Stewardship Ecosystem Services Study Series: Assessing Forest Water Yield and Purification Ecosystem Services in the Lower Suwannee River Watershed, Florida[1]

Sonia Delphin, Francisco J. Escobedo, Amr Abd-Elrahman, Alison E. Adams, Jackie Martin, Ronald Cademus[2]

Ecosystem services are the components of nature that are directly enjoyed, consumed, or used to produce specific, measurable human benefits (Escobedo et al. 2012, p. 11). Water quality improvement, or *purification*, is one these highly valued forest ecosystem services that ensures clean water for human consumption (Kreye et al. 2013; Stein et al. 2013). Nutrients are necessary for healthy plants, humans, and animals, yet increased levels of certain nutrients in the environment can be problematic for water quality. These water quality problems in the form of nutrient pollution in lakes, rivers, and streams are mostly due to human activities, including runoff from urban and agricultural areas, and, to a lesser degree, runoff from forestry activities (Stets et al. 2012). This runoff can contain high levels of such nutrients as nitrogen and phosphorus. These nutrients create the eutrophication that leads to algal blooms and unstable oxygen supplies in the aquatic ecosystem (Nesheim and Fishel 2009). In addition, places like the Suwannee River watershed in Florida are characterized by sandy soils, through which nutrients leach quickly, and shallow groundwater. Leaching of nutrients from agricultural fertilizers and animal wastes is a threat to groundwater and is thought to have contributed to the greening of the region's freshwater springs (German 1997).

Land-use decisions and ecosystem characteristics (e.g., soil and forest types and associated management practices and agricultural systems) affect the amounts of nutrients that end up in water bodies and the ability of the land to provide ecosystem services. Water quality is also highly valued by Florida forest landowners and managers (Stein et al. 2013). So, understanding the role of land use and forest cover and types, management practices, and conservation programs in reducing nutrient pollution will allow landowners, forest managers, and policy makers to make informed and better management decisions (Kreye et al. 2013). In this fact sheet, we present the results of a study that used easily available models and information to assess the role of forests in providing ecosystem services, including water quality improvement or purification (Escobedo and Timilsina 2012). Specifically, this assessment used available geospatial data and the InVEST (Integrated Valuation of Environmental Services and Tradeoffs, http://www.naturalcapitalproject.org/InVEST.html) Water Purification model to estimate

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2. Sonia Delphin, graduate student, School of Forest Resources and Conservation, UF/IFAS Extension, Gainesville, FL 32611; Francisco J. Escobedo, associate professor, School of Forest Resources and Conservation, UF/IFAS Extension, Gainesville, FL 32611; Amr Abd-Elrahman, associate professor, School of Forest Resources and Conservation, UF/IFAS Extension, Gainesville, FL 32611; Alison E. Adams, graduate student, Department of Sociology, University of Florida, Gainesville, FL 32611; Jackie Martin, research assistant, School of Forest Resources and Conservation, UF/IFAS Extension, Gainesville, FL 32611; and Ronald Cademus, graduate student, School of Natural Resources and Environment, UF/IFAS Extension, Gainesville, FL 32611.

how forest vegetation and soils purify water through the retention, and subsequent export, of nitrogen and phosphorus polluted runoff.

Modeling Water Purification

Researchers at the University of Florida used the InVEST model to assess the influence of land use and land cover on water quality and water yield over a 10-year period in the Lower Suwannee River watershed in Florida (Figure 1; Mendoza et al., 2011). *Water yield* as used in this assessment was the precipitation that does not evaporate from ground or water surfaces or transpire from plant surfaces. Determining water yield provides a better understanding of the potential nutrient load that can enter a body of water in a particular watershed. The assessment used existing literature, satellite imagery, soil survey data, other Geographical Information Systems (GIS) data, and the InVEST model to determine the nutrient-retention capacity (the annual average nitrogen and phosphorus loads that are retained by vegetation rather than being exported from the watershed). For specific methods and assessment of the InVEST water purification model, see pages 37–52 in Escobedo and Timilsina (2012).

