	0.02	-
Use Code 55, 56, and 59	0.85	0.78	0.70	-
Institutional	0.01	0.10	0.16	-
Governmental	0.01	0.10	0.16	-
Use Code 82	0.85	0.78	0.70	-
Miscellaneous	0.01	0.10	0.16	-
Use Code 95 and 97	0.97	0.75	0.82	0.93
Centrally Assessed	0.01	0.10	0.16	-
Non-Agricultural Acreage	0.01	0.10	0.16	-

Results, Interpretations, and Conclusions

The Habitat Quality model generates the mapping results of the relative level of habitat degradation and the habitat quality of the LU parcels in the Pellicer watershed area. Figure 13 shows the relative level of habitat degradation and Figure 14 displays the habitat quality.

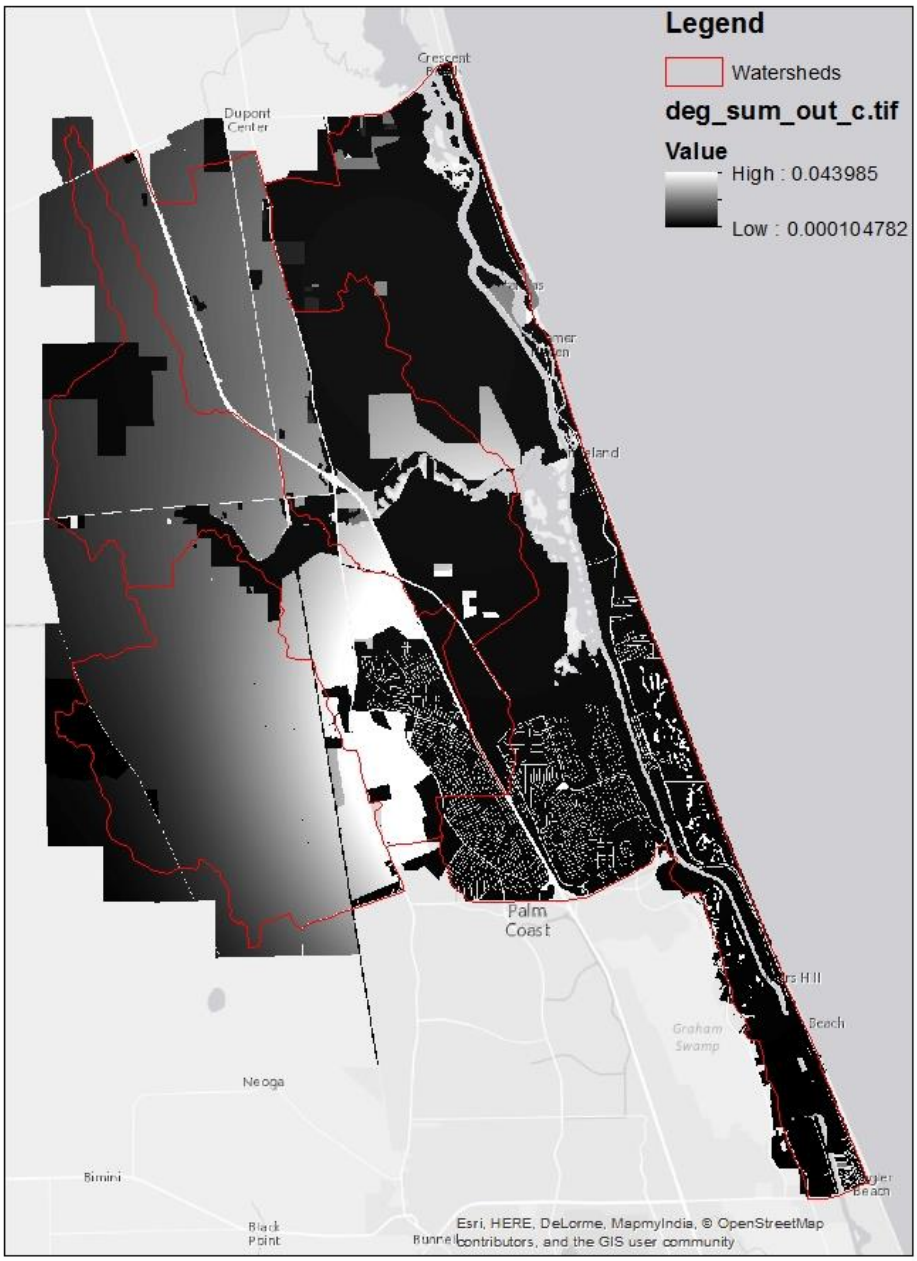


Figure 13. The Relative Level of Habitat Degradation on the Current Landscape

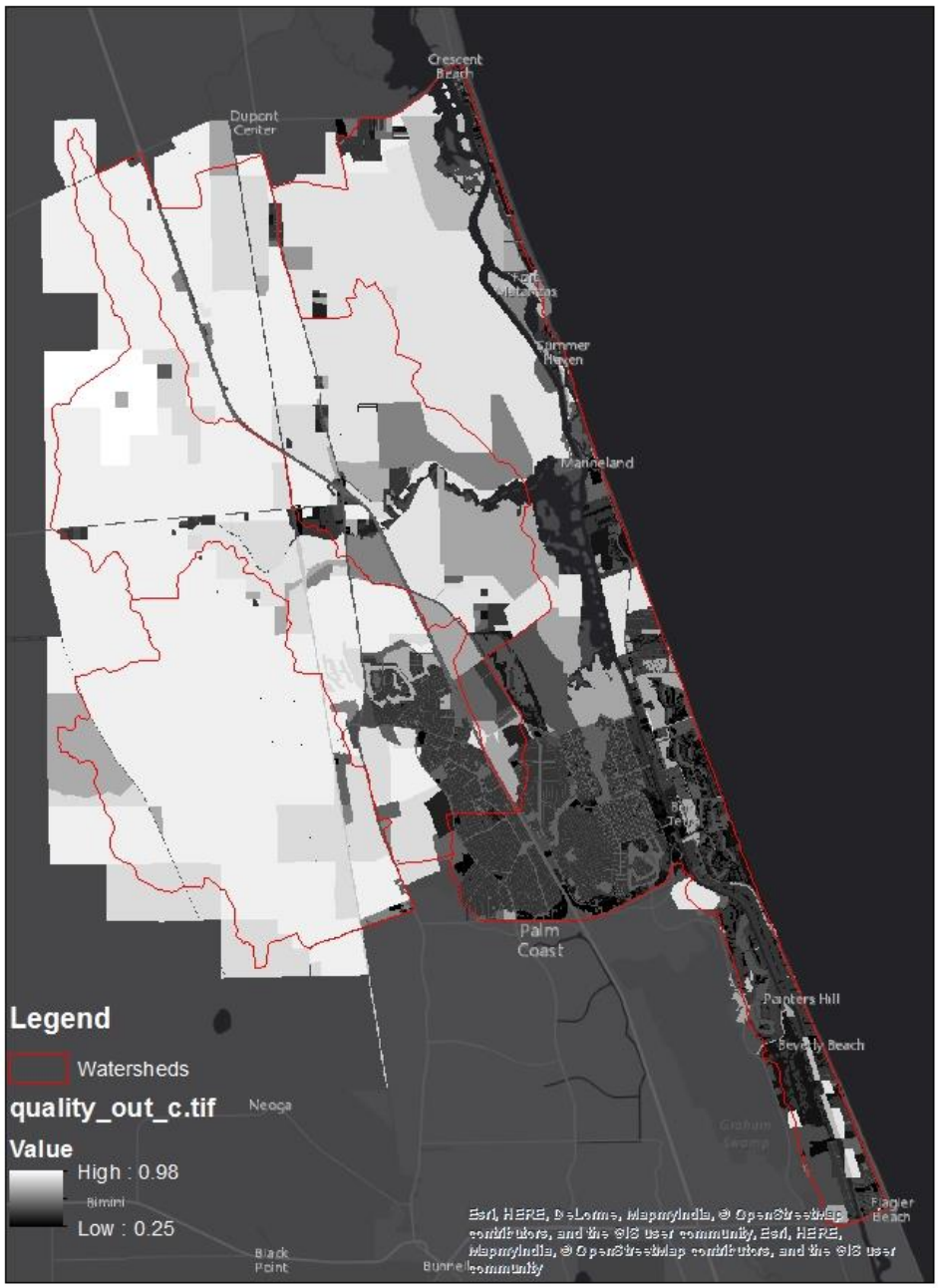


Figure 14. The Habitat Quality of the Pellicer Watershed Area

The mapping of relative levels of habitat degradation on the current landscape has a scale from 0.000 to 0.044. A high score in a grid cell means habitat degradation in the cell is high relative to other cells. Based on the threats chosen, the general relative level of degradation of LU parcels in Flagler County is high compared with that of LU parcels in St. Johns County. LU parcels "Agricultural" in Flagler County (which are adjacent to main highways US-1 and I-95), and the LU parcels of "Residential" and "Commercial", have high degradation scores.

LU parcels "Agricultural" in St Johns County (which are adjacent to main highways US-1 and I-95) and are closed to high invasive plants distributions, have high degradation scores. However, compared with the LU parcels of "Agricultural" in Flagler County, the relative level of degradation is lower. Parcels belonging to LU "Governmental" in St Johns County (which are at the boundary of St. Johns County and Flagler County), are with higher degradation scores and vulnerable to the effects of roads and invasive species.

Other parcels of "Governmental" in Flagler County and St. Johns County also reflect low degradation scores.

Habitat quality is the ability of the ecosystem to provide conditions appropriate for individual and population persistence. It is represented by a continuous variable on a scale from 0 to 1 in the model, ranging from *low to medium to high* (0 - 0.33, 0.33 – 0.67, and 0.67 – 1 respectively). As show in Figure H5, based on the threats chosen, LU parcels in Flagler County have relative low habitat quality because of a high percent acreage of "Residential" and "Commercial" LU parcels: 28.05%, while this number of St. Johns County is only 4.21%[28]. The parcels of "Governmental" in Flagler County show *low - medium* and *medium* habitat quality. The parcels of "Agricultural" in Flagler County display *medium – high* and *high* habitat quality.

"Agricultural" and "Governmental" are two main LU categories in St. Johns County intersecting with the Pellicer watershed area, comprising 89.27% of the total acreage analyzed. The parcels of "Agricultural" show high habitat quality, and the parcels of "Governmental" display *medium – high* and *high* habitat quality. Table 9 summarizes the main results of the habitat quality analysis.

Table 9. Habitat Quality of LU Parcels in "Residential", "Commercial", "Agricultural", and "Governmental" Category

LU Category	Flagler County	St. Johns County
Residential and Commercial	Low	-
Agricultural	Medium – High, High	High
Governmental	Low – Medium, Medium	Medium – High, High

[28] See Table 4 for details of the number of parcels, the acreage, and the just-value.

Fisheries Model

Summary

Both Recreational and Commercial Fisheries are important components of the Florida economy. Wild capture fisheries not only provide a significant source of protein for human consumption but create employment for fishers and fisheries-related industries. According to data related to fisheries economics reported by the National Oceanic and Atmospheric Administration (NOAA), the number of jobs in Commercial Fishing, Seafood Industry, and Recreational Fishing was 191,200 in Florida.[29] Poor harvesting practices and habitat loss and degradation can reduce the ability of ecosystems to support healthy, productive fisheries. The study team uses the "commercial landings of white shrimp" as an example in the InVEST model to show how changes in habitat or harvesting practices will impact the production of wild fish. The results of this analysis provide useful implications on the impacts to the marine or aquatic ecosystems for decision makers.

Purpose

The Fisheries model produces estimates of harvest volume and economic value of single-species fisheries (e.g. white shrimp), and answers questions such as how changes in habitat or harvesting practices will impact the production of wild fish.

The following scenario analysis provides alternating survival rates at certain life stages or in certain locations in response to changes in habitat extent, environmental variables, and/or fishing.

Model

The Fisheries model is composed by two parts: the Core Model and the Habitat Scenario Tool. The Core Model uses the life-history information and survival parameters of white shrimp to estimate the volume of the harvest. The Habitat Scenario Tool explores how the amount of harvest (and, optionally, value) responds to changes in the amount of habitat.

The Core Model is an age – or stage – structured, deterministic, population dynamics model for an individual species. Information of local fish or shellfish, both species and geographies, is required to run this model. A series of decisions about the model's structure should be made:

- Are population structured by age or by stage?

[29]National Oceanic and Atmospheric Administration (NOAA): Fisheries Economics of the U.S. 2013 Regional Highlights. See: https://www.st.nmfs.noaa.gov/economics/publications/feus/fisheries_economics_2014/index

Age-structured populations are modeled as:

$$N_{a,s,x,t} = \begin{cases} Rec_{s,x,t} & a = 0 \\ \left(N_{a-1,s,x,t-1} Mig^{x}_{a-1,s,x} + \sum_{x' \neq x} N_{a-1,s,x',t-1} Mig^{x}_{a-1,s,x'}\right) S_{a-1,s,x} & 1 \leq a < A \\ \left(N_{A-1,s,x,t-1} Mig^{x}_{A-1,s,x} + \sum_{x' \neq x} N_{A-1,s,x',t-1} Mig^{x}_{A-1,s,x'}\right) S_{A-1,s,x} & a = A \\ \quad + (N_{A,s,x,t-1} Mig^{x}_{A,s,x} + \sum_{x' \neq x} N_{A,s,x',t-1} Mig^{x}_{A,s,x'}) S_{A,s,x} & \end{cases}$$

$N_{a,s,x,t}$: the number of individuals of age a of sex s in area x at the start of time step t

A: the maximum age

$S_{a-1,s,x}$: the survival from natural and fishing mortality from age $a-1$ to a for each sex and area:$S_{a,s,x} = surv_{a,s,x}(1 - Ex_x * V_{a,s})$

$surv_{a,s,x}$: the survival from natural fishing mortality from age a to a+1

Ex_x: exploitation

$V_{a,s}$: the vulnerability to harvest by age and sex

$Rec_{s,x,t}$: the recruitment of new individuals/number of offspring

$Mig^{x}_{a,s,x'}$: the proportion of individuals migrating from area x' to area x

Stage-structured populations are modeled as:

$$N_{a,s,x,t} = \begin{cases} \left(N_{a,s,x,t-1} Mig^{x}_{a,s,x} + \sum_{x' \neq x} N_{a,s,x',t-1} Mig^{x}_{a,s,x'}\right) P_{a,s,x} + Rec_{s,x,t} & a = 0 \\ \left(N_{a-1,s,x,t-1} Mig^{x}_{a-1,s,x} + \sum_{x' \neq x} N_{a-1,s,x',t-1} Mig^{x}_{a-1,s,x'}\right) G_{a-1,s,x} & a \geq 1 \\ \quad + (N_{a,s,x,t-1} Mig^{x}_{a,s,x} + \sum_{x' \neq x} N_{a,s,x',t-1} Mig^{x}_{a,s,x'}) P_{a,s,x} & \end{cases}$$

Ga, s, x: the probability of surviving from natural and fishing mortality and growing into the next stage for each sex and area:

$$G_{a,s,x} = \frac{S^{D_a}_{a,s,x}(1 - S_{a,s,x})}{1 - S^{D_a}_{a,s,x}}$$

D_a: the stage duration

$\mathrm{Pa,s,x}$: the probability of surviving from natural and fishing mortality and remaining in the same stage for each sex and area:

$$\mathrm{P_{a,s,x}} = \mathrm{S_{a,s,x}} \frac{1 - \mathrm{S_{a,s,x}^{D_a - 1}}}{1 - \mathrm{S_{a,s,x}^{D_a}}}$$

- Should males and females be modeled separately or together?
- Are there multiple sub-regions?
- Is there migration between sub-regions?
- How is recruitment determined?

Recruitment is determined by the researcher-specified recruitment function, which is one of the following four representative recruitment functions:

- Beverton-Holt: $\mathrm{Rec_{s,x,t}} = \frac{\mathrm{LarvalDispersal_x}}{\mathrm{SexSpecific}} * \frac{\alpha * \mathrm{Sp_t}}{\beta + \mathrm{Sp_t}}$
- Ricker: $\mathrm{Rec_{s,x,t}} = \frac{\mathrm{LarvalDispersal_x}}{\mathrm{SexSpecific}} * (\alpha * \mathrm{Sp_t} * \mathrm{e^{-\beta Sp_t}})$
- Fecundity: $\mathrm{Rec_{s,x,t}} = \frac{\mathrm{LarvalDispersal_x}}{\mathrm{SexSpecific}} * \sum_{\mathrm{a,s,x}} \mathrm{N_{a,s,x,t-1}} \mathrm{Maturity_{a,s}} \mathrm{Fecundity_{a,s}}$
- Fixed Recruitment: $\mathrm{Rec_{s,x,t}} = \frac{\mathrm{LarvalDispersal_x}}{\mathrm{SexSpecific}} * \mathrm{Recruitment}$

$\mathrm{Sp_t}$: the spawners, either number or biomass:

$$\mathrm{Sp_t} = \sum_{\mathrm{a,s,x}} \mathrm{N_{a,s,x,t-1}} \mathrm{Maturity_{a,s}}, \text{ for SexSpecific} = 1, \text{aggregated}$$

$$\mathrm{Sp_t} = \sum_{\mathrm{a,s,x}} \mathrm{N_{a,s,x,t-1}} \mathrm{Maturity_{a,s}} \mathrm{W_{a,s}}, \text{ for SexSpecific} = 2, \text{sex} - \text{specific weighted}$$

Valuation is optional and reflects the earnings from the sale of harvest. Denote $\mathrm{H_{x,t}}$ as the harvest from each sub-region in the final time step. If the species are harvested by numbers, the harvest volume is:

$$\mathrm{H_{x,t}} = \sum_{\mathrm{a,s,x}} \mathrm{N_{a,s,x,t}} \mathrm{Ex_x} \mathrm{V_{a,s}}$$

If the species are harvested by weight, the harvest volume is:

$$\mathrm{H_{x,t}} = \sum_{\mathrm{a,s,x}} \mathrm{N_{a,s,x,t}} \mathrm{Ex_x} \mathrm{V_{a,s}} \mathrm{W_{a,s}}$$

The earnings $\mathrm{V_{t,x}}$ from the sale of harvest, which is at current market value is:

$$\mathrm{V_{t,x}} = \mathrm{H_{t,x}} * \mathrm{FractionProcessed} * \mathrm{Price}$$

- For how many time steps should the model run?

  The user supplies the necessary parameters, which usually range from 100 to 300.

The Habitat Scenario Tool analyzes a change in habitat coverage within a region, which can result in a change in the survival rate of ages/stages which depend on that habitat. Changes in the area of critical habitats are linked to changes in survival as follows:

$$S_{a,x} = surv_{a,x}\left[\frac{\sum_{d_{a,h}>0}\left(1+\frac{H_{h,x,SCEN}-H_{h,x,BL}}{H_{h,x,BL}}\right)^{d_{a,h\gamma}}}{n_a}\right]^{T_a}$$

$surv_{a,x}$: the baseline survival from natural mortality from age $a-1$ to a

T_a: the indicator for a transition to a new habitat from age $a-1$ to a

$H_{h,x}$: the amount of habitat h in the region x

$d_{a,h}$: the habitat dependency degree

γ: the shape parameter describing the relationship between a change in habitat and a change in survival

n_a: the number of non-zero habitat-dependency values for age a

Data and Data Statistics

There are three groups of data needed: general parameters, population parameters, and habitat parameters.

General Parameters describe the area of interest (AOI), the number of steps for model run, and the choice of species analyzed.

The AOI is optional if only one region is analyzed. The AOI in this study is the Pellicer watershed and its tributaries. As introduced in the previous section, it includes: Pellicer Creek, Pellicer Creek-Big Mulberry Branch Frontal, Pringle Branch, and Stevens Branch.[30] Since shellfish harvest areas are only located in the Pellicer Creek-Big Mulberry Branch Frontal area, we examined the four watersheds as an entire region. Thus, the AOI is not divided into sub-regions.

The number of time steps for the model run is set to 300, given a larger iteration number assures the final results will converge or reach equilibrium. This number is larger than the default number 100.

