Using Forest Thinning to Re-Charge the Floridan Aquifer

A Report for the Florida Springs Institute
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May, 2018

Definitions

We have cited a number of related and somewhat confusing terms in this paper because a variety of them are used in the technical and academic literature that we've cited. The basic concept behind this paper, however, is quite simple – namely, that removing some trees from an area ("forest thinning") may enhance the re-charge of water to the groundwater in that area. Here are four terms used in this paper:

Forest Thinning – Removing trees from an area to enhance re-charge.

Basal Density – Number of trees per unit area.

Basal Area – The term is used in two different ways: (1) the cross-sectional area of a single tree at breast height, or 4½ feet above ground or (2) the cross-sectional area of all stems of a species or all stems in a stand measured at breast height and expressed as per unit of land area. We will use the second definition in this paper.

Leaf Area Index - A dimensionless quantity that characterizes plant canopies, defined as the one-sided green leaf area per unit ground surface area in broadleaf canopies.
In conifers, various definitions are used for LAI, including one half of the total needle surface area per unit ground surface area.

Introduction

Florida is home to more springs (over 1000) and more large ("first-magnitude") springs than any place in the world. [1] Florida springs provide wildlife habitat, water sources for the human population, and recreational opportunities for both residents and tourists.[2] For many years, scientists and locals have noted a decline in the flows and overall water quality of these springs.[3] Dr. Robert Knight of the Florida Springs Institute estimates that overall spring flow in the State is down 32% and notes that dissolved nitrate levels in many springs are at least five times higher than State pollution standards.[4] Both poor water quality and reduced flow levels have severe effects on springs, and state of Florida has a legal obligation to improve the conditions of its springs.[5]

The state addresses spring flows and levels in *Section 373.042, Florida Statutes*. The statute establishes that state water management districts or the Florida Department of Environmental Protection (FDEP) must establish minimum flows and levels (MFLs) for aquifers, surface water bodies, surface watercourses, and other water bodies, in order to determine at what point withdrawal from those water sources would be significantly harmful to them or the ecology of the area.[6] Districts must develop strategies to attain or maintain those MFLs once they have been determined and to adopt them by rule after they've been developed.[7]

While state agencies and water management districts already employ a host of policies aimed at improving the state's springs and meeting the statutory requirements from *Section §373.042, Florida Statutes*[8], recent theoretical and field work by researchers at the University of Florida has brought to light a novel idea for increasing water in springs recharge areas.[9] Recharge is important as it affects spring flow levels; recharge occurs as rainwater enters the aquifer, creating pressure on water already in the aquifer which pushes the water through cracks and holes in the aquifer and eventually out into surface water bodies like springs.[10] The crux of this research has been to show that forestland can be managed to increase significantly the amount of water that makes its way to groundwater, as opposed to being lost to surface waters or, because of evapotranspiration, to the atmosphere (evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants).[11] The research suggests that by managing forests at lower basal densities[12], foresters could increase the amount of water yielded to surface water bodies and groundwater sources.[13] This matters; if this management technique can increase the amount of water being percolated in high recharge areas, then forestry could play an important role in Florida springs restoration. Currently, a four-year field study by the Florida Department of Agriculture and Consumer Services (FDACS) is testing this hypothesis.[14] The field study has so far largely confirmed that managing pine stands for lower basal density increases water yield.[15] This hypothesis has also been confirmed, to an extent, by a study investigating the effects of forest thinning on forest fires.[16] That study found that intensive thinning reduced evapotranspiration rates between 21% and 27% on plots in the Sierra Nevada mountain range in California.[17]

In addition to existing theory and fieldwork on the science behind managing forests for water yield, forest economists have investigated the economic sustainability of managing forests for water yield.[18] A study by Susaeta et al showed – via economic modeling – that payments for managing for water yield based on the price for pumping water could induce foresters to change their silvicultural practices. [19] Of course, the cost of pumping water from the ground may differ greatly from the price foresters are willing to accept to change their practices. This study is promising, but its real-world application remains to be seen.