The Lower Suwannee River watershed was chosen for this analysis because it encompasses the second largest river in Florida (Light, Darst, and Lewis 2002) and has multiple private forests managed under the Florida Forest Stewardship Program (FSP), a program that encourages multiple-use forest stewardship practices on private lands (http://www.sfrc.ufl.edu/Extension/florida_forestry_information/additional_pages/forest_stewardship_program.html). The watershed contains most of the springs of the upper Floridan aquifer. Land use/cover in the watershed is predominantly forest, agriculture, and wetlands (Katz et al. 1997, Figure 1).

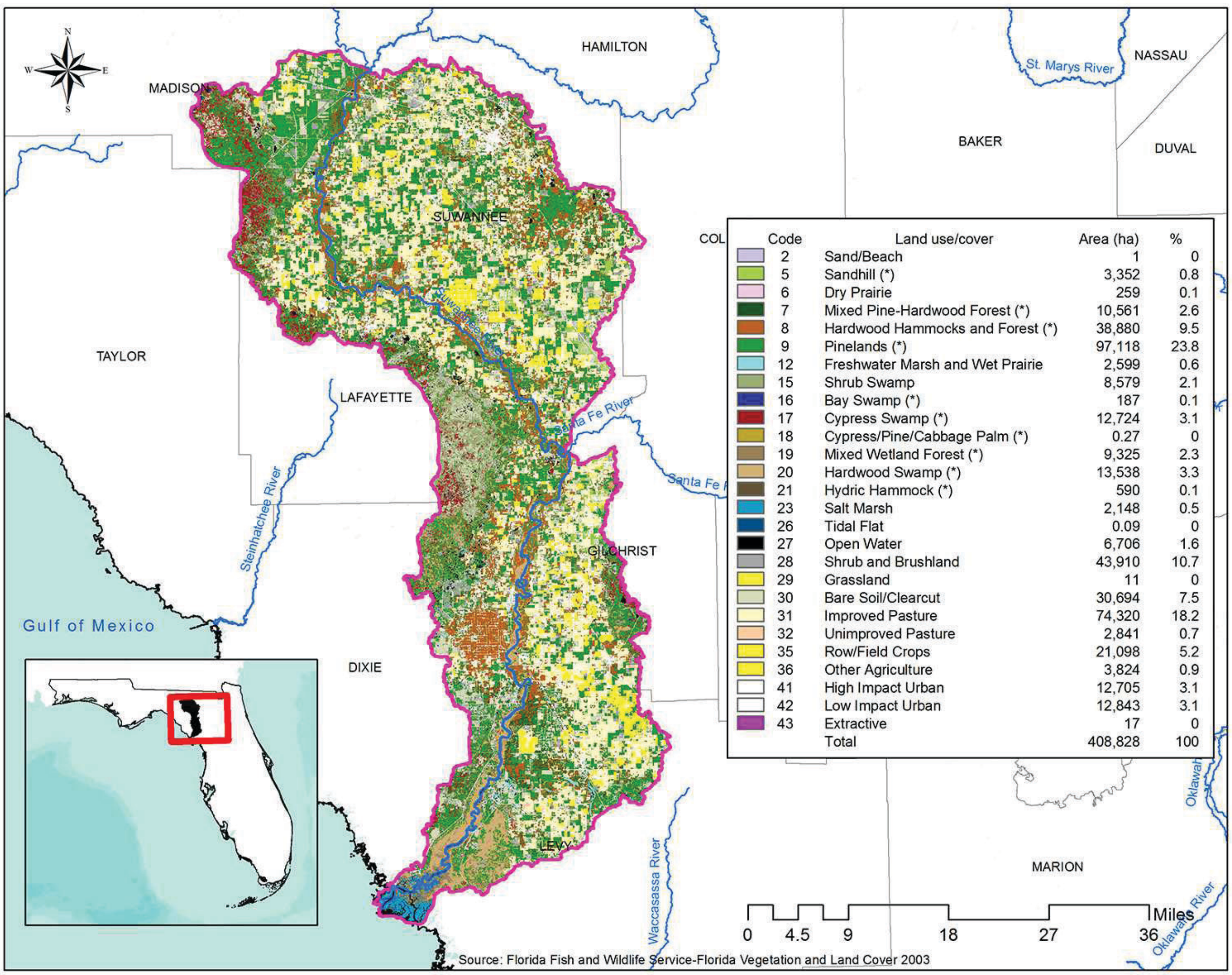

Figure 1. Land use and covers in the Lower Suwannee River Watershed, Florida.