The species analyzed in this study are white shrimp. According to the recorded data from the Florida Fish and Wildlife Conservation (FWC) Commission,[31] the majority of shrimp harvested for food in Florida belong to the shrimp family Penaeidae. The pink shrimp (Farfantepenaeus duorarum) is the most abundant shrimp species harvested in the state. The two other species are the brown shrimp (Farfantepenaeus aztecus) and the white shrimp (Litopenaeus setiferus). The white shrimp is also caught principally in northeast and northwest Florida, but it is generally found in waters that are muddier, shallower, and less salty than waters where pink shrimp and brown shrimp live. Figure 15 presents the geographic distribution of commercial landings of white shrimp in Florida. St. Johns County is one of the main areas of the commercial landings of white shrimp.[32]

[30] Data source: USDA Geospatial Data Gateway https://datagateway.nrcs.usda.gov/

[31] See: http://myfwc.com/research/saltwater/crustaceans/shrimp/faq/

[32] Data Source: http://myfwc.com/media/195867/penaeid-shrimps.pdf

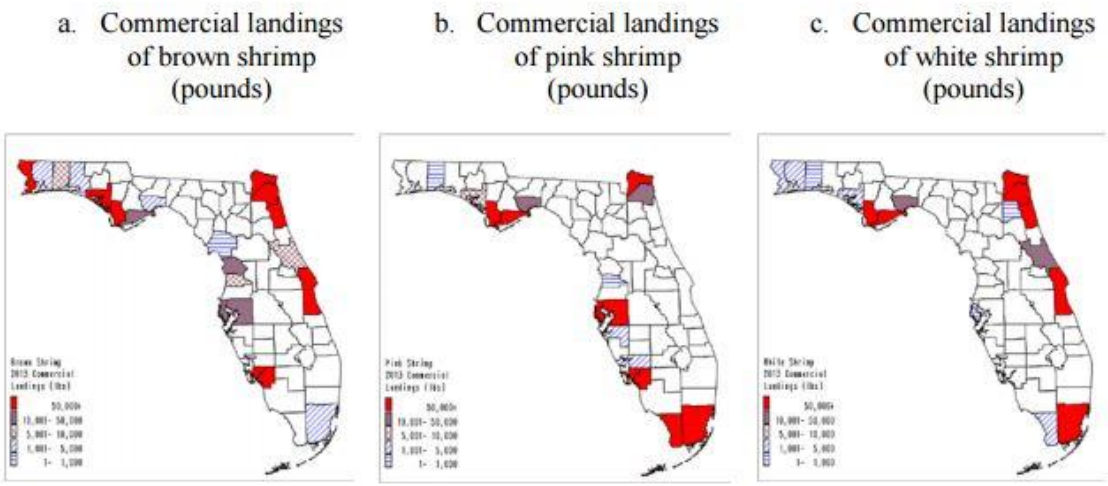


Figure 1 (a)-(c). Geographic distribution of penaeid shrimp landed commercially during 2013 by species and county.

Figure 15. Commercial Landings of Shrimp (by Type) in Florida from Florida Fish and Wildlife Conservation (FWC) Commission

The *Population parameters* provide answers for the questions in the core model, including primary population parameters, recruitment parameters, and valuation parameters. The primary population parameters of white shrimp are from the InVEST's online sources. For the analysis of other species, some fisheries science expertise is necessary.

- Are population structured by age or by stage?

Population Model Type: Stage-structured:

There are five stages in the life-cycle of the white shrimp according to Baker et al. (2008). They are: eggs/larvae, post-larval, marsh, bay, and adult.

- Should males and females be modeled separately or together?

The males and females are modeled together. So the choice for the Population Classes are Sex-Specific is No in the model dialogue window.

- Are there multiple sub-regions?

The four watersheds are treated as an entire region.

- Is there migration between sub-regions?

No.

The harvest of white shrimp is measured by Weight. So in the model dialogue window, the choice for the Harvest by Individual, or Weight, is Weight.

The values of variables in the core model are summarized in the Population Parameters Table, which is in the Excel CSV format. Table 10 shows the structure of the Population Parameters Table.

Table 10. Population Parameters

Stage	AOI	VulnFishing	Duration	Weight
eggs/larvae	0.675839	0	16	0.000175
post-larval	0.889674	0	30	0.029036
marsh	0.964062	0	52	0.758789
bay	0.974910	0.109788	33	4.026686
adult	0.980983	1	234	7.454849
Exploitation Fraction	0.064			

The time step of Duration is set as one day. It represents the number of time steps for which an average individual will be in that stage before moving to the next one. The unit of Weight is set in gram(s). This is the average biomass of an individual of the population at each stage. VulnFishing is the relative vulnerability to harvest for each class. The most vulnerable stage(s) should have a value of 1.0, indicating full vulnerability. The values in the AOI column are survival rates at each stage.

The exploitation fraction is the proportion of the population vulnerable to harvest that is actually harvested. This may vary by sub-region. Because of the limit of the available data, we assume all sub-regions (the four watersheds) have the same exploitation fraction. We further define the exploitation fraction the ratio of the (conditionally) approved area to the area of interest (approximately 76,742 acres): 0.064. Table 11 lists the description of management for closures of shellfish harvest areas in St. Johns County:[33] St. Johns, North #92 and St. Johns, South #88. Flagler County does not have shellfish harvest areas.

[33] Data Source: Florida Shellfish Harvest Areas: Florida Department of Agriculture and Consumer Services (FDACS): http://www.freshfromflorida.com/Business-Services/Aquaculture/Shellfish-Harvesting-Area-Classification/Shellfish-Harvesting-Area-Maps

Table 11. Description of Management for Closures

	Approved Acres	Conditionally Approved Acres	Restricted Acres	Conditionally Restricted Acres	Prohibited Acres	Unclassified Acres	Total Acres
St. Johns, North #92	0	882	0	2,196	2,595	0	5,673
St. Johns, South #88	0	1,541	0	314	43	0	1,898
Avg.	0	1,212	0	1,255	1,319	0	3,786

- How is recruitment determined?

Recruitment Parameters:

The initial number of recruits is the youngest stage in the initial recruitment. The default number is 200,000. Because the population model is run to equilibrium, the initial number of recruits will not affect the model results, but may affect the number of the time steps required before the model reaches equilibrium.

The recruitment function type chosen in this study is the Fixed Recruitment. The fixed recruitment may be appropriate in cases where the region of interest is small relative to the range or distribution of the fished population (0.064 in this study), e.g., , when recruits may drift into the region of interest from nearby spawning areas.

Because the white shrimp is harvested by weight, the choice of the Spawners by Individuals, or Weight, in the dialogue window is: Weight.

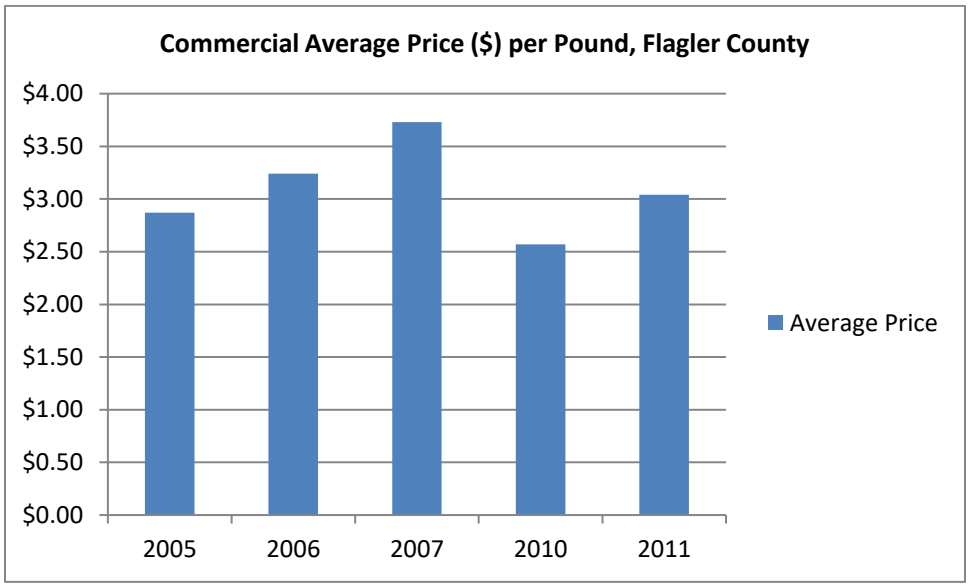
The Fixed Number of Recruits in the dialogue window is 178,000,000,000. This number is cited from the report Stock Assessment Update for White Shrimp (Litopenaeus setiferus) in the U.S. Gulf of Mexico for 2014.

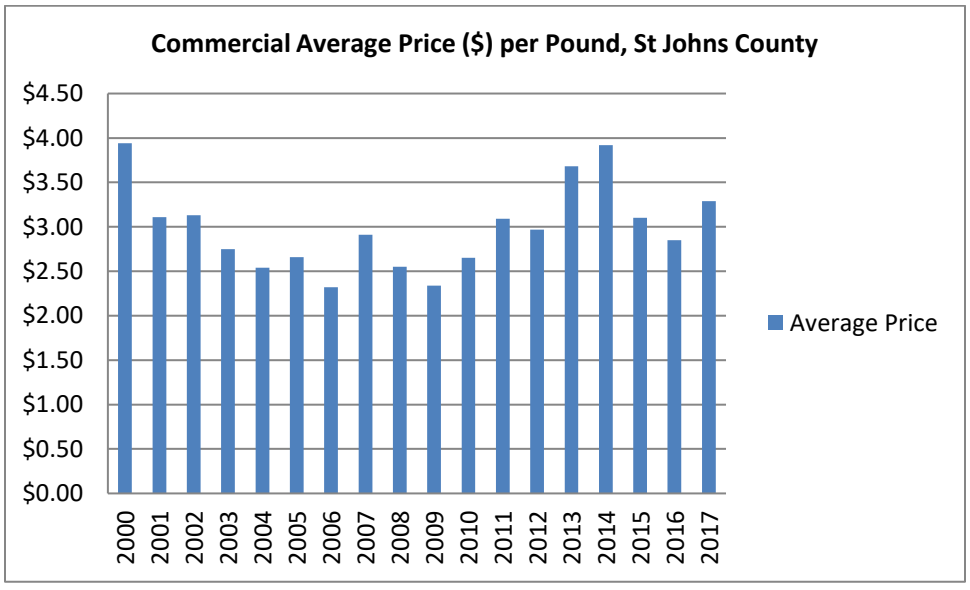
Harvest and Valuation:

The parameter of the Fraction of Harvest Kept after Processing is 0.3515, by default.

Unit Price is set as $3.04/lb or $0.0068/g in nominal USD. This is calculated based on the annual average price of white shrimp in Flagler County and St. Johns County from the year 2000 to the year

2017. Figure 16 displays the time series plots of the annual average sale price of white shrimp in Flagler County and St. Johns County.[34]





[34] Data Source: Florida Fish and Wildlife Conservation (FWC) Commission
https://publictemp.myfwc.com/FWRI/PFDM/

Figure 16. Commercial Unit Price of Oyster in Flagler County and St. Johns County

Habitat parameters are used to calculate the new survival rates from the natural mortality rate of the baseline population given the dependencies of certain classes on certain habitats, and the change in the areas of those habitats over certain regions or sub-regions. The inputs of the habitat scenario tool include three tables: Baseline Population Parameters Table, Habitat Dependency Parameters Table, and the Habitat Change Parameters Table.

The Population Parameters Table contains all necessary parameters for population classes based on stage, sex, and region, excluding possible migration parameters. Information of the Population Parameters Table in the core model is used as the baseline information.

The Habitat Dependency Parameters Table uses a binary approach to show certain habitat dependency for each stage of white shrimp.[35] White shrimp inhabit estuaries, marshes, and coastal areas generally to about 100 feet offshore. Juveniles live and grow in protected nursery areas with muddy ocean bottoms and low to moderate salinity. As they grow older, white shrimp move further offshore where they will spawn. Though white shrimp generally occur higher in the water column, they have also been found in association with other shrimp species – particularly brown shrimp.[36] Table 12 shows the habitat dependency for each stage in the population parameter based on the summary table of white shrimp life history information for the Gulf of Mexico.

Table 12. Habitat Dependency Table

Habitats	Eggs/larvae	Post-larval	Marsh	Bay	Adult
Marshes	0	0	1	0	0
Estuaries	1	1	1	0	0
Coastal Areas	1	1	0	1	1

The Habitat Change Parameters Table contains the percent changes in habitat area in the AOI or by sub-region (if applicable). We conducted a scenario analysis of decreasing the estuaries area by 10%, and increasing the coastal areas by 10% to see how the survival matrix (vector) of white shrimp will be affected by this land use – land cover (LULC) change. Table 13 lists the change in habitats of the estuaries and coastal areas.

[35] The measurement in the example given by the InVEST is a Binary approach.

[36] Atlantic white shrimp prefer shallow, warm, low salinity waters to about 90 feet deep with organic-rich, muddy bottoms. They actually require water temperatures above 37 °Fahrenheit to survive. In general, white shrimp prefer shallow water, typically less than 90 feet deep but up to 270 feet deep.
For more details, see:
1. http://gulffishinfo.org/Species?SpeciesID=100
2. http://www.fishchoice.com/buying-guide/white-shrimp
3. http://www.gsmfc.org/pubs/Habitat/tables/whiteshrimp.pdf
4. https://www.nwf.org/Wildlife/Wildlife-Library/Invertebrates/Atlantic-White-Shrimp.aspx

Table 13. Habitat Change Parameters Table

Habitats	Pellicer Creek	Pellicer Creek-Big Mulberry Branch Frontal	Pringle Branch	Stevens Branch
Marshes	0	0	0	0
Estuaries	-0.1	-0.1	-0.1	-0.1
Coastal Areas	0.1	0.1	0.1	0.1

Gamma, γ, the shape parameter describing the relationship between a change in habitat and a change in survival, is set to 0.5, by default. The value of Gamma can be specified with a value between 0 and 1 for other individual species.

Results, Interpretations, and Conclusions

The outputs of in this study include a harvest table after equilibration, and a population parameters table with modified survival rates for white shrimp. Table 14 summarizes the harvest volume and its corresponding economic valuation.

Table 14. Harvest Table with Valuation

Final Harvest by Sub-region after 300 Time Steps			
Sub-region	Harvest (in grams)	Harvest (in pounds)	Valuation
1	3,897,715	8,662	$9,315.99
Total	3,897,715	8,662	$9,315.99
Equilibrium is reached at T = 190			

The estimated harvest of white shrimp in the areas of Pellicer Watershed and its tributaries is 8,662 pounds (3,897,715 g), with the simple estimated value $9,315.99 (or $9,316). Compared with the commercial landings and estimated values of St Johns County and Flagler County, the estimated harvest is reflective of a reasonable interval. It should be noted that if the default parameters for the recruitment function and parameters are varied, it will affect the results. For comparison purposes, Figure 17 (a) – (d) shows a time series of the data on the white shrimp commercial landings and estimated values of St Johns County and Flagler County. The commercial landings data for Flagler County are only available in the year 2005, 2006, 2007, 2010, and 2011.

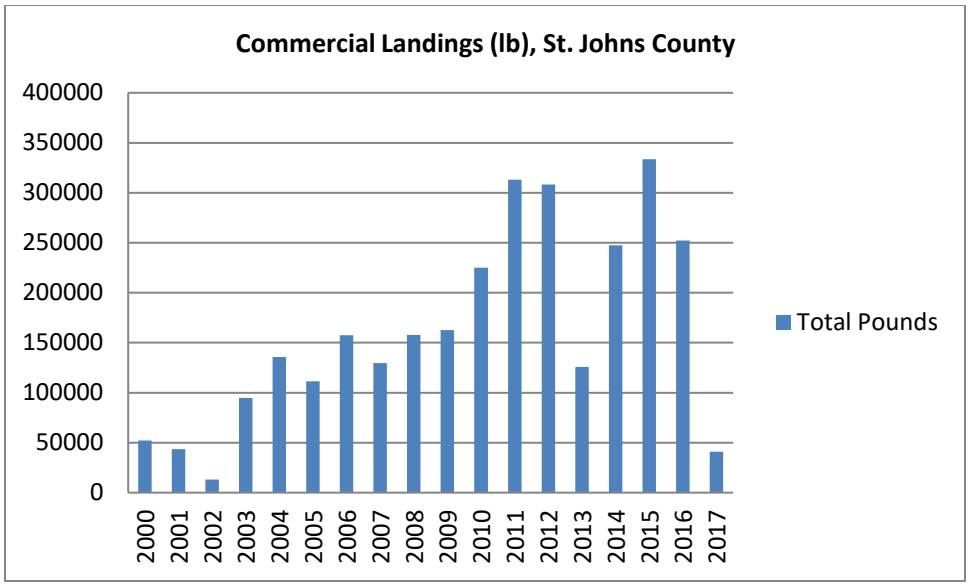


Figure 17 (a). Commercial Landings of White Shrimp in St Johns County

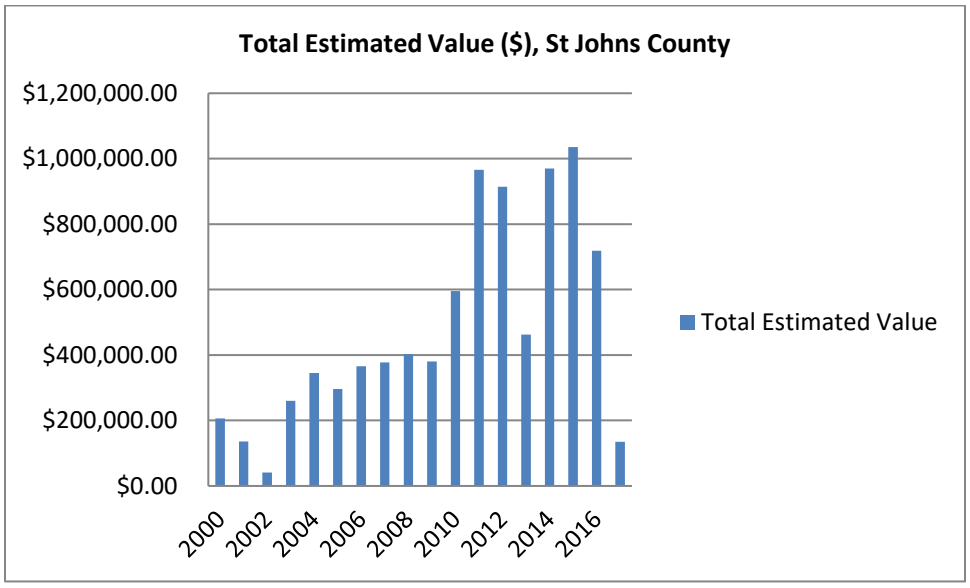


Figure 17 (b). Total Estimated Value of White Shrimp in St Johns County

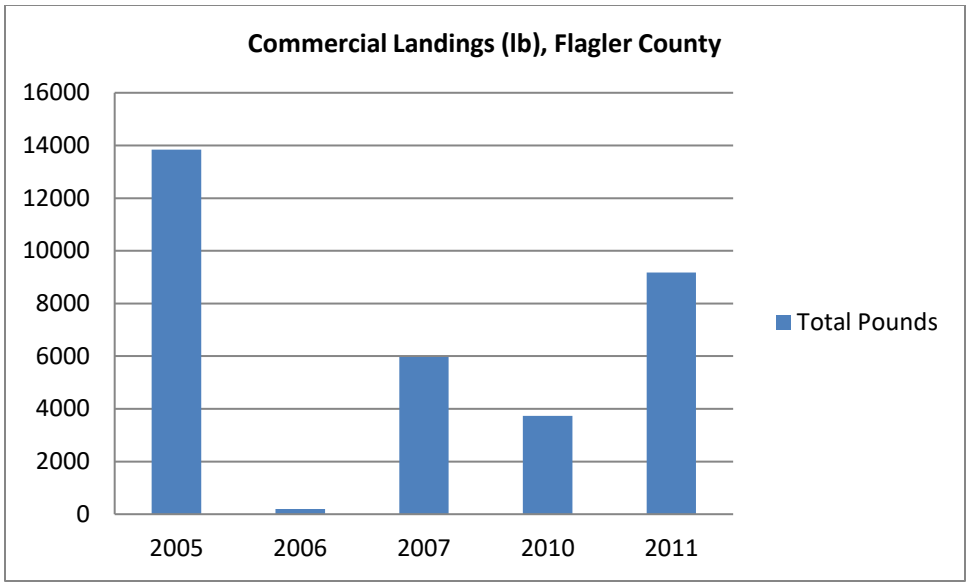


Figure 17 (c). Commercial Landings of White Shrimp in Flagler County

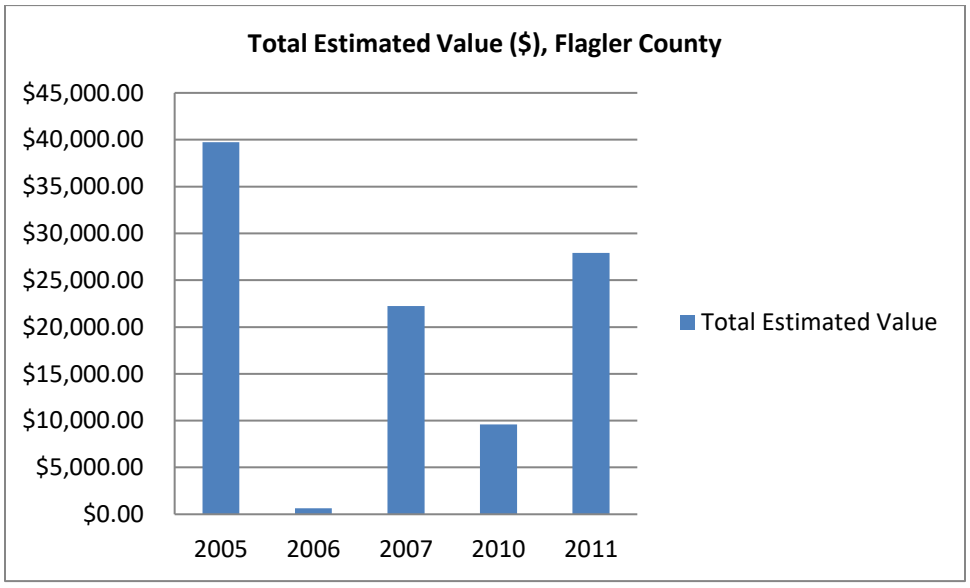


Figure 17 (d). Total Estimated Value of White Shrimp in Flagler County

Table 15 displays a new population parameters file with an adjusted survival matrix based on the Habitat Scenario equation. AOI (Modified) and AOI are two columns show the survival rates after and before the change in the areas of habitats, respectively.