One method of incentivizing landowners to follow more environmentally beneficial practices has been payments for environmental services (PES). PESs have been used around the world as a method of effecting changes in land management practices to promote greater environmental good.[20] This simple concept could easily translate to paying foresters to manage their pine stands for water yield. A more relevant PES example exists in springs country, where the Suwannee River Water Management District (SRWMD) has allocated $500,000 for a pilot program aimed at implementing a thinning regime like the one described by the UF researchers.[21] This SRWMD initiative, to aim funds at foresters to manage for water yield, is a first step towards determining whether the research has real-world applicability.

Research

The premise of the UF research cited earlier was investigation of land management strategies to increase water availability in regions with threatened hydrologic resources.[22] The research focused on managing forest uplands for lower basal area, with the theory being that lower basal areas in forest uplands would increase water yield by decreasing evapotranspiration.[23] In addition to basal area, the research looked at the relationship between Leaf Area Index (LAI) and water yield; LAI is a variable that measures how dense the leaf area of a particular pine stand is.[24] Water yield is defined as the difference between precipitation and evapotranspiration.[25] By taking the difference of precipitation and evapotranspiration, researchers can judge how much water from rainfall has not been returned to the atmosphere -- in other words, how much water has been yielded to surface or groundwater.[26]

The FDACS-funded study by Cohen et al is currently in year four of a four-year research program, with the final report to become available during 2018.[27] The study is being conducted on six different parcels to quantify water yield under different forest management conditions. [28] These management conditions range from complete clear cuts to mature intensive pine plantations, which allowed for the collection of data based on different leaf area indexes (LAI).[29] To measure precipitation and evapotranspiration researchers used sensors measuring soil moisture and groundwater level, as well as high frequency meteorological data from scientific weather stations.[30] The data from the sites are collected quarterly.[31]

Findings from the 2017 annual report on the field study have largely confirmed hypotheses from the 2013 paper by McLaughlin et al, especially in regards to LAI being a good predictor for water yield.[32] The second most important factor in predicting water yield, per this annual report, is site location.[33] A third and interesting finding is that sand and longleaf pine plots have the highest water yield of the different species of trees tested.[34]

The annual report does note that there is no clear answer yet as to whether the water yielded is diverted to surface water or percolated into the groundwater.[35] It stands to reason that if the water is not evapo-transpirated into the atmosphere, then it likely will either be diverted to surface water or percolated into the groundwater depending on the geologic specifics of the site where the pine stands are.

Economic Sustainability

Proving that managing forests for water yield is a plausible method of increasing water in high recharge areas may be an important step in protecting Florida springs, but if managing in that way is not economically sustainable (both for the state in incentivizing foresters to manage accordingly and for foresters who are not in the business of losing money) then the applicability of the research will be limited.

Susaeta et al sought to explore the economic tradeoffs between traditional pine plantation management and managing for water yield.[36] Their study employed a sample case of slash pine production, a forest stand-level optimal rotation model, and a range of water prices (from $0.03/kL to $0.30/kL).[37] The study looked at 16 different thinning scenarios ranging from minimal to extensive thinnings and a multitude of timber prices in addition to the water prices.[38] By including prices for the water that was being yielded by different management techniques, the publication analyzes at which price points it is effective for foresters to change from traditional management styles to those that have positive effects on water yield.[39] At low planting densities, managing for timber production and water yield is preferable to timber production alone using moderate to high water prices; at high planting densities, managing for timber production alone was preferable with low to moderate water prices.[40]

This study provides theoretical support for the notion that managing forests for water yield is economically sustainable for governments and for foresters but it is not the end of the discussion. The true variables are what dollar amount foresters will accept to change their management techniques, and whether any government agency would be willing to pay that amount. Professor Scott Roberts of the Mississippi State University Forestry Department estimates that foresters ought to expect to make between $50 and $200 per acre per year on their pine plantations.[41] St. Johns Water Management District has a general rule on water savings programs that a program is considered efficient if it costs less than $2 per thousand gallons of water saved, and recently the SRWMD signed contracts with farmers to save water by changing their crop rotations at a cost to the district of $195 per acre per year.[42] These numbers provide some real-world insight into how much foresters expect to make and how much water management districts are willing to pay, beyond the theoretical modeling used by the Susaeta study.