Water Yield

Water is necessary for all life, and its availability for drinking water is strongly influenced by watershed vegetation, as well as land- and water-management practices (Florida Forest Service 2008). Within the Lower Suwannee River watershed, this assessment modeled and compared the water yield among 63 sub-watersheds. Water yield estimates from the InVEST model, and actual measurements from the Gopher River (Site # 02323592) gauging station measuring the entire flow of the Suwannee River for the entire watershed, were normalized on a scale of 0 to 1 for assessment purposes and are presented in Figure 2. Overall, areas with less forest cover had higher water yield, which often corresponded to increased levels of runoff and potential nutrient pollution of surface waters.

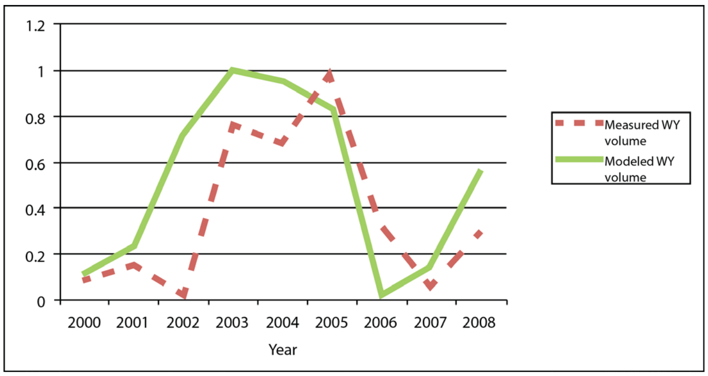

Figure 2. Normalized values for the Integrated Valuation and Ecosystem Services Tradeoff (InVEST) model estimates and measured water yield (WY; m^3) volumes in the Lower Suwannee River watershed, Florida. The y axis values are InVEST model estimates and measured values, normalized on a scale of 0 to 1, and the x axis is year of measurement and model estimate. Note that non-normalized InVEST-modeled WY volumes were less than actual measured WY volumes; See Escobedo and Timilsina 2012 for possible explanations behind this difference.

To assess the role of multiple-use forest-management activities and forested land uses on water quality, we compared sub-watersheds with no FSP forests to sub-watersheds with measurable areas of FSP forests. Sub-watersheds with FSP forests had 47.9% forest land covers, while sub-watersheds with no FSP forests had 52.4% forest land cover. The study found that sub-watersheds with no FSP forests had, on average, significantly lower water yields than sub-watersheds with FSP forests. The lower water yields found in sub-watersheds with no FSP forests might be explained by the fact that these regions had on average more overall forest cover. This explanation is corroborated by other studies that have linked greater forest cover in a watershed to a decreased water yield (Mendoza et al. 2011; Stets et al. 2012).

Nutrient Retention

All terrestrial and aquatic plants require nutrients for growth and productivity. Nutrients required in the greatest amounts by plants include nitrogen and phosphorus (Georgia Department of Natural Resources, 1998; Light, Darst, and Lewis 2012). However, excess *nutrient loading*, which occurs when too much nitrogen and phosphorus enter a body of water, can result in an overabundance of algae, unstable dissolved oxygen supply, and even fish kills (Stets et al. 2012). The major sources of nutrients entering the Suwannee basin are wastewater treatment facilities, urban stormwater runoff, and agricultural runoff (Georgia Department of Natural Resources 2002; Hallas and Magley 2008). Reducing nutrient loads can help meet *Total Maximum Daily Loads* (TMDLs) of nutrients for impaired water bodies. The TMDL is a metric used for allocating acceptable loads for all known pollutant sources in a watershed. Once acceptable TMDLs have been determined, appropriate control measures and practices can be implemented to achieve desired water quality standards (Hallas and Magley 2008 p. 73). Below, we review how this study assessed the role of forests in nitrogen and phosphorus loading to water bodies.