Table 15. Population Parameters Table with Modified Survival Rates

Class	AOI (Modified)	AOI	Duration	VulnFishing	Weight
eggs/larvae	0.675839	0.675839	16	0	0.000175
post-larval	0.889674	0.889674	30	0	0.029036
marsh	0.457295	0.964062	52	0	0.758789
bay	1	0.974910	33	0.109788	4.026686
adult	0.980983	0.980983	234	1	7.454849
Exploitation Fraction	0.064	0.064			

The scenario analysis shows that: A reduction in the estuary area of 10%, and an increase of coastal areas by 10%, will result in a slight increase in the survival rate of the "bay" stage of white shrimp by 3% (1 minus 0.97). However, the diminishing of estuaries significantly affects the survival rate of the "marsh" stage of white shrimp. The survival rate of the "marsh" stage dramatically drops to 45.73%, which will affect the harvest.

In order to study effects of other factors on the white shrimp harvest, further fisheries science expertise will assist in the application of estimation parameters from field analysis and experiments to the population parameters, habitat dependency, and habitat changes tables. In Appendix 2, we attached the data and information needed for the species of Eastern Oyster for further application of the Fisheries model.

Unobstructed Views: Scenic Quality Provision Model

Summary

Scenic amenities play an important role in augmenting Florida economies by attracting visitors who support local businesses. The value of the Pellicer watershed and its tributaries, and other local properties is highly dependent on locational attributes. Scenic views are often correlated with increased property values. This study analyzes two human use features, aquaculture and boat ramp(s), as examples to provide information about potential tradeoffs between nearshore and offshore development proposals and the visual impacts of those projects.

Purpose

The Unobstructed Views: Scenic Quality Provision model determines the locations from which new nearshore or offshore features can be seen. Viewshed maps were generated. These viewshed maps can be used to further identify the visual footprint of new offshore development and the locations of properties whose values may be affected, and provide information about potential tradeoffs between nearshore and offshore development proposals and the visual impacts of those projects.

The model does not quantify economic impacts of altering the viewshed, but it can be adapted to compute viewshed metrics for use in a more detailed valuation study.[37]

Model

Offshore and nearshore development projects, such as boat ramps or aquaculture facilities, have the potential to impact the visual amenities. This model assumes the objects viewed have a negative impact on views. However, positive interpretation of viewing other objects such as beaches and historical sites can be included with the interpretation of model results.

There are two tabs in the model dialogue window. They are the General Tab, which provides the viewshed analysis without valuation, and the Valuation Tab, which provides the valuation-related analysis.

- General Tab

  The General Tab initially performs the visibility calculation, by computing a visibility raster for each point feature x. It follows a simple "line of sight" algorithm, where visibility is computed along the lines originating from the viewpoint to the center of the perimeter raster cells.

- Valuation Tab

  The Valuation Tab applies a valuation function (either logarithmic or third order polynomial for long distance, linear for short distance) across the visibility raster using the distance to the point feature. It returns the value of the total number of points visible from each cell on the land or seascape.

[37] Some features of the scenic quality model created by the InVEST staff, are under development.

Value functions can be chosen from the following three functional forms based on the opinions of field experts.

- Logarithmic:

$$f(x) = a + blog(x)$$

- Third order polynomial:

$$f(x) = a + bx + cx^2 + dx^3$$

- Linear:

$$l = Ax + B$$

x: the distance from the center of each cell to a point feature

$a, b, c, d, A, and\ B$: the coefficients

Each feature in the point shapefile can have a field coefficient, which is used to scale the values returned by the valuation function (weighting process). The weighted raster layers are summed up to produce the visual impact output raster (summation process).

Data and Data Statistics

General Tab (Input should be projected):

- Area(s) of Interest (AOI) (Polygon Shapefile)

The AOI in this study is the Pellicer watershed area and its tributaries.[38] The Polygon shapefile must intersect the local digital elevation model (DEM).

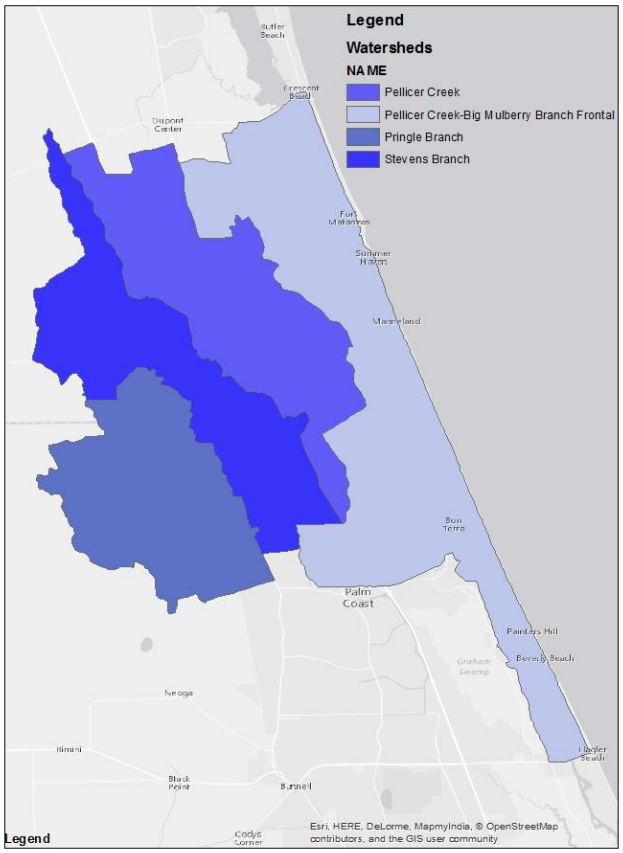


Figure 18. Pellicer Watershed and Its Tributaries

[38] USDA Geospatial Data Gateway: https://datagateway.nrcs.usda.gov/

- Cell Size (Parameter)

75 m. The spatial resolution of results cannot be smaller than the cell size of local DEM, which is 30m in this study. The Default value in InVEST is 500m.

- Features Impacting Scenic Quality (Point Shapefile)

A feature (negatively) impacting scenic quality is a point feature layer that indicates locations of objects that contribute to negative scenic quality, such as aquaculture netpens or boat ramps in this study. Figure 19 displays the human use and socio economic resources points in Florida.[39]

[39] Data source: Human Use and Socio Economic Resource (2013): http://geodata.myfwc.com/

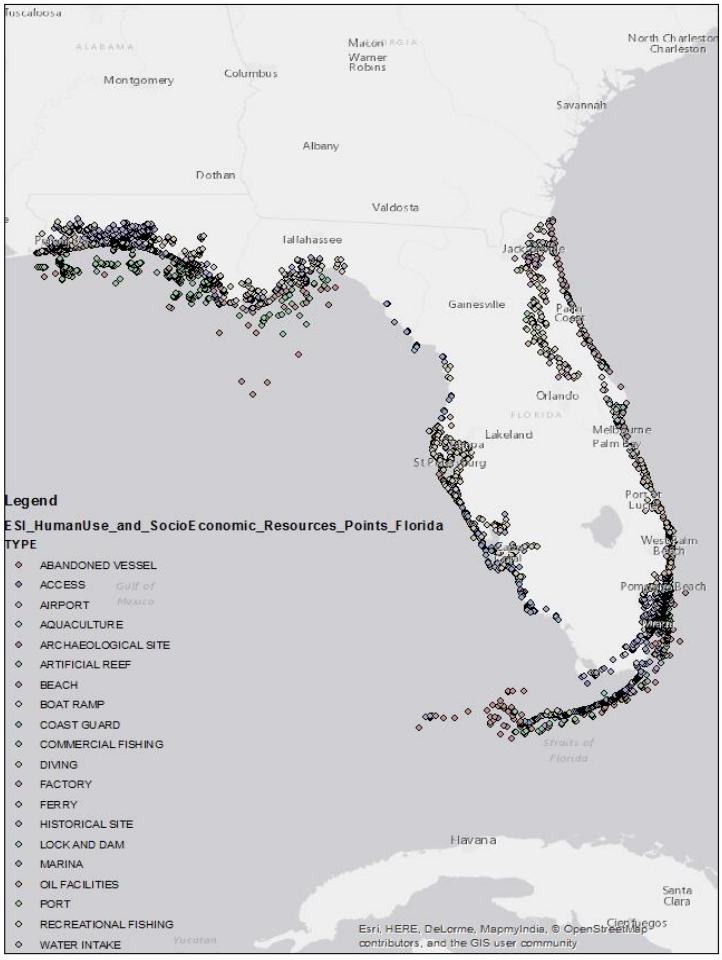


Figure 19. Human Use and SocioEconomic Resources Points in Florida

Features negatively impacting scenic quality, including abandoned vessels, aquaculture, boat ramp, commercial fishing, factory, lock and dam, and oil facilities, are selected. Figure 20 shows those selection features.

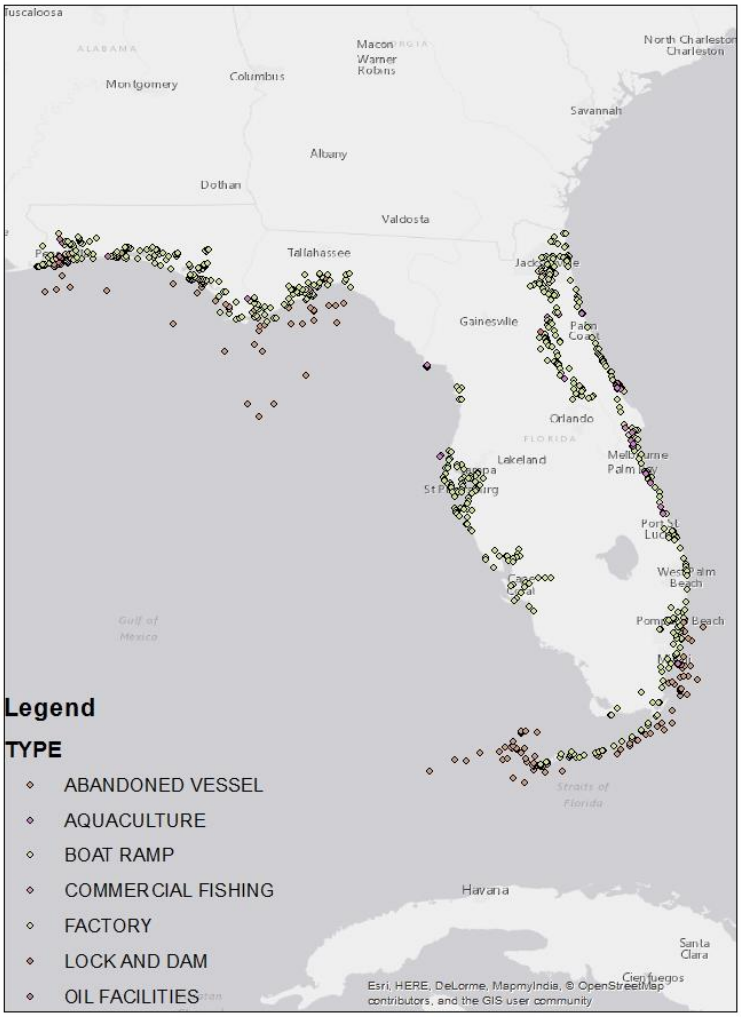


Figure 20. Features Impacting Scenic Quality

Only one aquaculture site and three boat ramp sites fall in the Pellicer watershed area. The model will compute a viewshed for each site separately and aggregate them into a combined viewshed. Three fields can be specified optionally: a maximum viewing distance, viewshed importance coefficient, and viewpoint height. Here we use the default values 8,000m, 1, and 0, respectively. Figure 21 shows the features impacting the scenic quality in the Pellicer watershed area.

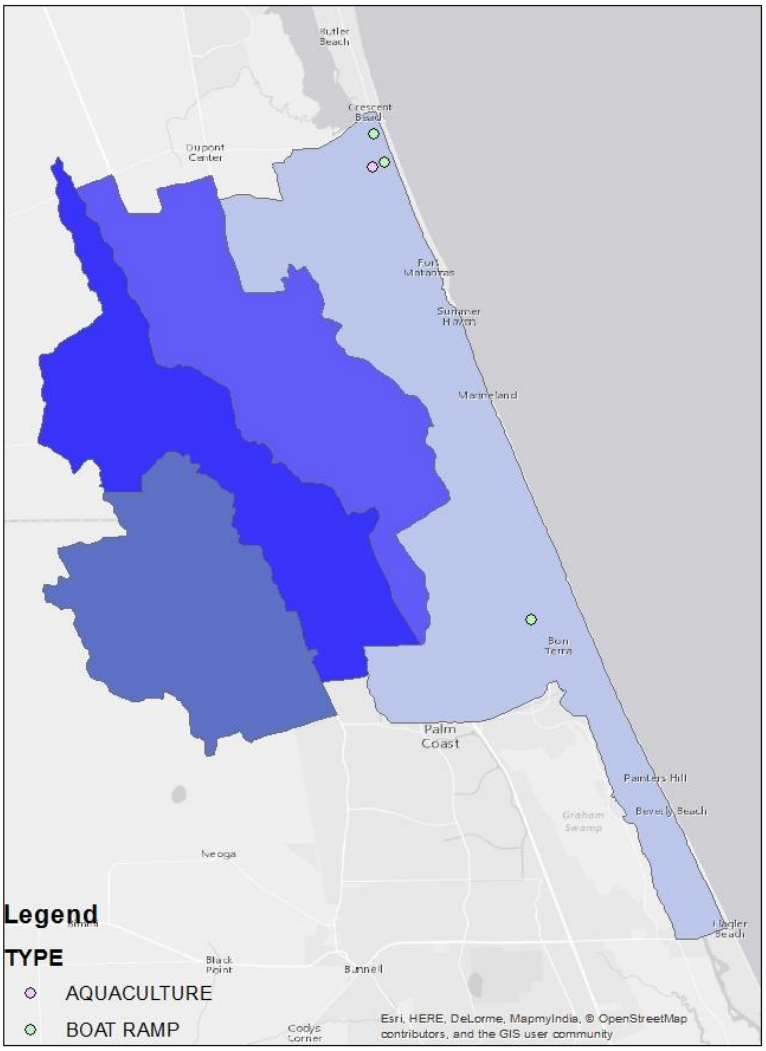
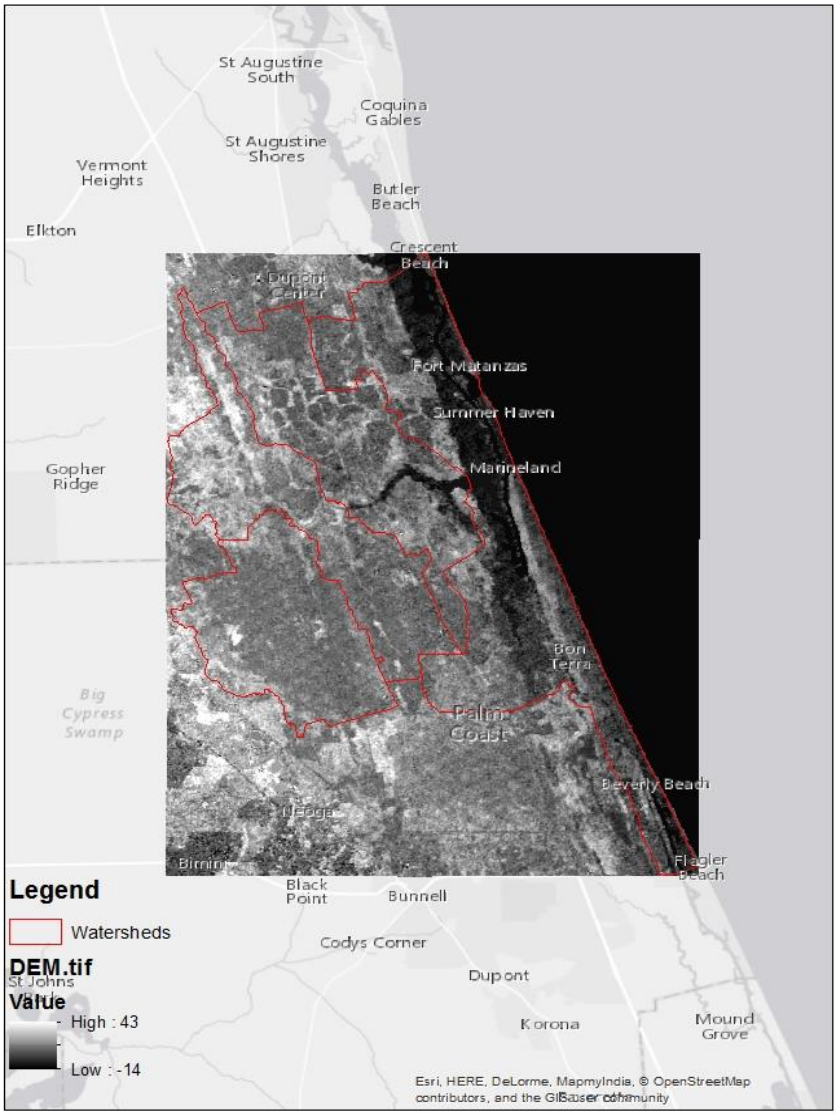


Figure 21. Features Impacting the Scenic Quality in Pellicer Watershed Area

- Local Digital Elevation Model (DEM)

The local DEM is from the United States Geological Survey (USGS) Earth Explore.[40] The data is in the 30m resolution, with SRTM Void Filled. The value of elevation of the raster data ranges from -14m to 43m. Figure 22 displays the local DEM covering the AOI.



[40] Data source: The USGS EarthExplorer: http://earthexplorer.usgs.gov/

Figure 22. Local Digital Elevation Model (DEM) of the Pellicer Watershed Area

- Refractivity Coefficient

The refractivity coefficient is the earth curvature correction option corrects for the curvature of the earth and refraction of visible light in air. It is a value between 0 and 1. This parameter can be estimated from local data. In this study, we use the default parameter with the value 0.13.

- Global (Local) Population (Raster)

The global (local) population raster[41] determines population within the AOI's land-seascape where features are visible and not visible. The density of population is relatively low in the AOI, ranging from 0 to 2,099 per cell. The high density of population appears in the "Residential/Commercial" LU categories in the section of the Land Use (LU) Data and Information on the Pellicer Watershed Area.

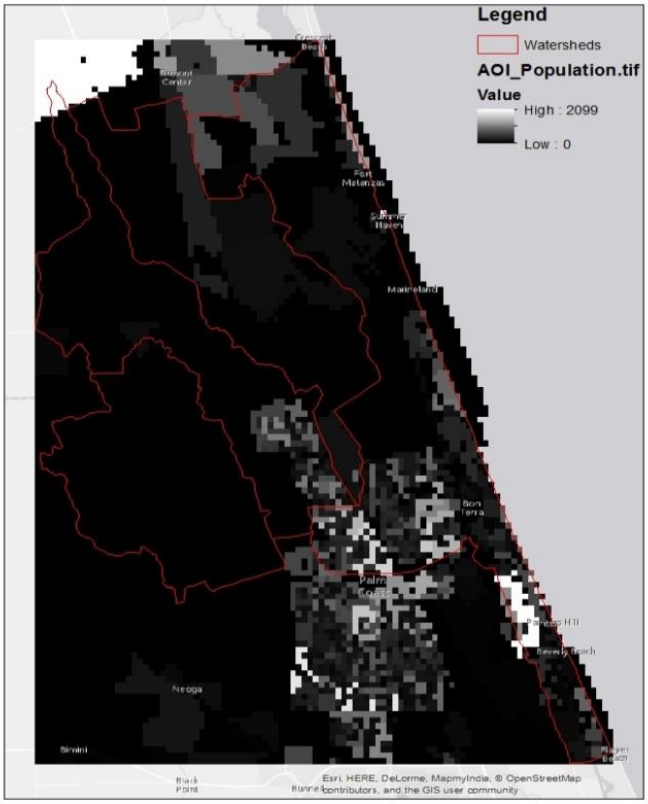
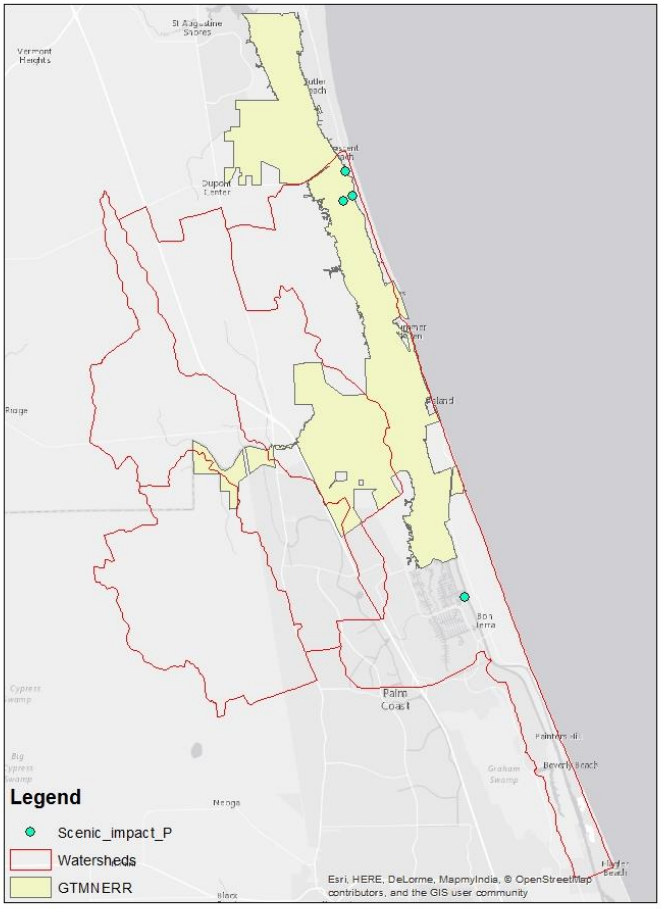


Figure 23. Population Density in the Pellicer Watershed Area

[41] Data source: United States Census Bureau, https://www.census.gov/geo/maps-data/data/tiger.html

- Overlap Analysis Features (Polygon Shapefile, Optional)

In this study, we also analyzed the visual impacts on the AOI where the view is of particular concern (e.g. parks, trails, marine reserves, GTM NERR). Overlap analysis features are polygon layers projected in meters, which are selected to determine the impact of feature points on visual quality. This study uses the data on "NATIONAL ESTUARINE RESEARCH RESERVES (NERR) IN FLORIDA – 2011" from the Florida Geographic Data Library (FGDL).[42] Figure 24 shows parts of the GTM NERR, Pellicer watershed area, and impacting feature points. Three features impacting the scenic quality (one aquaculture and two boat ramps) are in the GTM NERR, and one boat ramp site is outside the area of GTM NERR.



[42] Data source: FDGL, http://www.fgdl.org/metadataexplorer/explorer.jsp

Figure 24. GTM NERR, Pellicer Watershed Area, and Impacting Feature Points

Valuation Tab

In this study, we changed the default setting of the maximum valuation radius which is 8,000m to 500m due to the range of AOI. The Default value function is in the polynomial functional form with coefficient $[a, b, c, d]$ = [1, 0, 0, 0], by assuming the existence of each site has an effect, but the effect does not depend on the distance. Parameters of the effects of viewing distance can also be estimated from real data.

Results, Interpretations, and Preliminary Conclusions

There are four final results in the output folder. Since the Unobstructed Views: Scenic Quality Provision model is still under development by the InVEST group, the project team could only interpret two main results which are currently available in the output folder.

The Overlap Viewshed Map

The output, "vshed", is a valuation raster based on the visual quality at any given pixel. If the valuation is set to the constant 1 (default) independent of the viewing distance, the raster reduces to a record of the number of sites (e.g. boat ramps or aquaculture farms) that are visible from a given raster cell on the land or seascape. It contains values ranging from 0 to the total number of points visible from each cell on the land or seascape. With the default maximum valuation radius 500m, the scenic quality in the Pellicer Creek-Big Mulberry Branch Frontal watershed is highly impacted by the features of aquaculture and boat ramp. Figure 25 shows the total number of points visible from each cell on the land or seascape. The four sites have no scenic quality effect on the cells in the black area. Cells, with values from 1 to 3 can see 1 to 3 obstructed sites, respectively. In Appendix 2,[43] the Viewshed maps for individual sites are included.

[43] Appendix 2: Figure A2 (a) – (d)

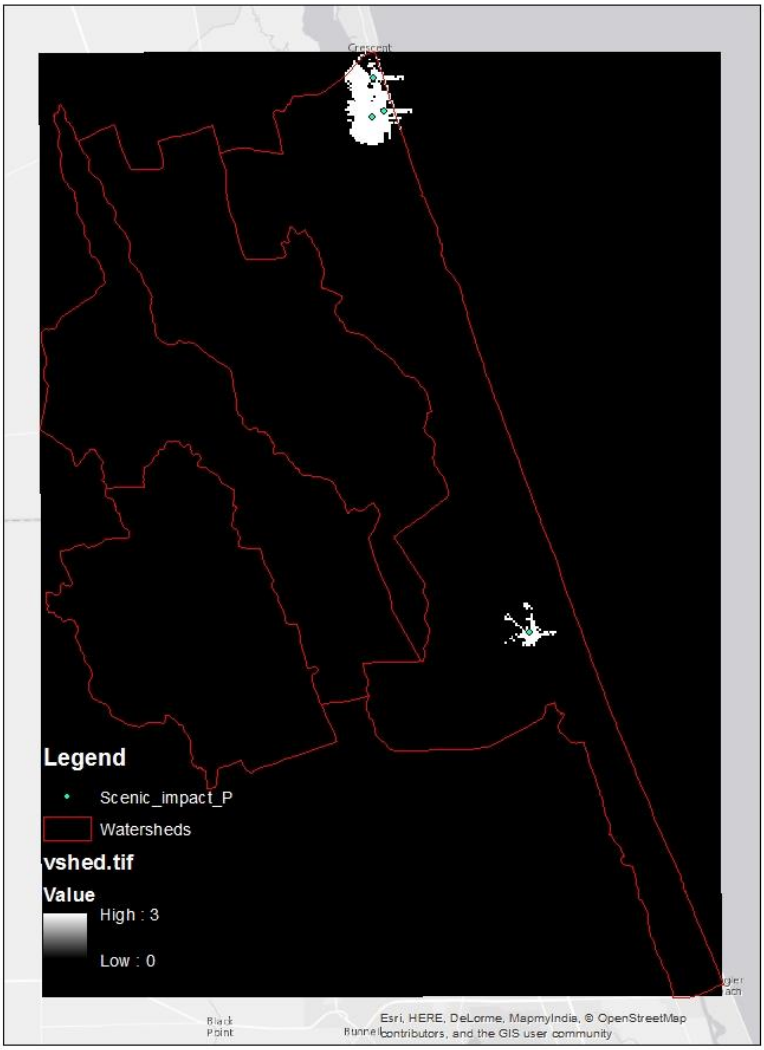


Figure 25. The Total Number of Points Visible from Each Cell on the Land or Seascape

The Visual Impacts on the AOI Where the View is of Particular Concern (GTM NERR)

This polygon feature layer contains a field called “vp_overlap” which expresses the percentage of area within each polygon where at least one point contributing to negative scenic quality is visible as compared to the total area of that polygon. Figure 26 displays the four regions in GTM NERR are negatively affected by the aquaculture and boat ramp features. By examination of *the percentage of area impacted in each region*, areas along the county boundary are significantly affected.

During the analysis, we find that results are significantly affected by cell size, refractivity coefficient, and valuation parameters, which need to be further estimated from empirical data from persons of greater expertise.

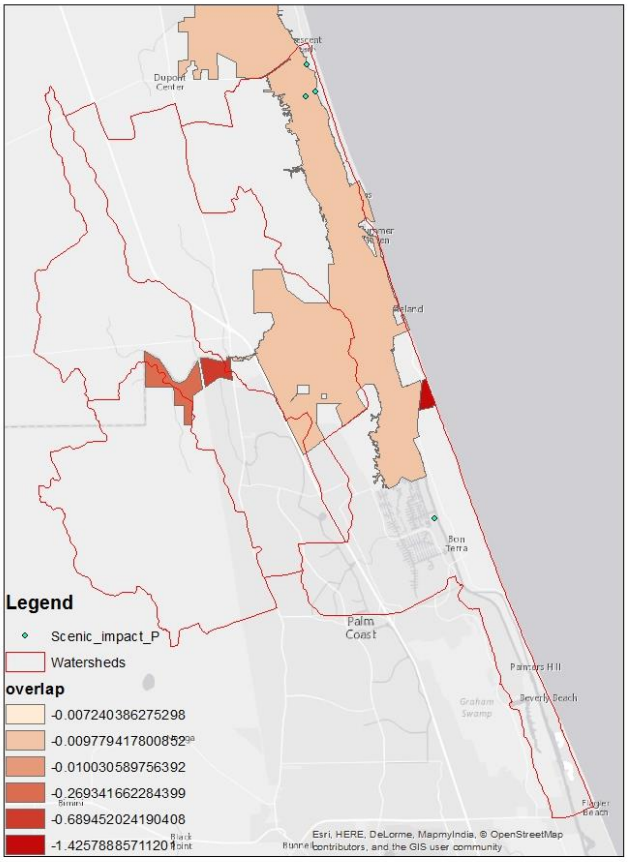


Figure 26. Negative Scenic Quality Area Percentage of Individual Polygon

This study analyzes the visual effects of two human use features, aquaculture and boat ramp(s), on the scenic quality of the Pellicer watershed and its tributaries area. The number of features impacting scenic quality in the area(s) of interest is four, including one aquaculture site and three boat ramp sites. All four sites are located in the Pellicer Creek-Big Mulberry Branch Frontal watershed. Scenic quality in Pellicer Creek-Big Mulberry Branch Frontal watershed is highly impacted by the features of aquaculture and boat ramp. This study also analyzes the visual impacts on parts of the GTM NERR, where the view is of particular concern. The four regions in GTM NERR are negatively affected by the aquaculture and boat ramp features. Depending on the percentage of area impacted in each region, areas along the county boundary will also be significantly affected.

Visitation: Recreation and Tourism Model

Summary

Recreation and tourism are important components of the Florida economy. This study quantifies the tourism value of the Pellicer watershed area and its tributaries. The visitation – recreation and tourism model uses photo-user-days (PUD) as proxies for tourism development. Factors considered that can impact visitation include transportation (airports and roads), development (parks and recreational facilities, hotels, and swimming beaches), and the natural environment (marsh habitat).

Purpose

The Visitation: Recreation and Tourism model quantifies the value of the natural environments and predicts the spread of person-days of recreation.[44]

Model

The mathematical framework applied is a Linear Regression model with cross-sectional data on factors considered that can impact visitation in a specific area.

$$y_i = \beta_0 + \beta_1 x_{i1} + \cdots + \beta_p x_{ip}, for\ i = 1, \cdots, n$$

y_i: the empirical data on visitation for part i in the area of interest (AOI)

x_{ip}: the predictor p of LU type for part i in the area of interest (AOI)

There are three assumptions for the application of the model:

- People's responses to attributes that serve as predictors in the model will not change over time.
- The model does not presuppose that any predictor variable has an effect on visitation.
- The model estimates the magnitude of each predictor's effect based on its spatial correspondence with current visitation in the area of interest.

Data and Data Statistics

Data needed includes the empirical data on visitation (PUD), the area(s) of interest (AOI), the period of analysis, and predictors selected.

- Empirical Data on Visitation:

  The information of PUDs is automatically analyzed by InVEST. It is imported from the website flickr by InVEST directly, including the total number of annual person-days of photographs uploaded to the photo-sharing website flickr.

[44] The optional scenario analysis shows how future changes to natural features will alter visitation rates.

- Area(s) of Interest:

The AOI of this study is the Pellicer watershed area.

- The Period of Analysis:

InVEST provides the information of visitation over the period from years 2005 to 2014. This study chooses the most recent five years, 2011 to 2014, as the period of interest. Figure 27 shows the geographic distribution of average annual PUDs of the four watersheds in the AOI. Figure 28 displays the histograms of the average annual and monthly PUDs of the four watersheds in the AOI.

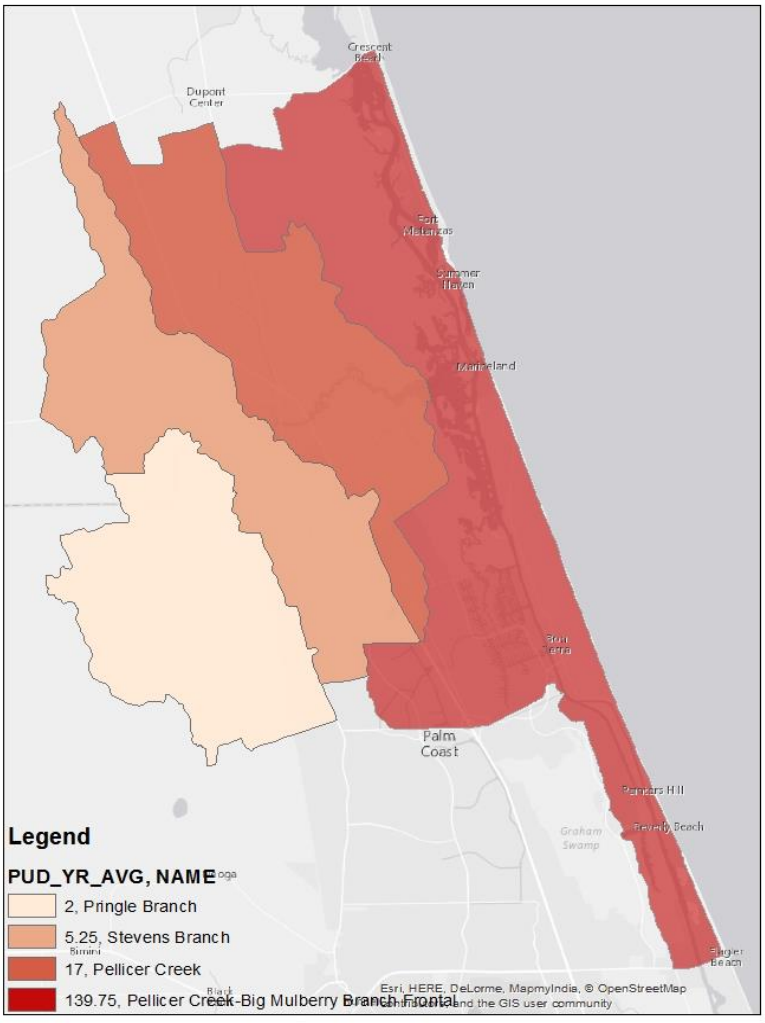
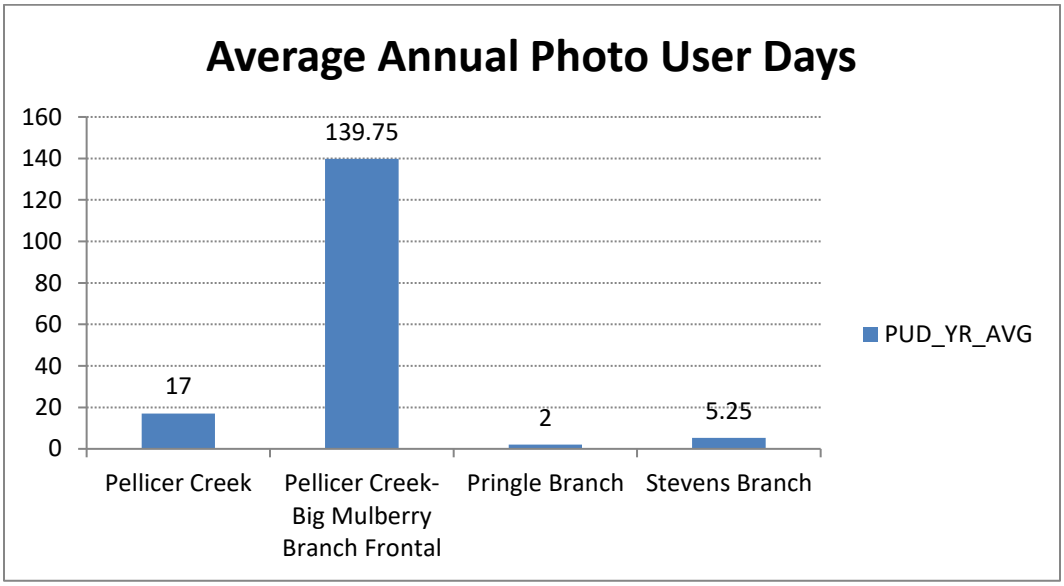


Figure 27. Geographic Distribution of the Annual Average Photo-User-Days (PUDS) in the Pellicer Watershed Area



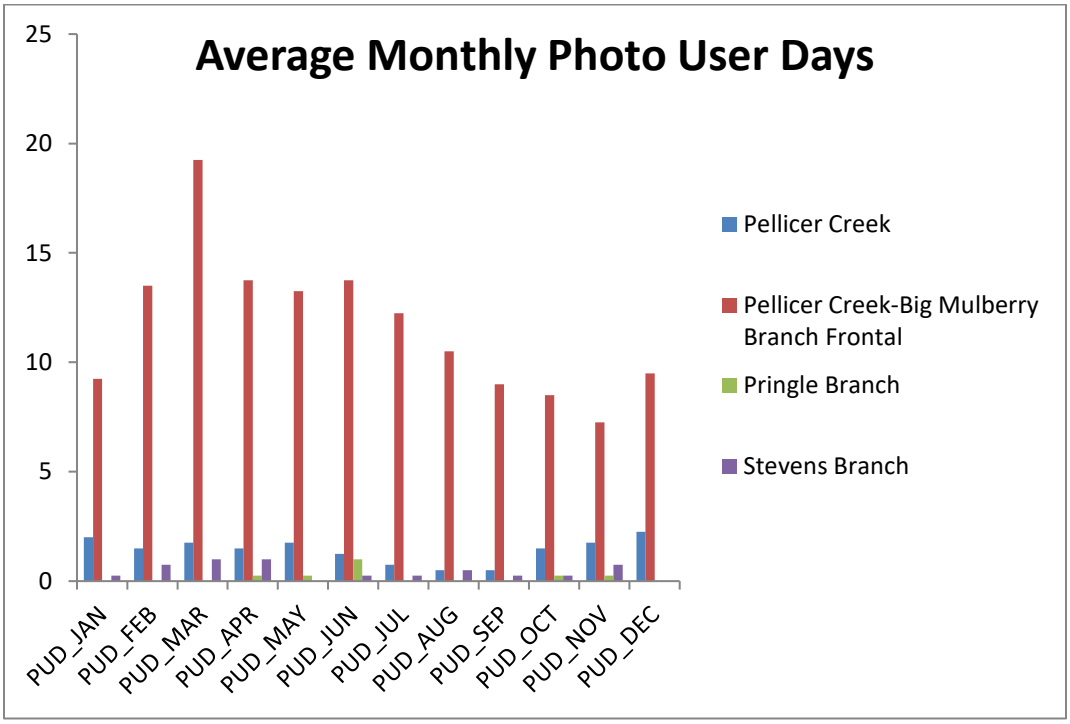


Figure 28. Histogram of the Average Annual and Monthly Photo-User-Days in the Pellicer Watershed Area

The Pellicer Creek-Big Mulberry Branch Frontal Watershed has the highest visitation rates annually and monthly. The average annual visitation measured by PUDs on fliklr is approximately 140. The most popular tourist season for the Pellicer Creek-Big Mulberry Branch Frontal Watershed is March, with approximately 20 average monthly PUD. Ranked second is the Pellicer Watershed, with the 17 average annual PUD and December as the most popular tourist season during winter and spring.

- Predictors:

Predictors are selected based on the research on "frequently asked" questions (FAQs) from Visit Florida, the official tourism marketing corporation for the State of Florida. Research questions of high interest are:

  - Do most visitors come to Florida by car or plane?
  - How many nature parks are in Florida?
  - What activities do Florida visitors participate in the most?
  - How many hotel rooms are in Florida?

Based on those questions, the FSU CEFA study team selected predictors affecting the visitation in the Pellicer watershed area: main highways, airports, the number of parks and recreational facilities, number of hotels, marsh habitat, and swimming beach. Predictors are in shapefile format and collected for the Florida Geographic Data Library (FGDL) and St Johns River Water Management District (SJRWMD) Open Data.[45] Table 16 presents the name, file name, and correlation types with PUD of the predictors. Figure 29 shows the geographic relationships between the AOI and the predictors.

Table 16. Predictor Table

ID	Path	Type
habitats	saltmarshes.shp	polygon_area_coverage
rds	main_hwy.shp	line_inersct_length
hotels	hotel.shp	point_count
airdist	airports.shp	point_nearest_distance
beach	swimbeach.shp	polygon_area_coverage
park_rf	park_rf.shp	point_count

[45] Roads (polyline): FLORIDA DEPARTMENT OF TRANSPORTATION - RCI DERIVED MAJOR HIGHWAYS – 2016, data source: Florida Geographic Data Library (FGDL)
Airports (point): AIRPORTS IN FLORIDA – 2015, data source: Florida Geographic Data Library (FGDL)
Parks and Recreational Facilities (point): PARKS AND RECREATIONAL FACILITIES IN FLORIDA – 2016, data source: Florida Geographic Data Library (FGDL)
Habitats: SALT MARSHES HABITAT IN FLORIDA, data source: St Johns River Water Management District (SJRWMD) Open Data
Beach: SJRWMD LULC – 2012, data source: Florida Geographic Data Library (FGDL)
Hotels: LODGING FACILITIES IN FLORIDA – 2011, data source: Florida Geographic Data Library (FGDL)

The type “polygon_area_coverage” is the area overlap between layers, the type “line_inersct_length” is the total length intersecting of the polyline predictor with the AOI, the type “point_count” is the count of points in the AOI, and the type “point_nearest_distance” is the Euclidean distance between the center of each watershed and the nearest airport point.