Nitrogen is associated with human inputs, such as fertilizers and septic systems (Hallas and Magley 2008; Stets et al. 2012). In total, 28 of the 63 sub-watersheds within the Lower Suwannee River watershed did not export (i.e., transport to the stream) any nitrogen beyond the established annual critical load (the TMDL is 0.35 mg/l/month), or the level at which water quality can be impaired, as determined by Hallas and Magley (2008) and Trepanier et al. (2002). The largest amount of nitrogen, 52% of the total, was retained by the Tenmile Hollow sub-watershed, which is located in the northeastern part of the watershed (Figure 3) and has 39% non-FSP forests, 6% FSP forests (39 properties), and 41% intensive land uses (e.g., crops, pastures, and urban areas). Lower nutrient retention was identified in sub-watersheds with no FSP properties and less forest cover. Ecosystems with intact natural vegetation tend to be net retainers of both nutrients and sediments, whereas ecosystems used intensively for urban uses or agricultural and even timber production tend to be sources of both nutrients and sediments (Conte et al. 2011; Stets et al. 2012).

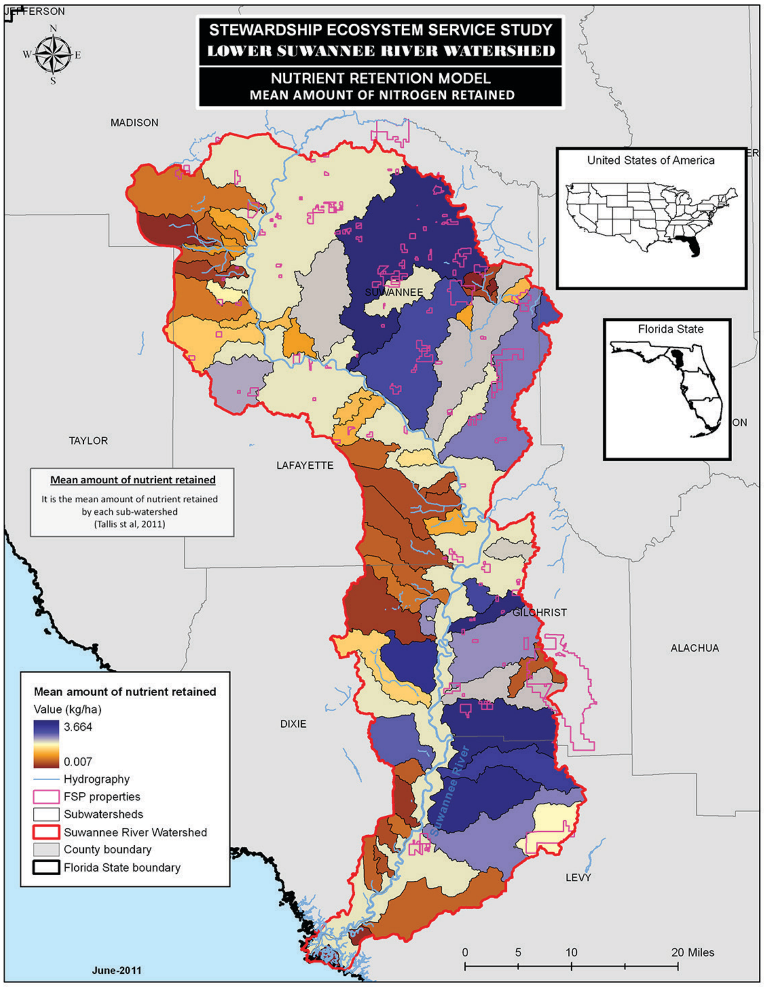

Figure 3. Nitrogen retention in the Lower Suwannee River Watershed, Florida.