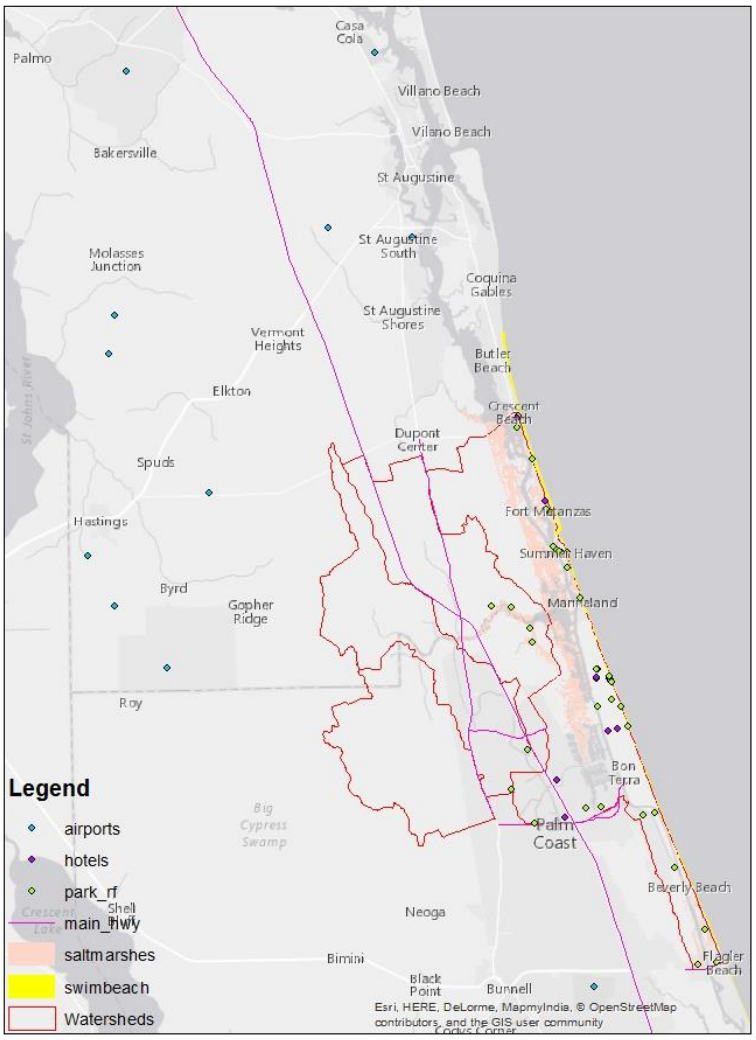


Figure 29. Predictors and the Area(s) of Interest (AOI)

Units: Maps/Display (Meters)

Results, Interpretations, and Conclusions

Table 17 summarizes the estimated coefficients of the regression. Significant coefficients of predictors are highlighted in bold font.

Table 17. Estimated Coefficients of the Regression

Watershed	Roads: the total length intersecting	Airports: the Euclidean distance between the center of each watershed and the nearest airport	Parks and Recreational Facilities: the count of points	Salt Marshes Habitats: the area overlap between layers	Swimming Beach: the area overlap between layers	Hotels: the count of points
Pellicer Creek	**0.233**	0.082	**4**	0	0	0
Pellicer Creek-Big Mulberry Branch Frontal	0.088	0.059	**33**	0.001	0	**7**
Pringle Branch	0.008	**0.100**	0	0	0	0
Stevens Branch	**0.152**	0.075	**2**	0	0	0

The results show the following:

Roads: I-95, Palm Coast Pkwy, Hammock Dunes Bridge, Matanzas Woods Pkwy, Moody Blvd, US 1/SR 5, and US 1. The length of roads intersecting with watersheds has significant impacts on the visitation of Pellicer Creek and Stevens Branch Watershed. Everything else constant, 1,000 more meters of intersection of the main highways can increase the average annual PUD by 233, and 152, respectively.

Airports: The distance of the nearest airport has positive effects on the visitation of Pringle Branch Watershed. With less disturbance from the airports, i.e. 1,000 meters further from the center of the Pringle Branch Watershed, the number of visitation will increase by 100 average annual PUDs.

Parks and recreational facilities: The number of park and recreational facilities is an important driving factor for the development of tourism in Pellicer Creek-Big Mulberry Branch Frontal. One more park or recreational facility can increase the time of visitation dramatically in the Pellicer Creek-Big Mulberry

Branch Frontal Watershed by 33 average annual PUDs. This number for Pellicer Creek Watershed and Stevens Branch Watershed are 4, and 2, respectively.

Marsh Habitat: The overlap area of marsh habitat has no significant impact on the visitation of all watersheds.

Hotels: The number of hotels is also a major factor for the development of tourism in Pellicer Creek-Big Mulberry Branch Frontal. Everything else constant, one more hotel increases 7 average annual PUDs in Pellicer Creek-Big Mulberry Branch Frontal.

Swimming beaches: We expected the area overlap between the AOI and the swimming beach has significant positive effect on visitation. Because of the limitation of the data, the overlap area on the map is relatively small. The results of the regression in this study is insignificant.

Vulnerability and Economic Assessment

In this section, the research team firstly examined the Vulnerability Hotspots tool (Kernel Density tool) in the Spatial Analysis in ArcGIS 10.3.1[46], by answering the questions in the vulnerability assessment approach introduced by Hammill et al. (2013). Answering the following questions help make the vulnerability assessment, a very broader concept, more specific to this study.

- Which system: What is the social/socio/ecological system being threatened?

The system being threatened is the ecological system.

- Feature of concern: What is the valued feature within the vulnerable system that is potentially threatened (e.g. specific crop, human health)?

The value feature of the vulnerable system potentially being threatened are the just values of the corresponding LU parcels in various classifications defined by Florida Department of Revenue (FDOR).

- Type of hazard: What is the potentially damaging influence, which may adversely affect the valued feature of the system (e.g. changes in precipitation and temperature and its consequences like droughts or floods)?

The threats are from the analysis in the Habitat Quality model. They are four invasive species plants chosen by the GTM NERR environmental experts. The potentially damaging influence is endangering the biodiversity in the Pellicer watershed area.

- Temporal reference: What is the period of interest? Is the assessment considering current vulnerability of future vulnerability?

Based on the information of data on threats and LUs, the period of interest (POI) is the time till the year 2016. The assessment is considering current vulnerability.

The study team combined the Risk Hazard and the Political Economy approach. By choosing the indicators of threats and by analyzing the vulnerability hotspots from individual threat of invasive species in the Habitat Quality model, the study team gave the top ranking of priority conservation areas (parcels) with the main determinants of vulnerability, and the corresponding LU classifications, acreage, and just values.

Figures 30 to 33 display the density of invasive plants calculated by the Kernel Density tool. There is no item or special value used for the calculation. Each feature is counted once. Areas impacted are the intersection of the Pellicer watershed area and the vulnerability hotspots area. The relative level of impacts is decreasing as the color of the mapped hotspots becomes brighter. Figures 34 to 37 show the LU parcels located in each invasive plant area (Figures are shown in the order of importance). Table 18 shows the acreage and JVs of LU parcels corresponding to each invasive plant.

[46] How the Kernel Density tool in ArcGIS 10.3.1 works: http://pro.arcgis.com/en/pro-app/tool-reference/spatial-analyst/how-kernel-density-works.htm.