In addition, the sub-watersheds with a greater number of FSP properties and 47.9% forest cover were compared in terms of nitrogen retention to sub-watersheds with no FSP properties and 52.4% forest cover (Figure 3). The assessment found that nitrogen retention was higher in sub-watersheds with FSPs, although the difference was not statistically significant. The lack of significance could be due to the low number of sub-watersheds with a high acreage of forests under the FSP (n=10) compared to sub-watersheds with no FSP forests (n=35) and other larger areas of land-use practices characteristic of urban and agricultural land covers. Other literature has found that increased forest cover, especially in forests managed like those of the FSP, might be an effective management solution for decreasing nitrogen concentration in waters (Florida Forest Service 2008; Stets et al. 2012).

Phosphorus is another key nutrient responsible for water pollution in Florida (Agyin-Birikorang, O'Connor, and Obreza 2009; Trepanier et al. 2002). High phosphorus concentrations are associated with lawn and garden fertilizers, improperly sited and maintained septic systems, leaking sewers, agricultural drainage, pet waste, urban stormwater runoff, and the use of phosphate-based detergents (Stets et al. 2012). This type of pollution is largely due to inefficient fertilization practices and the discharge of municipal waste and agricultural animal waste into water bodies. Once again, 28 of the 63 sub-watersheds did not export any phosphorus beyond the determined annual critical load determined by Trepanier et al. (2002) of 2 mg/l. Given the lack of urban land cover in this sub-watershed, this might be due to increased forest vegetation cover and soils retaining the phosphorus. The largest percentage of phosphorus (96%) was retained by the Old Grassy Lake sub-watershed located in the northwestern part of the watershed. This watershed is 57% non-FSP forest, 29% intensive land uses, and 3% FSP forest (2 properties).

The Escobedo and Timilsina study (2012) also compared sub-watersheds with FSP forests to others without FSP forests and found that phosphorus retention was 17% higher in sub-watersheds with FSPs, although the difference was not statistically significant. Again, as for nitrogen, forest land covers were similar for both sub-watersheds, but the lack of significance could be due to the low number of sub-watersheds with a high acreage of forests under the FSP (n=10) compared to sub-watersheds with no FSP forests (n=35). Once again, other land-use practices (e.g. fertilization, sewage, etc.) in urban and agricultural land covers might affect phosphorus export to water bodies. However, as previously mentioned, other studies have shown how increased forest cover and better management practices in a watershed can improve water quality by reducing nutrient export into water bodies (Florida Forest Service 2008; Stets et al. 2012).

Key Implications

The results of this assessment were based on modeled estimates and the best available information and geospatial technology and data. Although the direct link between the FSP forests and nutrient pollution could not be statistically made in this study, the assessment did show that increased overall forest cover decreased water yield in the sub-watersheds, thereby likely increasing nutrient retention and decreasing export of potentially harmful nitrogen and phosphorus that can end up in Florida's water bodies. Most importantly, these types of modeling assessments can be used to better guide forest-management decisions regarding the conservation of working forests and to better assess the importance of forestry BMPs in maintaining water quality (Kreye et al. 2013). The same concepts and approach can also be applied to urban forests. Properly managing urban and urban-interface forests to use less fertilizer and fewer herbicide applications, for example, can increase nutrient retention and reduce water pollution. Management alternatives that increase or maintain existing forested land, native ground covers, and soil quality are effective and implementable BMPs that can protect water quality (Florida Forest Service 2008) and provide other valuable ecosystem services that are important to society (Stein et al 2013).

Models, methods, and GIS approaches such as those described in this publication can be used to better understand how private forests managed under the Florida FSP can have the capacity to retain nitrogen and phosphorus on the uplands and decrease runoff pollution to water bodies while continuing to provide other ecosystem services. Policy makers will find the information from this publication helpful in efforts to support and promote programs that maintain working forests and preserve valuable, forest-based ecosystem services. Finally, these findings indicate that best management practices for land management and future education programs for land managers should emphasize the importance of conserving forested land for maintaining and improving Florida's water quality.

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