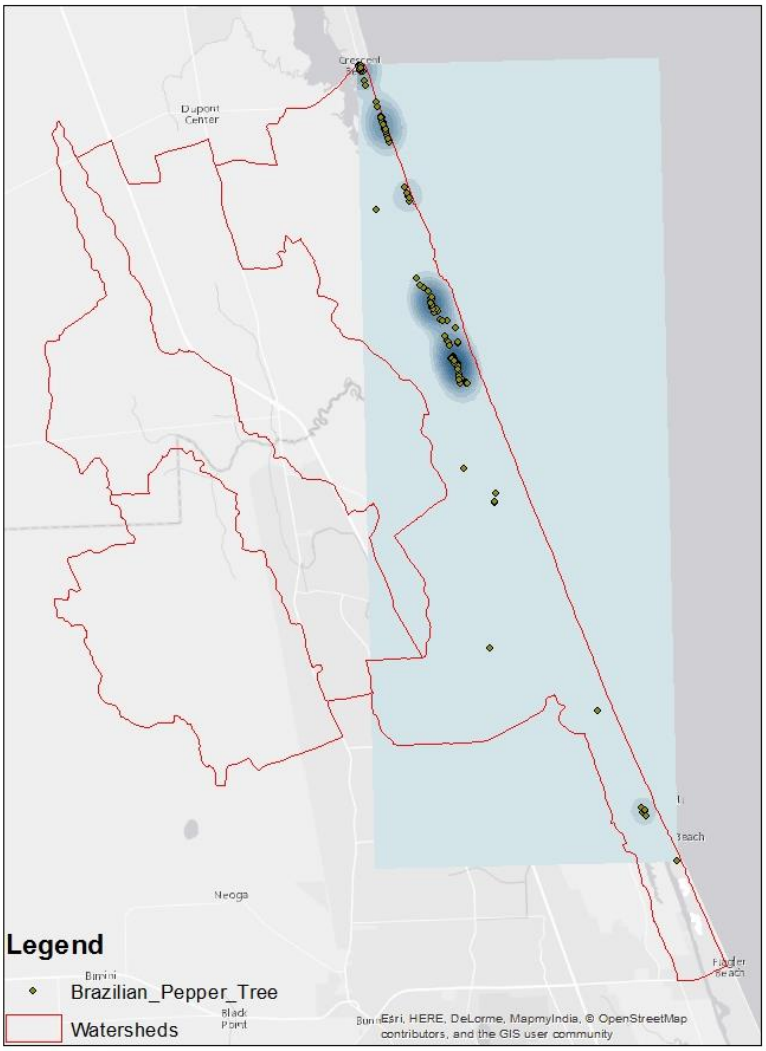


Figure 30. The Vulnerability Hotspots of Brazilian Peppertree

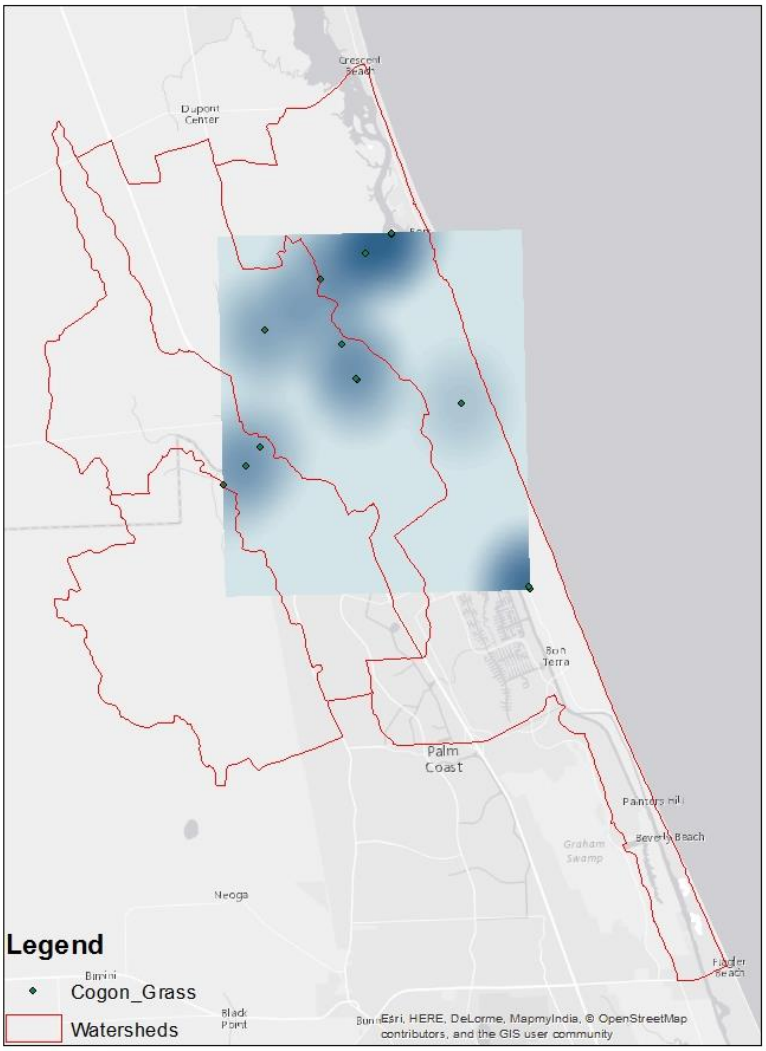


Figure 31. The Vulnerability Hotspots of Cogongrass

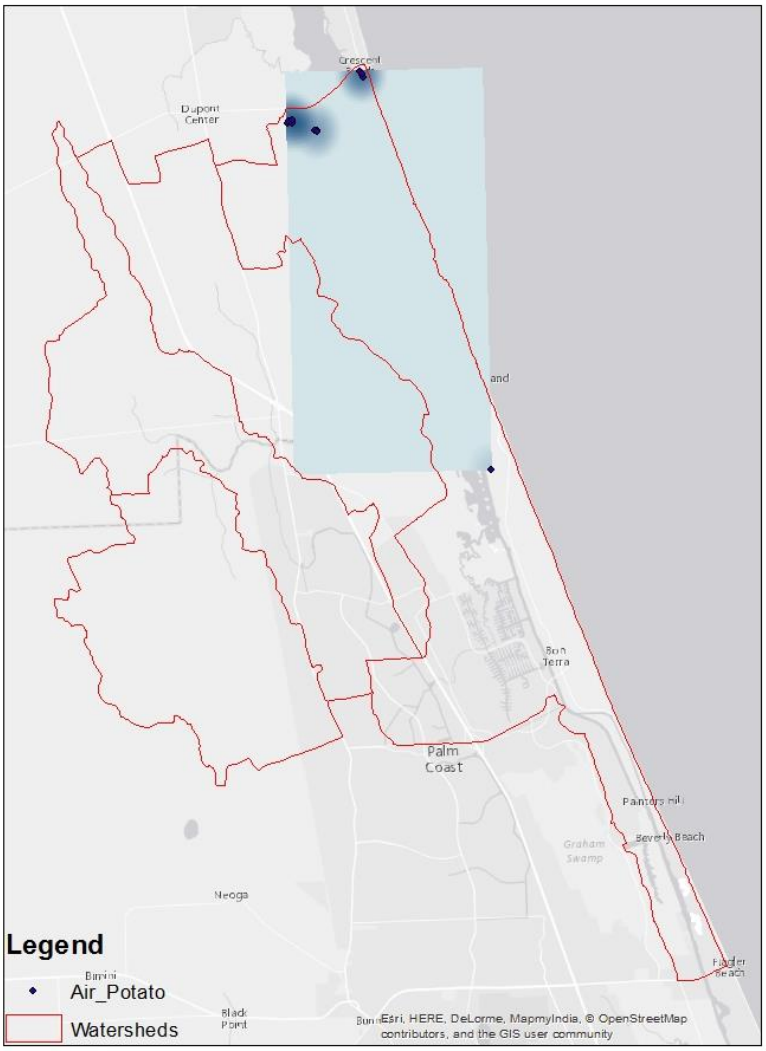


Figure 32. The Vulnerability Hotspots of Air-Potato

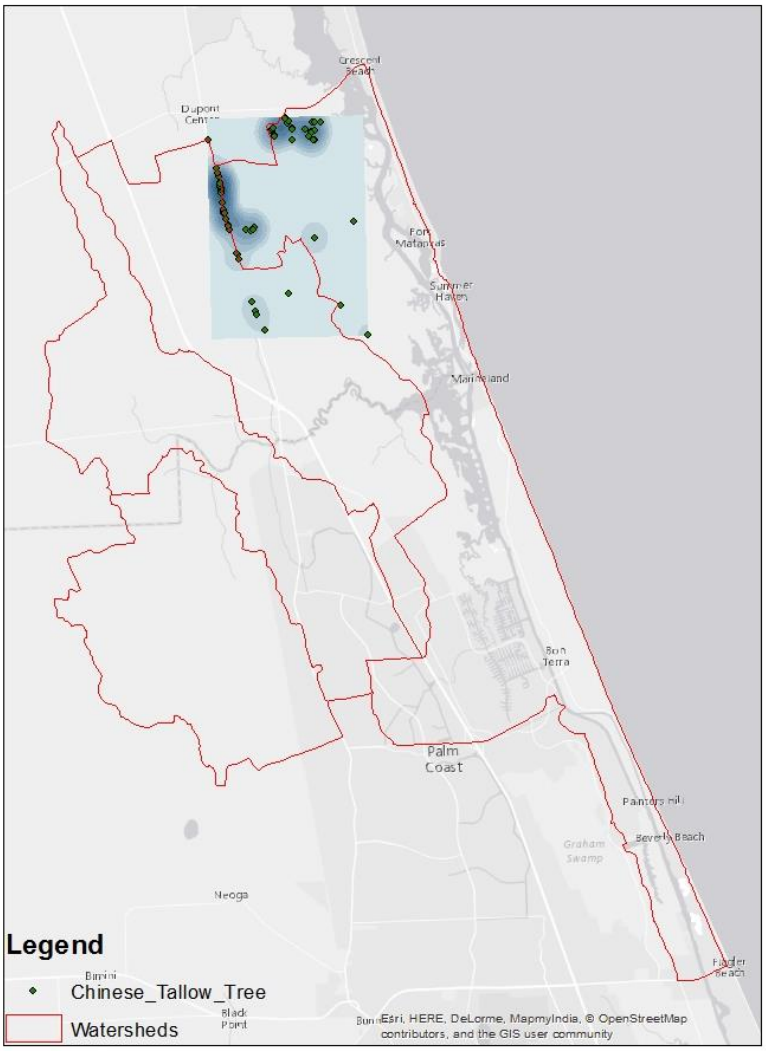


Figure 33. The Vulnerability Hotspots of Chinese Tallow Tree

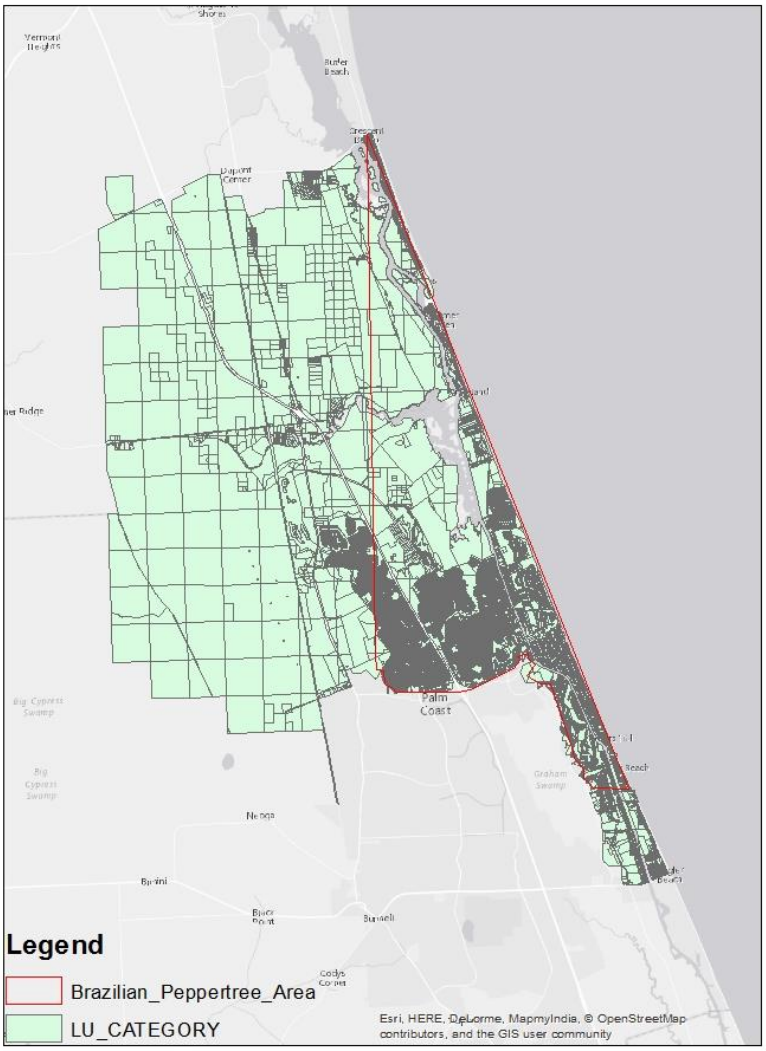


Figure 34. Land Use (LU) Parcels in the Brazilian Peppertree Effects Area

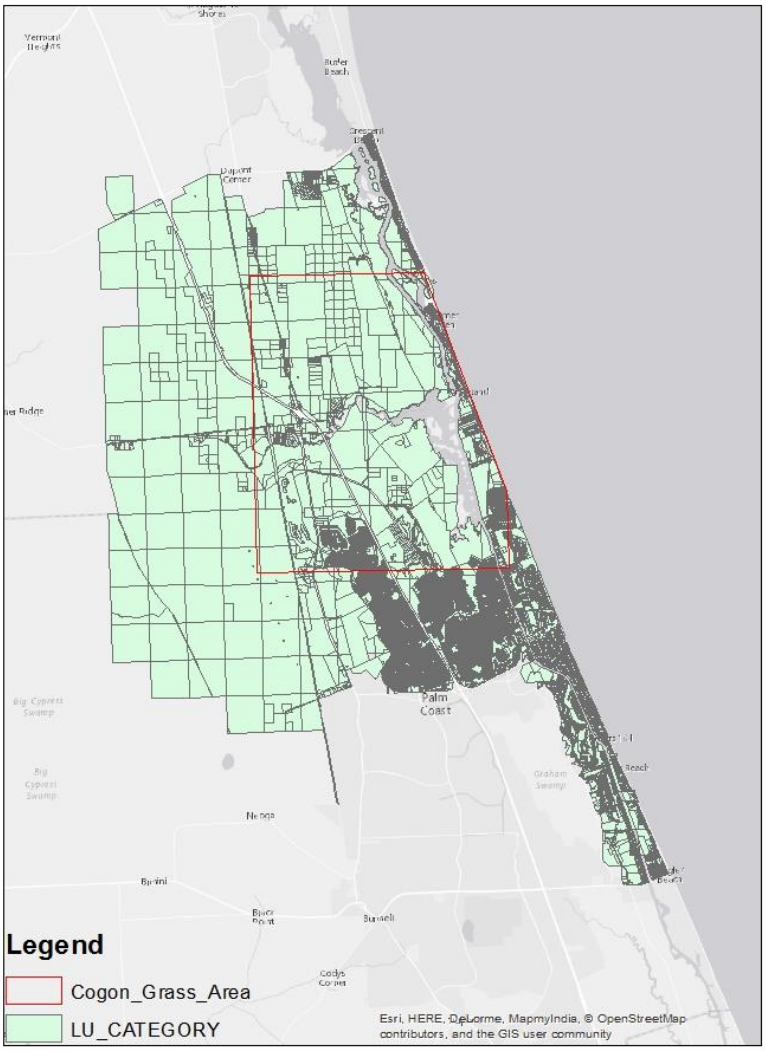


Figure 35. Land Use (LU) Parcels in the Cogongrass Effects Area

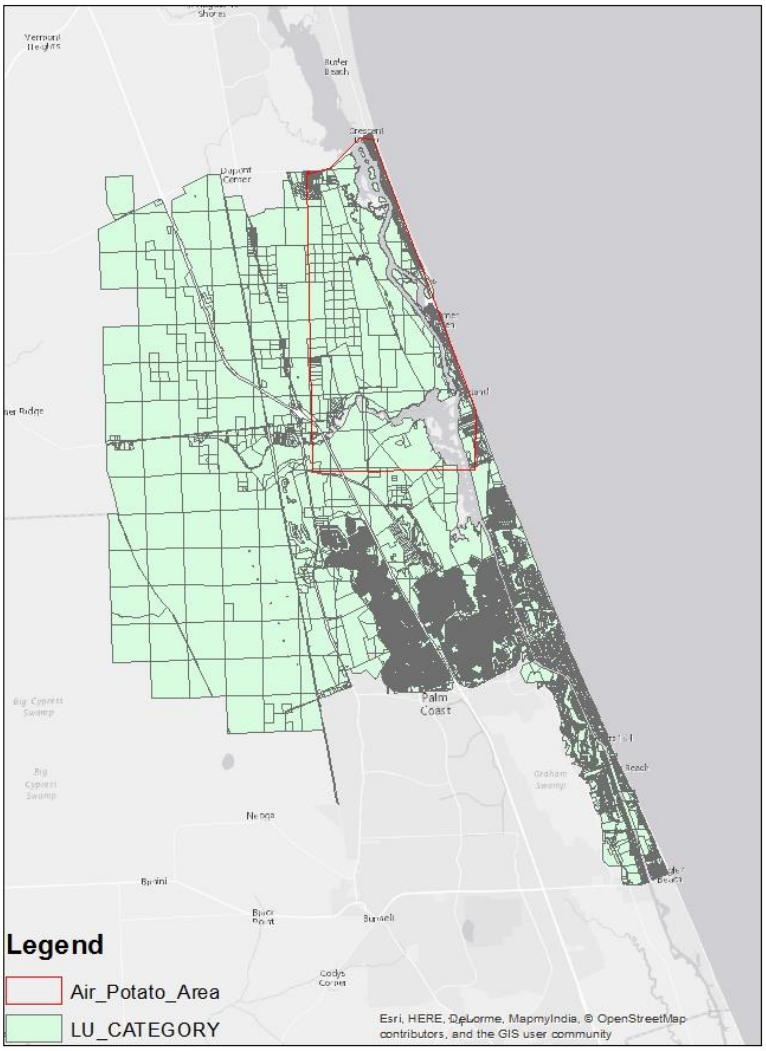


Figure 36. Land Use (LU) Parcels in the Air-potato Effects Area

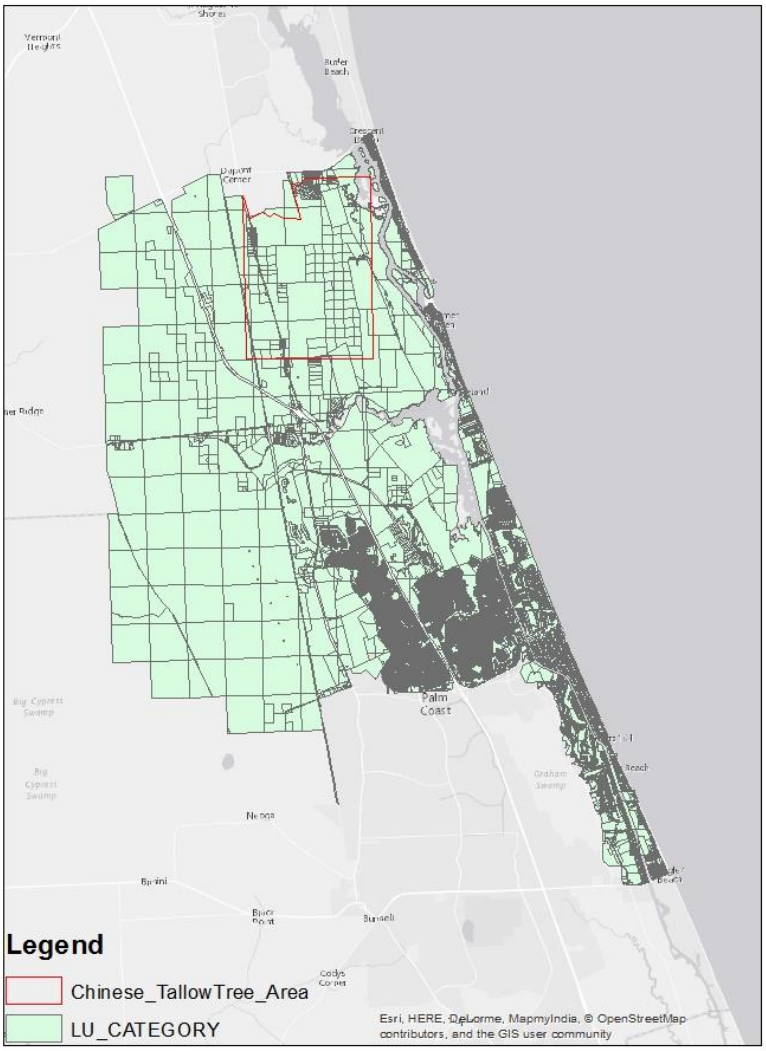


Figure 37. Land Use (LU) Parcels in the Chinese Tallow Tree Effects Area

Table 18. The Determinants of Vulnerability and the Corresponding Parcel Acreage and Just-value

Determinants of Vulnerability	Total Parcel Acreage Affected	Total Parcel JVs
Brazilian Peppertree	38,657.04	$5,172,143,751
Cogongrass	64,679.28	$1,241,911,011
Air-potato	65,880.39	$848,201,562
Chinese Tallow Tree	50,552.68	$131,949,217

The total parcel JV's ranking is consistent with the experts' list concerning the order of importance. The LU parcels corresponding to the Brazilian Peppertrees effect area has the highest JV, $5,172,143,751. The LU parcels corresponding to the Air-potato effect area has the highest parcel acreage which is 65,880,39. Appendix 1[47] summaries the use code, use description, the acreage, and the just-value of LU parcels intersection with each invasive plant area. Table 19 shows the top-three ranking LU classifications based on the land parcel JVs.

For the species of Brazilian Peppertree and Cogongrass, the LU classification "001: Single Family", "004: Condominiums", and "000: Vacant Residential – with/without extra features" in the "Residential" category, comprise the top-three rankings of JV.

The vulnerability hotspots area of Air-potato and Chinese Tallow Tree are mainly located in the area of St. Johns County in the Pellicer Watershed, where the acreage of LU parcels of "Agricultural" and "Governmental" categories comprise the majority of the total acreage. The corresponding JVs have relatively large portions of the total JV. The top four LU classifications are: "001: Single Family" and "000: Vacant Residential – with/without extra features", the LU classification "055: Timberland - site index 80 to 89" in the "Agricultural" category and "087: State, other than military, forests, parks, recreational areas, colleges, hospitals" in the "Governmental" category, are top-ranking in JVs as well.[48]

[47] Appendix 1, Table A4 –A7.
[48] For parcel owners' detail, please contact FSU CEFA at http://www.cefa.fsu.edu/contact-cefa.

Table 19. The Top-Three Ranking Land Use (LU) Classifications in Each Invasive Plant Area

Invasive Plant	LU Classification	Ranking	Acreage	Acreage Percentage	Just-value	Just-value Percentage
Brazilian Peppertree	001: Single Family	1	3,845.88	9.95%	$3,419,332,194	66.11%
	004: Condominiums	2	0.00	0.00%	$807,518,995	15.61%
	000: Vacant Residential – with/without extra features	3	1,754.50	4.54%	$350,852,324	6.78%
Cogongrass	001: Single Family	1	1,082.26	1.67%	$664,845,785	53.53%
	004: Condominiums	2	0.00	0.00%	$127,987,400	10.31%
	000: Vacant Residential – with/without extra features	3	997.80	1.54%	94,790,913	7.63%
Air-potato	001: Single Family	1	857.20	1.30%	$494,131,336	58.26%
	087: State, other than military, forests, parks, recreational areas, colleges, hospitals	2	45,661.35	69.31%	$84,806,426	10.00%
	000: Vacant Residential – with/without extra features	3	304.40	0.46%	$65,353,692	7.70%
Chinese Tallow Tree	087: State, other than military, forests, parks, recreational areas, colleges, hospitals	1	37,365.00	73.91%	$64,456,422	48.85%
	001: Single Family	2	195.54	0.39%	$26,269,470	19.91%
	055: Timberland - site index 80 to 89	3	5817.05	11.51%	$11,485,145	8.70%

Conclusions and Results

In 2016, the FDEP GTM NERR commissioned the Florida State University Center for Economic Forecasting and Analysis (FSU CEFA) to conduct an economic valuation and assessment analysis study of the Pellicer watershed area and its tributaries in order to provide local planners and other stakeholders with information on the value of the Pellicer estuarine ecosystem. FSU CEFA initially conducted an extensive literature review of the ecosystem services valuation software in order to determine, in concert with the GTM NERR, the model that would be most suitable for this study. The study team chose the Integrated Valuation of Ecosystem Services and Tradeoffs model (InVEST), a multi-service system that allows for trade-off analysis. The study team also examined the LU classifications by various categories of the Pellicer watershed area, by county, parcel number, acreage, just-value (JV), and the LU features of Flagler County and St. Johns County, in order to recommend suitable ecosystem valuation data for the InVEST model.

According to the Florida Department of Revenue (FDOR) County Property Appraiser Data for 2016, the LU patterns are analyzed by separating the entire Pellicer watershed area and its tributaries into the Flagler county and the St. Johns county sections. “Residential” and “Commercial” categories comprise the majority of the parcel number and the JV’s for both counties (96.98%, and 94.68%, respectively, for Flagler County, and 82.18%, and 78.15%, respectively, for St. Johns County). The “Agricultural” category encompasses large portions of the total acreages in both Flagler County and St. Johns County (37.43%, and 52.23%, respectively). The “Government” LU category, with the second top percentage relative to acreage, had the same pattern with “Agricultural” category for both counties. As the Pellicer watershed area is expected to almost double in population growth by year 2040, further LU decisions will place substantial pressure on this area. The larger average LU needs, by category (FDOR code), are expected to be in: “Residential” (000 – 009), “Commercial” (010 – 039), “Agricultural” (050 – 069), and “Governmental” (080 – 089).

The study team examined four models using InVEST based on the GTM NERR researchers’ priority and the availability of data for the Pellicer watershed area. The four models were: Habitat Quality, Fisheries, Unobstructed Views: Scenic Quality Provision and Visitation: Recreation and Tourism. Based on the input provided by the GTM NERR and the project team, and preliminary results of the InVEST, FSU CEFA provided an on-site training to GTM NERR staff and other FDEP participants that demonstrated the functions of the InVEST model. The training was held at the FDEP office’s computer lab, in Tallahassee. The training on the InVEST model included providing a training manual, two lectures of representative models (Habitat Quality and Visitation: Recreation, and Tourism), and organizing a practice/discussion session. The project team trainer collected and summarized comments and suggestions from GTM NERR researchers for further data refinement, and identification and ranking of priority conservation areas in the Pellicer watershed area.

Results

The Habitat Quality model estimates the extent of habitat and vegetation types across a landscape, and their state of degradation. The model uses habitat quality and rarity as proxies for biodiversity. Based on the threats chosen, the general relative level of degradation of LU parcels in Flagler County is high compared with that of LU parcels in St. Johns County. For LU parcels of "Agricultural" in Flagler County, which are adjacent to main highways US-1 and I-95, as well as the LU parcels of "Residential" and "Commercial" have high degradation levels. Parcels belonging to LU of "Governmental" in St Johns County, which are at the boundary of St. Johns County and Flagler County, are with higher degradation levels and vulnerable to the effects of roads and invasive species. Habitat quality is the ability of the ecosystem to provide conditions appropriate for individual and population persistence. It is represented by a continuous variable on a scale from 0 to 1 in the model, ranging from *low to medium to high*. LU parcels in Flagler County have relative low habitat quality because of a high percent acreage of "Residential" and "Commercial" LU parcels: 28.05%. This leads to *low - medium* and *medium* habitat quality of the adjacent parcels of "Governmental". The parcels of "Agricultural" in Flagler County display *medium – high* and *high* habitat quality. For the two main LU categories "Agricultural" and "Governmental" in St. Johns County, the parcels of "Agricultural" show high habitat quality, and the parcels of "Governmental" display *medium – high* and *high* habitat quality.

The Fisheries model produced estimates of the harvest volume and economic value for the "commercial landings of white shrimp" and showed the impact of changes in habitat on the production of wild fish in the Pellicer watershed area. The estimated harvest of white shrimp in the areas of Pellicer Watershed and its tributaries was 8,662 pounds (3,897,715 g), with the simple estimated value $9,316. Compared with the commercial landings and estimated values of St Johns County and Flagler County, the estimated harvest was reflective of a reasonable interval. The scenario analysis showed that a reduction in the estuary area of 10% and an increase of coastal areas by 10% would result in a slight increase in the survival rate of the "bay" stage of white shrimp by 3%. However, the diminishing of estuaries significantly affects the survival rate of the "marsh" stage of white shrimp. The survival rate of the "marsh" stage dramatically drops to 45.73%, which would affect the harvest. The results of this analysis provided useful implications on the impacts to the marine or aquatic ecosystems for decision makers. The methodology in the Fisheries model can be applied to the estimates of other single-species fisheries.

The Unobstructed Views: Scenic Quality Provision model determined the locations from which new nearshore or offshore features can be seen, by analyzing two human use features, aquaculture and boat ramp(s), as example, and by generating viewshed maps that can be used to further identify the visual footprint of new offshore development. It provided information about potential tradeoffs between nearshore and offshore development proposals and the visual impacts of those projects. Based on the features selected, scenic quality in the Pellicer Creek-Big Mulberry Branch Frontal watershed is highly impacted. Locations of development feature sites can be used for further research questions concerning home sale prices.

The Visitation: Recreation and Tourism Model quantified the value of the natural environments and predicted the spread of person-days of recreation by using photo-user-days (PUD) as proxies for tourism

development. Factors considered that can impact visitation include transportation (airports and roads), development (parks and recreational facilities, hotels, and swimming beaches), and the natural environment (habitat). The impacts of the number of parks and recreational facilities and the number of hotels on the Pellicer Creek-Big Mulberry Branch Frontal watershed are significant. With everything else being constant, one more park or recreational facility can increase the time of visitation dramatically in Pellicer Creek-Big Mulberry Branch Frontal Watershed by 33 annual PUD. And one more hotel increases 7 annual PUD in Pellicer Creek-Big Mulberry Branch Frontal Watershed by 33 annual PUD. The overlap area of marsh habitat has no significant impact on the visitation of all watersheds.

The Vulnerability and Economic Analysis were conducted based on the inputs and results of the InVEST models and economic statistics of the DOR LU parcels. The results of the vulnerability and economic valuation assessment show that the LU classifications “001: Single Family”, “004: Condominiums”, and “000: Vacant Residential – with/without extra features” in the “Residential” category have the highest JVs in the vulnerable area to the invasive species Brazilian Peppertree and Cogongrass. The vulnerable areas of Air-potato and Chinese Tallow Tree are mainly located in the area of St. Johns County in the Pellicer watershed area. The most vulnerable LU classifications, which comprise the top-three ranking, are “001: Single Family”, “000: Vacant Residential – with/without extra features”, “055: Timberland - site index 80 to 89” in “Agricultural” category, and “087: State, other than military, forests, parks, recreational areas, colleges, hospitals” in “Governmental” category.

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Appendix 1

Table A1. Land Uses and Definitions and Land Use Classification, Nonrenewable Empower Density, and Resulting LDI Coefficients in Brown and Vivas (2005)

LU Classification and LDI in Brown, M.T. & Vivas, B. M. (2005)			
Land Use	Non-renewable Empower Density (E14/sej/ha/yr)	Ln Non-renewable empower density	LDI (on a scale 1 - 10)
Natural system	0.00		1.00
Natural open water	0.00		1.00
Pine/tree plantation	5.10	1.63	1.58
Recreational/open space - low intensity	6.55	1.88	1.83
Woodland pasture (with livestock)	8.00	2.08	2.02
Improved pasture (without livestock)	17.20	2.84	2.77
Improved pasture - low intensity (with livestock)	33.31	3.51	3.41
Citrus	44.00	3.78	3.68
Improved pasture - high intensity (with livestock)	46.74	3.84	3.74
Row crops	107.13	4.67	4.54
Single family residential - low density	1077.00	6.98	6.90
Recreational/open space - high intensity	1230.00	7.11	6.92
Agricultural - high intensity	1349.20	7.21	7.00
Single family residential - medium density	2175.00	7.68	7.47
Single family residential - high density	2371.80	7.77	7.55
Mobile home - medium density	2748.00	7.92	7.70
Highway - 2 lanes	3080.00	8.03	7.81
Low intensity commercial	3758.00	8.23	8.00
Institutional	4042.20	8.30	8.07
Highway - 4 lanes	5020.00	8.52	8.28
Mobile home - high density	5087.00	8.53	8.29
Industrial	5210.60	8.56	8.32
Multi-family residential - low rise	7391.50	8.91	8.66
High intensity commercial	12661.00	9.45	9.18
Multi-family residential - high rise	12825.00	9.46	9.19
CBD - average 2 stories	16150.30	9.69	9.42
CBD - average 4 stories	29401.30	10.29	10.00

Table A2. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area

Table 1. Pellicer Watershed Parcels and Acreage in the Pellicer Watershed Area, Flagler County and St. Johns County Sections of the Pellicer Watershed Area, by Department of Revenue Use Code

Use Code	Use Description	Flagler County			St. Johns County		
		Number of Parcels	Total Acres by Use	Total Just-Value by Use ($)	Number of Parcels	Total Acres by Use	Total Just-Value by Use ($)
	Residential						
000	Vacant Residential – with/without extra features	7,681	2,050.3	$ 334,372,076	293	369.1	$ 40,194,749
001	Single Family	16,971	3,895.4	$ 3,512,614,740	686	693.5	$ 303,112,735
002	Mobile Homes	189	31.2	$ 10,252,026	92	104.5	$ 5,151,719
003	Multi-family - 10 units or more	2	40.0	$ 11,179,078			
004	Condominiums	3,358	0.0	$ 834,998,135			
005	Cooperatives	251	0.0	$ 19,492,250			
006	Retirement Homes not eligible for exemption						
007	Miscellaneous Residential (migrant camps, boarding homes, etc.)	287	83.0	$ 60,652,973			
008	Multi-family - fewer than 10 units	282	73.6	$ 39,238,265	45	134.3	$ 21,496,303
009	Residential Common Elements/Areas	513	1,597.4	$ -	109	195.3	$ -
	Commercial						
010	Vacant Commercial - with/without extra features	141	1,154.8	$ 32,784,433	22	73.4	$ 3,221,093
011	Stores, one story	17	43.1	$ 14,621,328	8	9.2	$ 1,985,545
012	Mixed use - store and office or store and residential combination	13	46.1	$ 8,542,398	1	4.3	$ 351,406
013	Department Stores						
014	Supermarkets						
015	Regional Shopping Centers						
016	Community Shopping Centers	13	47.9	$ 26,722,458			
017	Office buildings, non-professional service buildings, one story	250	35.4	$ 26,137,001	2	1.1	$ 408,828
018	Office buildings, non-professional service buildings, multi-story	12	19.0	$ 9,023,515			
019	Professional service buildings	18	8.7	$ 7,642,164			
020	Airports (private or commercial), bus terminals, marine terminals, piers, marinas	6	46.8	$ 5,987,181	3	5.3	$ 2,573,342
021	Restaurants, cafeterias	8	7.7	$ 5,229,524	3	0.9	$ 1,098,701
022	Drive-in Restaurants	4	5.6	$ 3,133,740			
023	Financial institutions (banks, saving and loan companies, mortgage companies, credit services)	6	6.6	$ 4,293,528			
024	Insurance company offices						
025	Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats	2	1.1	$ 451,350	1	4.7	$ 140,875
026	Service stations				1	1.0	$ 107,891

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027	Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment, mobile home sales, motorcycles, construction vehicle sales	6	5.9	$ 2,156,955	1	2.0	$ 301,248
028	Parking lots (commercial or patron), mobile home parks	13	60.2	$ 8,237,159	3	5.8	$ 1,663,224
029	Wholesale outlets, produce houses, manufacturing outlets						
030	Florists, greenhouses	1	0.9	$ 160,318			
031	Drive-in theaters, open stadiums						
032	Enclosed theaters, enclosed auditoriums						
033	Nightclubs, cocktail lounges, bars	1	0.1	$ 159,426	1	0.5	$ 173,796
034	Bowling alleys, skating rinks, pool halls, enclosed arenas	1	6.0	$ 771,165			
035	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)	7	37.4	$ 9,043,202			
036	Camps						
037	Race tracks (horse, auto, or dog)						
038	Golf courses, driving ranges	9	1,511.6	$ 14,432,264			
039	Hotels, motels	4	12.3	$ 3,967,619	2	2.6	$ 1,546,188
	Industrial						
040	Vacant Industrial -with/without extra features	12	113.3	$ 1,848,023			
041	Light manufacturing, small equipment manufacturing plants, small machine shops, instrument manufacturing, printing plants	12	28.1	$ 5,092,906			
042	Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants	2	43.8	$ 6,187,500			
043	Lumber yards, sawmills, planing mills						
044	Packing plants, fruit and vegetable packing plants, meat packing plants				1	5.0	$ 230,225
045	Canneries, fruit and vegetable, bottlers and brewers, distilleries, wineries						
046	Other food processing, candy factories, bakeries, potato chip factories						
047	Mineral processing, phosphate processing, cement plants, refineries, clay plants, rock and gravel plants						
048	Warehousing, distribution terminals, trucking terminals, van and storage warehousing	7	20.8	$ 4,583,407			
049	Open storage, new and used building supplies, junk yards, auto wrecking, fuel storage, equipment and material storage						
	Agricultural						
050	Improved agricultural	6	164.5	$ 2,318,432			
051	Cropland soil capability Class I						
052	Cropland soil capability Class II						
053	Cropland soil capability Class III						
054	Timberland - site index 90 and above						
055	Timberland - site index 80 to 89	66	11,524.0	$ 41,426,629	78	16,494.4	$ 34,174,626
056	Timberland - site index 70 to 79	22	1,929.5	$ 15,354,566	11	1,918.3	$ 6,218,072
057	Timberland - site index 60 to 69						

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058	Timberland - site index 50 to 59						
059	Timberland not classified by site index to Pines	7	733.6	$ 7,213,242	8	1,246.0	$ 1,390,295
060	Grazing land soil capability Class I	3	96.5	$ 1,306,355			
061	Grazing land soil capability Class II						
062	Grazing land soil capability Class III				6	107.6	$ 920,071
063	Grazing land soil capability Class IV						
064	Grazing land soil capability Class V						
065	Grazing land soil capability Class VI						
066	Orchard Groves, citrus, etc.						
067	Poultry, bees, tropical fish, rabbits, etc.				1	120.2	$ 1,385,889
068	Dairies, feed lots						
069	Ornamentals, miscellaneous agricultural				7	34.3	$ 703,115
	Institutional						
070	Vacant Institutional, with or without extra features	2	5.6	$ 146,910			
071	Churches	13	87.0	$ 21,036,750	1	29.9	$ 1,431,421
072	Private schools and colleges	1	2.8	$ 1,132,867			
073	Privately owned hospitals						
074	Homes for the aged	15	6.8	$ 4,139,639			
075	Orphanages, other non-profit or charitable services				1	46.3	$ 329,826
076	Mortuaries, cemeteries, crematoriums	1	0.1	$ 1,968	1	4.3	$ 41,605
077	Clubs, lodges, union halls	5	26.9	$ 3,255,076			
078	Sanitariums, convalescent and rest homes						
079	Cultural organizations, facilities						
	Governmental						
080	Vacant Governmental - with/without extra features for municipal, counties, state, federal properties and water management district (including DOT/State of Florida retention and/or detention areas)						
081	Military						
082	Forest, parks, recreational areas	11	450.5	$ 549,448	17	1,568.9	$ 25,239,500
083	Public county schools - including all property of Board of Public Instruction	9	281.4	$ 61,704,294			
084	Colleges (non-private)	1	5.4	$ 4,038,599	1	1.3	$ 561,002
085	Hospitals (non-private)						
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	91	4,047.2	$ 24,766,933	27	431.1	$ 5,622,990
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	43	3,432.0	$ 19,036,274	52	10,515.5	$ 17,243,377
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	10	176.4	$ 2,004,558	7	1,509.2	$ 4,863,089
089	Municipal, other than parks, recreational areas, colleges, hospitals	354	2,325.7	$ 21,291,290	6	102.4	$ 847,493
	Miscellaneous						
090	Leasehold interests (government-owned property leased by a non-governmental lessee)						

091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	22	19.0	$ 957,592	7	30.1	$ 890,398
092	Mining lands, petroleum lands, or gas lands						
093	Subsurface rights						
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	122	238.1	$ 16,831,842	19	71.5	$ 629,487
095	Rivers and lakes, submerged lands	84	290.8	$ 476,078			
096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	3	41.7	$ 6,883,244	9	224.3	$ 54,645
097	Outdoor recreational or parkland, or high-water recharge subject to classified use assessment				8	1,668.6	$ 1,214,092
	Centrally Assessed						
098	Centrally assessed	1	0.0	$ 5,061,098			
	Non-Agricultural Acreage						
099	Acreage not zoned agricultural - with/without extra features	11	1,682.1	$ 2,919,287	8	403.7	$ 3,254,872
		31,002	**38,601.9**	**$ 5,287,861,078**	**1,549**	**38,140.3**	**$ 490,773,733**

Table A3. Land Use (LU) Classification and Relating Values in the Raster Map

LULC	NAME
1	Timberland - site index 80 to 89
2	Vacant Commercial - with/without extra features
3	Municipal, other than parks, recreational areas, colleges, hospitals
4	Churches
5	State, other than military, forests, parks, recreational areas, colleges, hospitals
6	Federal, other than military, forests, parks, recreational areas, hospitals, colleges
7	Vacant Residential – with/without extra features
8	Rivers and lakes, submerged lands
9	Residential Common Elements/Areas
10	Condominiums
11	Single Family
12	Miscellaneous Residential (migrant camps, boarding homes, etc.)
13	Counties (other than public schools, colleges, hospitals) including non-municipal government
14	Acreage not zoned agricultural - with/without extra features
15	Public county schools - including all property of Board of Public Instruction
16	Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants
17	Light manufacturing, small equipment manufacturing plants, small machine shops, instrument manufacturing, printing plants
18	Warehousing, distribution terminals, trucking terminals, van and storage warehousing
19	Right-of-way, streets, roads, irrigation channel, ditch, etc.
20	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication
21	Timberland - site index 70 to 79
22	Grazing land soil capability Class I
23	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps
24	Golf courses, driving ranges
25	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)
26	Office buildings, non-professional service buildings, one story
27	Airports (private or commercial), bus terminals, marine terminals, piers, marinas
28	Office buildings, non-professional service buildings, multi-story
29	Colleges (non-private)
30	Mixed use - store and office or store and residential combination
31	Parking lots (commercial or patron), mobile home parks
32	Clubs, lodges, union halls
33	Community Shopping Centers
34	Bowling alleys, skating rinks, pool halls, enclosed arenas

LULC	NAME
35	Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment, mobile home sales, motorcycles, construction vehicle sales
36	Professional service buildings
37	Stores, one story
38	Financial institutions (banks, saving and loan companies, mortgage companies, credit services)
39	Restaurants, cafeterias
40	Multi-family - fewer than 10 units
41	Homes for the aged
42	Drive-in Restaurants
43	Private schools and colleges
44	Forest, parks, recreational areas
45	Vacant Industrial -with/without extra features
46	Timberland not classified by site index to Pines
47	Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats
48	Multi-family - 10 units or more
49	Nightclubs, cocktail lounges, bars
50	Hotels, motels
51	Improved agricultural
52	Centrally assessed
53	Mobile Homes
54	Cooperatives
55	Vacant Institutional, with or without extra features
56	Mortuaries, cemeteries, crematoriums
57	Florists, greenhouses
58	Orphanages, other non-profit or charitable services
59	Ornamentals, miscellaneous agricultural
60	Packing plants, fruit and vegetable packing plants, meat packing plants
61	Outdoor recreational or parkland, or high-water recharge subject to classified use assessment
62	Orchard Groves, citrus, etc.
63	Service stations
64	Poultry, bees, tropical fish, rabbits, etc.

Table A4. Land Use (LU) Classifications in the Brazilian Peppertree Area

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
000	Vacant Residential – with/without extra features	1754.50	$350,852,324	4.54%	6.78%
001	Single Family	3845.88	$3,419,332,194	9.95%	66.11%
002	Mobile Homes	31.20	$10,252,026	0.08%	0.20%
003	Multi-family - 10 units or more	40.00	$10,700,000	0.10%	0.21%
004	Condominiums	0.00	$807,518,995	0.00%	15.61%
005	Cooperatives	0.00	$19,492,250	0.00%	0.38%
007	Miscellaneous Residential (migrant camps, boarding homes, etc.)	75.40	$56,744,076	0.20%	1.10%
008	Multi-family - fewer than 10 units	89.87	$57,500,278	0.23%	1.11%
009	Residential Common Elements/Areas	1718.58	$-	4.45%	0.00%
010	Vacant Commercial - with/without extra features	499.17	$17,051,814	1.29%	0.33%
011	Stores, one story	46.05	$15,936,973	0.12%	0.31%
012	Mixed use - store and office or store and residential combination	46.07	$8,542,398	0.12%	0.17%
016	Community Shopping Centers	36.90	$20,905,458	0.10%	0.40%
017	Office buildings, non-professional service buildings, one story	22.05	$24,720,220	0.06%	0.48%
018	Office buildings, non-professional service buildings, multi-story	19.00	$9,023,515	0.05%	0.17%
019	Professional service buildings	8.54	$7,189,533	0.02%	0.14%
020	Airports (private or commercial), bus terminals, marine terminals, piers, marinas	53.13	$9,043,578	0.14%	0.17%
021	Restaurants, cafeterias	8.14	$5,663,638	0.02%	0.11%
022	Drive-in Restaurants	5.60	$3,133,740	0.01%	0.06%
023	Financial institutions (banks, saving and loan companies, mortgage companies, credit services)	6.09	$3,966,053	0.02%	0.08%
027	Auto sales, auto repair and storage, auto service shops, body and fender shops, commercial garages, farm and machinery sales and services, auto rental, marine equipment, trailers and related equipment, mobile home sales, motorcycles, construction vehicle sales	5.06	$1,882,353	0.01%	0.04%
028	Parking lots (commercial or patron), mobile home parks	92.00	$14,913,871	0.24%	0.29%
030	Florists, greenhouses	0.92	$160,318	0.00%	0.00%

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
033	Nightclubs, cocktail lounges, bars	0.46	$173,796	0.00%	0.00%
034	Bowling alleys, skating rinks, pool halls, enclosed arenas	5.96	$771,165	0.02%	0.01%
035	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)	37.42	$9,043,202	0.10%	0.17%
038	Golf courses, driving ranges	1511.61	$14,432,264	3.91%	0.28%
039	Hotels, motels	12.71	$5,355,188	0.03%	0.10%
042	Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants	4.26	$1,198,408	0.01%	0.02%
048	Warehousing, distribution terminals, trucking terminals, van and storage warehousing	10.95	$2,729,102	0.03%	0.05%
050	Improved agricultural	66.93	$478,418	0.17%	0.01%
056	Timberland - site index 70 to 79	24.50	$87,770	0.06%	0.00%
059	Timberland not classified by site index to Pines	0.00	$81,700	0.00%	0.00%
060	Grazing land soil capability Class I	20.45	$106,575	0.05%	0.00%
070	Vacant Institutional, with or without extra features	0.03	$125	0.00%	0.00%
071	Churches	46.59	$11,618,096	0.12%	0.22%
074	Homes for the aged	4.64	$3,099,746	0.01%	0.06%
076	Mortuaries, cemeteries, crematoriums	0.08	$1,968	0.00%	0.00%
077	Clubs, lodges, union halls	26.94	$3,255,076	0.07%	0.06%
082	Forest, parks, recreational areas	1981.78	$46,543,120	5.13%	0.90%
083	Public county schools - including all property of Board of Public Instruction	281.42	$61,704,294	0.73%	1.19%
084	Colleges (non-private)	11.74	$6,843,609	0.03%	0.13%
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	4857.91	$51,157,921	12.57%	0.99%
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	11426.52	$19,322,426	29.56%	0.37%
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	5593.00	$15,762,132	14.47%	0.30%

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
089	Municipal, other than parks, recreational areas, colleges, hospitals	1921.83	$17,385,125	4.97%	0.34%
091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	14.15	$898,537	0.04%	0.02%
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	310.25	$17,612,197	0.80%	0.34%
095	Rivers and lakes, submerged lands	272.33	$452,407	0.70%	0.01%
096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	1781.82	$7,277,424	4.61%	0.14%
099	Acreage not zoned agricultural - with/without extra features	26.63	$226,355	0.07%	0.00%
Total		38657.04	$5,172,143,751	100.00%	100.00%

Table A5. Land Use (LU) Classifications in the Cogongrass Area

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
000	Vacant Residential – with/without extra features	997.80	$94,790,913	1.54%	7.63%
001	Single Family	1082.26	$664,845,785	1.67%	53.53%
002	Mobile Homes	66.45	$7,244,846	0.10%	0.58%
004	Condominiums	0.00	$127,987,400	0.00%	10.31%
007	Miscellaneous Residential (migrant camps, boarding homes, etc.)	8.97	$3,757,235	0.01%	0.30%
008	Multi-family - fewer than 10 units	43.18	$14,480,436	0.07%	1.17%
009	Residential Common Elements/Areas	772.18	$-	1.19%	0.00%
010	Vacant Commercial - with/without extra features	294.90	$14,521,934	0.46%	1.17%
011	Stores, one story	12.97	$2,396,843	0.02%	0.19%
012	Mixed use - store and office or store and residential combination	47.94	$8,043,268	0.07%	0.65%
018	Office buildings, non-professional service buildings, multi-story	2.07	$1,398,000	0.00%	0.11%
020	Airports (private or commercial), bus terminals, marine terminals, piers, marinas	17.73	$2,105,681	0.03%	0.17%
021	Restaurants, cafeterias	2.40	$1,431,788	0.00%	0.12%
025	Repair service shops (excluding automotive), radio and T.V. repair, refrigeration service, electric repair, laundries, Laundromats	4.74	$140,875	0.01%	0.01%
026	Service stations	2.08	$215,782	0.00%	0.02%
028	Parking lots (commercial or patron), mobile home parks	37.05	$6,927,572	0.06%	0.56%
035	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)	6.34	$5,765,655	0.01%	0.46%
038	Golf courses, driving ranges	951.08	$5,150,656	1.47%	0.41%
039	Hotels, motels	5.71	$1,349,000	0.01%	0.11%
040	Vacant Industrial -with/without extra features	66.26	$628,916	0.10%	0.05%
042	Heavy industrial, heavy equipment manufacturing, large machine shops, foundries, steel fabricating plants, auto or aircraft plants	4.26	$1,198,408	0.01%	0.10%

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
048	Warehousing, distribution terminals, trucking terminals, van and storage warehousing	5.00	$119,102	0.01%	0.01%
050	Improved agricultural	91.04	$937,416	0.14%	0.08%
055	Timberland - site index 80 to 89	10339.18	$30,965,500	15.99%	2.49%
056	Timberland - site index 70 to 79	2994.37	$12,902,115	4.63%	1.04%
059	Timberland not classified by site index to Pines	199.25	$1,879,319	0.31%	0.15%
060	Grazing land soil capability Class I	20.45	$106,575	0.03%	0.01%
062	Orchard Groves, citrus, etc.	174.71	$1,635,869	0.27%	0.13%
071	Churches	26.18	$650,951	0.04%	0.05%
074	Homes for the aged	1.68	$805,692	0.00%	0.06%
076	Mortuaries, cemeteries, crematoriums	0.08	$1,968	0.00%	0.00%
082	Forest, parks, recreational areas	3768.59	$50,886,015	5.83%	4.10%
083	Public county schools - including all property of Board of Public Instruction	98.59	$25,982,527	0.15%	2.09%
084	Colleges (non-private)	11.74	$6,843,609	0.02%	0.55%
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	3819.39	$37,980,762	5.91%	3.06%
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	33135.37	$67,380,277	51.23%	5.43%
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	710.27	$11,591,824	1.10%	0.93%
089	Municipal, other than parks, recreational areas, colleges, hospitals	958.97	$3,994,424	1.48%	0.32%
091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	90.77	$1,876,086	0.14%	0.15%
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	107.26	$929,112	0.17%	0.07%
095	Rivers and lakes, submerged lands	9.13	$13,695	0.01%	0.00%

096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	1745.11	$395,430	2.70%	0.03%
Use Code	**Use Description**	**Acreage**	**Just-value**	**Acreage Percentage**	**Just-value Percentage**
098	Centrally assessed	0.00	$5,061,098	0.00%	0.41%
099	Acreage not zoned agricultural - with/without extra features	1945.77	$14,590,652	3.01%	1.17%
Total		64679.28	$1,241,911,011	100.00%	100.00%

Table A6. Land Use (LU) Classifications in the Air-potato Area

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
000	Vacant Residential – with/without extra features	304.40	$65,353,692	0.46%	7.70%
001	Single Family	857.20	$494,131,336	1.30%	58.26%
002	Mobile Homes	11.58	$514,303	0.02%	0.06%
004	Multi-family - 10 units or more	0.00	$3,387,200	0.00%	0.40%
007	Miscellaneous Residential (migrant camps, boarding homes, etc.)	1.90	$786,386	0.00%	0.09%
008	Multi-family - fewer than 10 units	146.55	$37,693,472	0.22%	4.44%
009	Residential Common Elements/Areas	574.14		0.87%	0.00%
010	Vacant Commercial - with/without extra features	29.68	$2,507,138	0.05%	0.30%
011	Stores, one story	2.96	$1,315,645	0.00%	0.16%
012	Mixed use - store and office or store and residential combination	21.83	$1,697,713	0.03%	0.20%
017	Office buildings, non-professional service buildings, one story	3.51	$1,392,153	0.01%	0.16%
020	Airports (private or commercial), bus terminals, marine terminals, piers, marinas	22.67	$5,935,334	0.03%	0.70%
021	Restaurants, cafeterias	2.04	$1,680,874	0.00%	0.20%
028	Parking lots (commercial or patron), mobile home parks	39.41	$8,160,356	0.06%	0.96%
033	Nightclubs, cocktail lounges, bars	0.46	$173,796	0.00%	0.02%
035	Tourist attractions, permanent exhibits, other entertainment facilities, fairgrounds (privately owned)	6.34	$5,765,655	0.01%	0.68%
039	Hotels, motels	2.59	$1,546,188	0.00%	0.18%
044	Packing plants, fruit and vegetable packing plants, meat packing plants	5.00	$230,225	0.01%	0.03%
050	Improved agricultural	24.50	$213,170	0.04%	0.03%
055	Timberland - site index 80 to 89	265.21	$1,922,982	0.40%	0.23%
056	Timberland - site index 70 to 79	273.20	$3,381,600	0.41%	0.40%
062	Orchard Groves, citrus, etc.	54.62	$614,428	0.08%	0.07%
069	Ornamentals, miscellaneous agricultural	24.20	$483,355	0.04%	0.06%
076	Mortuaries, cemeteries, crematoriums	0.08	$1,968	0.00%	0.00%

082	Forest, parks, recreational areas	3703.00	$50,869,618	5.62%	6.00%
084	Colleges (non-private)	11.74	$6,843,609	0.02%	0.81%

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	2912.55	$37,389,585	4.42%	4.41%
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	45661.35	$84,806,426	69.31%	10.00%
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	7741.27	$15,107,324	11.75%	1.78%
089	Municipal, other than parks, recreational areas, colleges, hospitals	209.78	$2,121,507	0.32%	0.25%
091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	0.28	$64,694	0.00%	0.01%
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	118.94	$1,140,200	0.18%	0.13%
096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	1746.37	$396,060	2.65%	0.05%
097	Outdoor recreational or parkland, or high-water recharge subject to classified use assessment	3.74	$935	0.01%	0.00%
099	Acreage not zoned agricultural - with/without extra features	1097.29	$10,572,635	1.67%	1.25%
Total		65880.39	$848,201,562	100.00%	100.00%

Table A7. Land Use (LU) Classifications in the Chinese Tallow Tree Area

Use Code	Use Description	Acreage	Just-value	Acreage Percentage	Just-value Percentage
000	Vacant Residential – with/without extra features	106.69	$2,706,953	0.21%	2.05%
001	Single Family	195.54	$26,269,470	0.39%	19.91%
002	Mobile Homes	92.38	$5,401,712	0.18%	4.09%
008	Multi-family - fewer than 10 units	239.07	$5,971,663	0.47%	4.53%
009	Residential Common Elements/Areas	9.77	$-	0.02%	0.00%
044	Packing plants, fruit and vegetable packing plants, meat packing plants	5.00	$230,225	0.01%	0.17%
055	Timberland - site index 80 to 89	5817.05	$11,485,145	11.51%	8.70%
056	Timberland - site index 70 to 79	1627.64	$2,560,836	3.22%	1.94%
062	Orchard Groves, citrus, etc.	46.95	$381,700	0.09%	0.29%
067	Poultry, bees, tropical fish, rabbits, etc.	601.10	$6,929,445	1.19%	5.25%
069	Ornamentals, miscellaneous agricultural	33.23	$781,601	0.07%	0.59%
075	Orphanages, other non-profit or charitable services	92.64	$659,652	0.18%	0.50%
082	Forest, parks, recreational areas	691.08	$1,382,160	1.37%	1.05%
086	Counties (other than public schools, colleges, hospitals) including non-municipal government	22.76	$254,464	0.05%	0.19%
087	State, other than military, forests, parks, recreational areas, colleges, hospitals	37365.00	$64,456,422	73.91%	48.85%
088	Federal, other than military, forests, parks, recreational areas, hospitals, colleges	3531.00	$1,765,500	6.98%	1.34%
091	Utility, gas and electricity, telephone and telegraph, locally assessed railroads, water and sewer service, pipelines, canals, radio/television communication	0.23	$51,559	0.00%	0.04%
094	Right-of-way, streets, roads, irrigation channel, ditch, etc.	40.59	$400,550	0.08%	0.30%
096	Sewage disposal, solid waste, borrow pits, drainage reservoirs, waste land, marsh, sand dunes, swamps	1.26	$630	0.00%	0.00%
099	Acreage not zoned agricultural - with/without extra features	33.70	$259,530	0.07%	0.20%

Total		50552.68	$131,949,217	100.00%	100.00%

Appendix 2

A Sketch for the Analysis of Eastern Oyster

General Parameters

Number of Time Steps for Model Run: 100 - 300

Population Parameters

Population Parameters:

Most parameters are from scientific literature or report, and some parameters will likely need to be estimated from data. Some fisheries science expertise is necessary.

The largest oyster-producing body of water in the United States is Chesapeake Bay, although these beds have decreased in number due to overfishing and pollution. Willapa Bay in Washington produces more oysters than any other estuary in the US. Other large oyster farming areas in the US include the bays and estuaries along the coast of the Gulf of Mexico from Apalachicola, Florida in the east to Galveston, Texas in the west[49].

- Population Model Type: Stage-structured[50]
- Population Classes are Sex-Specific: No[51]
- Harvest by Individuals or Weight: Weight[52]
- Populations Parameters CSV Table[53]:

[49] NOAA Fish Facts: https://chesapeakebay.noaa.gov/fish-facts/oysters

[50] Hanley, Hughes, Williams, Garland, and Kimbro (2016) studies the cohort diversity on oyster (Crassostrea virginica) survivorship, growth, and colonization enhancement. In addition, aquaculture, which commonly excludes predators during early life history stages, may benefit from incorporation of oyster cohort diversity into standard practice.

[51] Florida Fish and Wildlife Conservation Commission, FWRI (2014) EASTERN OYSTER – 253: "Eastern oysters are hermaphrodites, but can become alternate hermaphrodites after an initial male state; they can alternate sex within a spawning season."

[52] Florida Fish and Wildlife Conservation Commission, FWRI (2014) EASTERN OYSTER – 253: "Atlanta coast landings are made mostly in St. Johns and Volusia Counties." "Commercial landing ratings on the Atlantic Coast have been fairly steady at 40-50 pounds (18kg – 22.5kg) per trip during the period 1997-2012 with a recent drop in 2013 at around 30 pounds (13.5 kg) per trip."

[53] Oyster life cycle: There are several definitions of oyster life cycle. We applied the definition of life cycle from eastern oyster Florida poster. Gap information is filled from other sources.
https://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/florida/newsroom/eastern-oyster-florida-poster.pdf
Weight: This is the average biomass of an individual of the population at each age/stage expressed in model-agnostic units and is required for each of the ages/stages listed in the stage column. Unit is set as gram. Survival Rates from Natural Mortality: A survival rate from natural mortality, expressed as a decimal fraction.

Table A8. Population Parameters

Stage	Survival Rates from Natural Mortality	VulnFishing	Duration	Weight	Maturity
Spawning and Fertilizing	<float>	<float>	<float>	<float>	<float>
Swimming and Setting	<float>	<float>	<float>	<float>	<float>
Spat and Juvenile Oysters	<float>	<float>	<float>	<float>	<float>
Adult Oyster	<float>	<float>	<float>	<float>	<float>
Exploitation Fraction	<float>				

Recruitment Parameters:

- Initial Number of Recruits: 200,000 (Default)

Because the population model is run to equilibrium, the initial number of recruits will not affect the model results but may affect the number of the time steps required before the model reach equilibrium.

- Recruitment Function Type[54]:

InVEST Online Document: "Choosing which recruitment function to use will depend on data availability as well as ecological knowledge about the species and region. **Density-dependent** recruitment functions such as the Ricker and Beverton-Holt are most common in fisheries models, as they recognize that a population depends on finite resources and cannot grow infinitely large. A model with the Fecundity function must be parameterized carefully or it is not guaranteed to reach equilibrium. The Fixed recruitment may be appropriate in cases where the region of interest is small relative to the range or distribution of the fished population, for instance, when recruits may drift into the region of interest from nearby spawning areas. "

Vulnerability (VulnFishing) to harvest: The relative vulnerability to harvest for each class. A decimal value for each class listed in this column is required. The most vulnerable age(s)/stage(s) should have a value of 1.0, indicating full vulnerability.

Duration: It represents the number of time steps for which an average individual will be in that stage before moving to the next one. Time step is set as 1 day.

Maturity: It represents the fraction of that age or stage which is mature and contributes to the spawning stock. A decimal value for each age/stage is required if maturity is included. For classes which do not reproduce, this should be 0.

Exploitation fraction: This is the proportion of the population vulnerable to harvest that is actually harvested. This may vary by sub-region.

[54] In Florida Department of Environmental Protection (FDEP), "Development and Implementation of a Regional Oyster Condition Assessment (2016)", the data collected includes: 1) Mapped & Photographed, 2) Reef Profile, 3) Percentage Cover, and 4) **Density**, Size, and Depth of Oyster

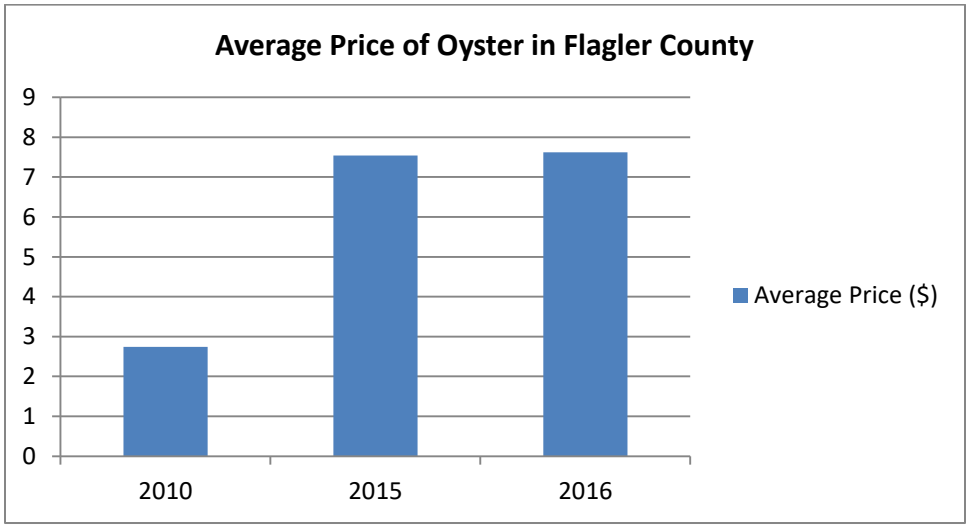
The stock-recruitment parameters need to be estimated by fitting the model to available data, and the available recruitment date is limit in this study.

- Spawners by Individuals or Weight: Weight

Harvest and Valuation:

- Fraction of Harvest Kept after Processing[55]: 0.3515 (Default)
- Unit Price[56]: $4.823/pounds (Nominal)

We take the average value of Oyster unit price from 2010 to 2016 for both St Johns and Flagler counties. Missing values are in the data for Flagler County. Figure A1 shows the time series plot of the annual average nominal prices.



[55] Harvesting regulations on Florida Fishing and Wildlife (FWC) Commission: http://myfwc.com/fishing/saltwater/recreational/shellfish/

[56] Florida Fishing and Wildlife (FWC) Commission: https://publictemp.myfwc.com/FWRI/PFDM/

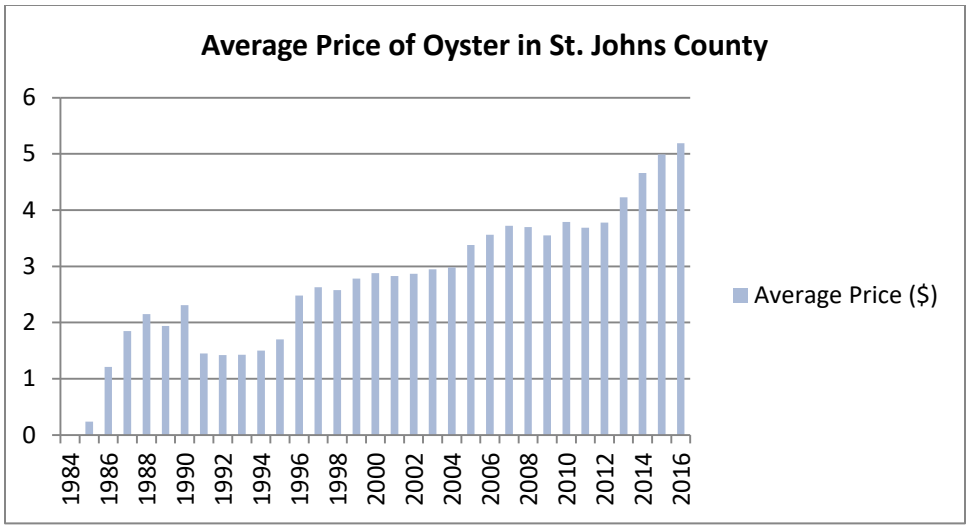


Figure A1. Commercial Unit Price (Nominal USD) of Oyster in Flagler County and St. Johns County

Habitat Scenario Tool

User-defined habitat scenario analysis[57]

Individual Site Viewshed in the Unobstructed Views: Scenic Quality Provision Model

[57] Habitat information: https://www.st.nmfs.noaa.gov/Assets/ecosystems/climate/images/species-results/pdfs/Eastern_Oyster.pdf

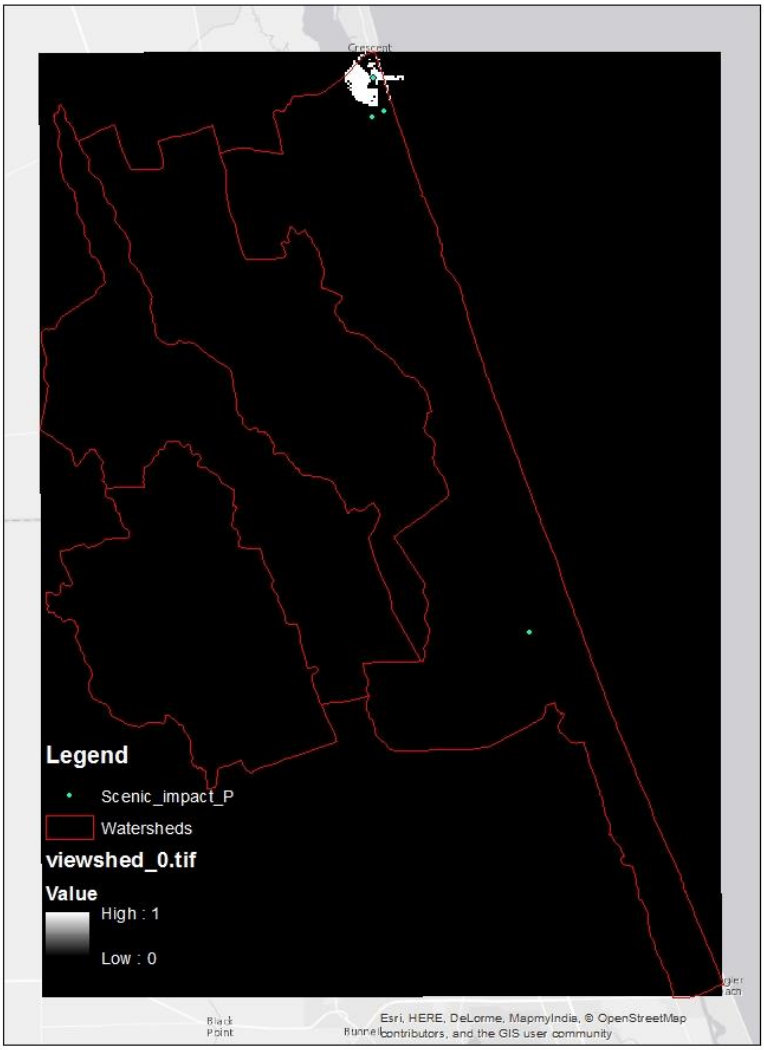


Figure A2 (a). The Number of Points Visible from Each Cell relating to Green Street County Boat Ramp

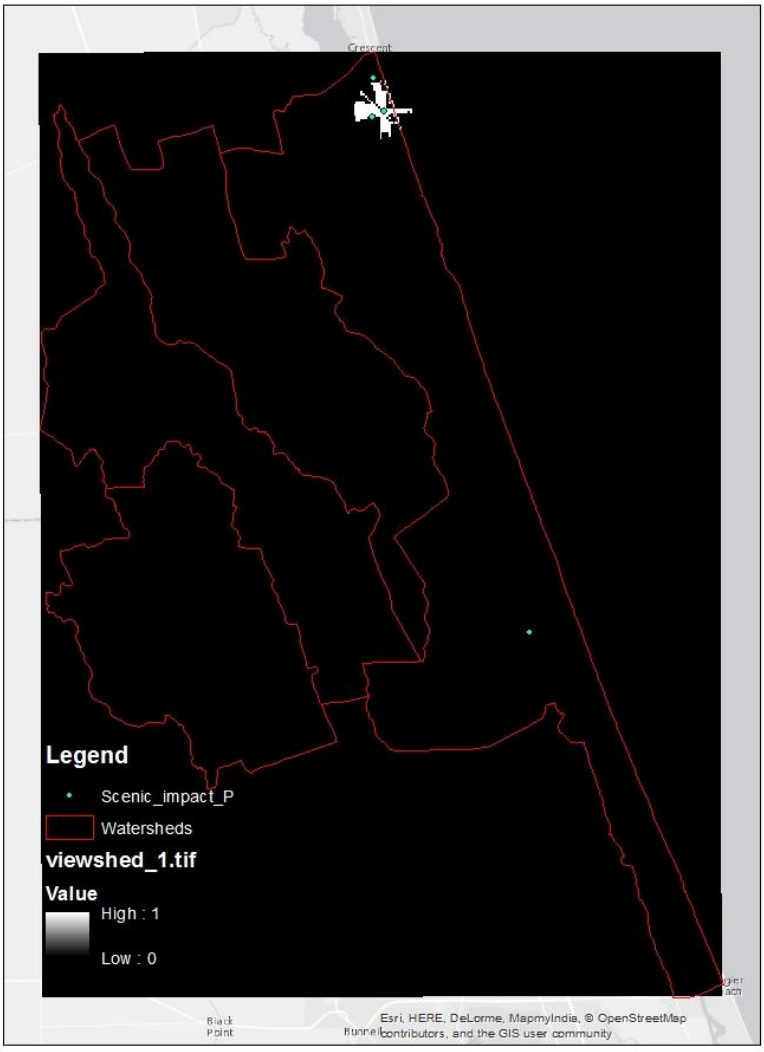


Figure A2 (b). The Number of Points Visible from Each Cell Relating to Devils Elbow Boat Ramp

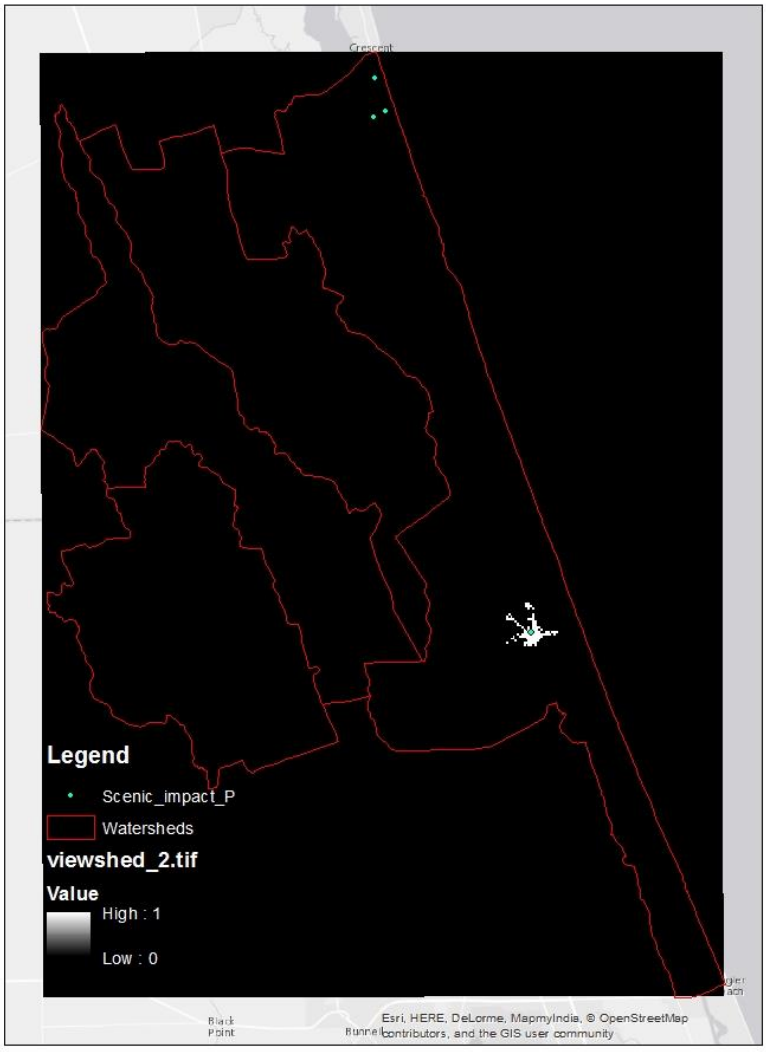


Figure A2 (c). The Number of Points Visible from Each Cell Relating to Palm Coast Marina Boat Ramp

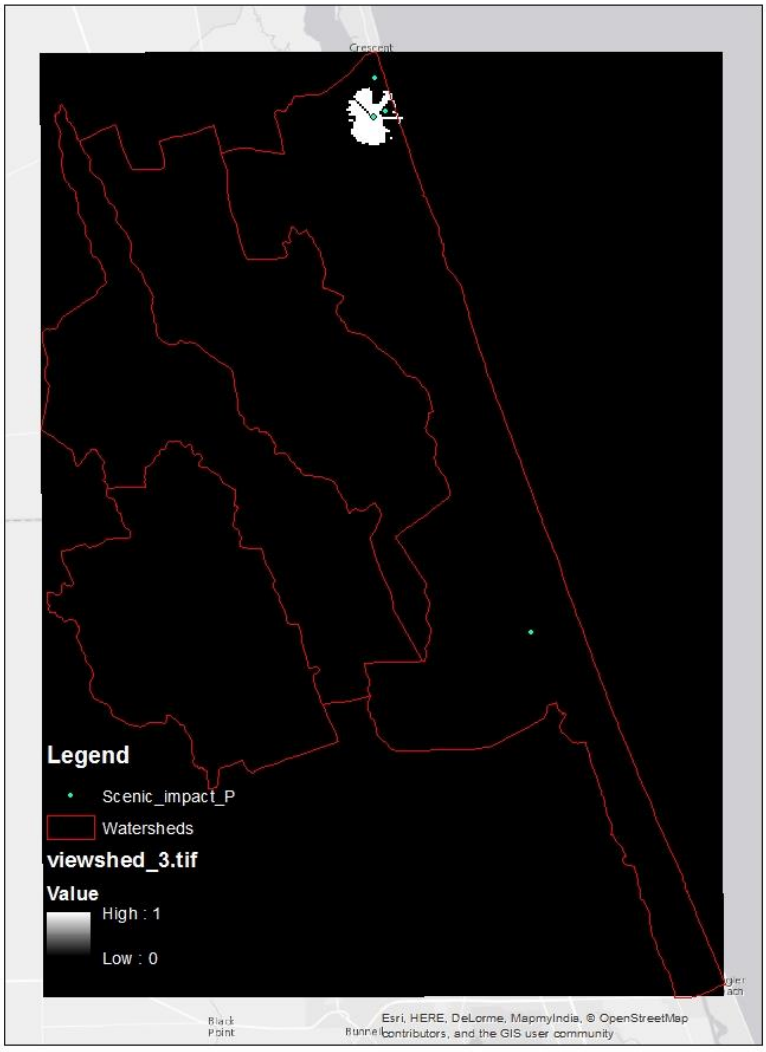


Figure A2 (d). The Number of Points Visible from Each Cell Relating to Aquaculture