Whether $195 per acre per year would be an appropriate figure to pay foresters for managing for water yield is an open question. Water management districts must weigh the benefits of increasing water yield, the funding available to implement programs that encourage foresters to manage differently than how they would traditionally, and what foresters would accept to make the changes in their management techniques.

State environmental agencies should undertake a comprehensive analysis of the economics underlying water-yield payments. Ultimately, the most efficient means of restoring flows and reducing nitrogen pollution in many impaired springs would be to convert intensive agricultural lands to pine, especially long-leaf pine. How much might that cost? Many landowners lease their land to growers, at rates ranging from $150-$250 per acre per year for irrigated land and considerably less for non-irrigated land. Landowners converting intensively farmed property to pine could still expect to earn $50-$200 per acre per year. How much should the State be willing to pay to reap the benefits from that conversion? How much should growers be willing to accept, given that converted agricultural lands will still generate substantial income? What is the likely cost/benefit ratio of paying landowners to manage their pine holdings for water-yield, versus that ratio for other types of projects (e.g. reservoirs, reclaimed water projects) that the State routinely funds? A rigorous, transparent analysis of these options is overdue.

Geographical Limitations

Spring flow in Florida is wholly dependent on re-charge of the aquifer. A program that manages forests for water yield would be best suited for use in regions with high recharge where spring flows and levels are compromised. A high recharge area is one where more precipitation makes its way to the groundwater than would otherwise occur. By targeting these areas, government funds directed towards increasing groundwater would be spent efficiently, and Florida springs would receive the most benefit. If this program was used in locations where there was little or no spring recharge, the benefits of the water yielded to the aquifer would be lost, and the regulatory requirement that MFLs be reached, as well as water quality be improved, would be compromised.[43] In simpler terms, if the goal is springs restoration, it would be a waste of funding to not target this program to high recharge areas.

Policy Options

Managing forests for water yield appears to be a useful technique to increase water in regions where it is needed; the current science indicates that the management technique is viable for retaining water in high recharge areas that would otherwise be lost through evapotranspiration, and water management districts and state agencies have demonstrated a willingness to pay landowners to manage their lands in a particular way.[44] The task then becomes developing these techniques from academic endeavors to policies employed by state agencies and water management districts, so the rewards of managing for water yield can be reaped at a large-scale level. Existing regulatory frameworks provide options for adopting this management technique so it can be implemented on forested lands as quickly as possible. Those frameworks include payments for environmental services, conservation easements, Best Management Practices (BMPs), and legislative reform.

Payments for Environmental Services (PES) are incentive based programs, where a regulatory or governmental agency incentivizes a landowner to perform some action on their land.[45] The landowner has the right to manage their land how they see fit and only act in the manner prescribed by the PES because they have an incentive to do so. A Floridian example of PES is the South Florida Water Management District’s Dispersed Water Management program.[46] The program paid working ranchland owners to keep cattle off parcels of their land so that the land could be used to store water that would otherwise be drained into Lake Okeechobee, in order to lighten the nutrient loaded water that would otherwise enter the Lake and flow into the Everglades.[47] To effectuate the payments, the district and landowners entered into termed contracts.[48] All that the district did was identify a problem, find a potential solution and willing participants, and incentivize them to participate.[49]

A conservation easement is a restriction placed on a piece of land to protect its associated resources.[50] The easement's restrictions can take many forms, sometimes including management practices. FDAC's Rural and Family Lands Protection Program (RFLPP) was designed to protect natural resources and working agricultural lands, and the provisions of the easement detail how the agricultural lands are to be managed.[51] Often, RFLPP requires the landowner to follow FDACS's Best Management Practices (BMPs) for whatever agricultural practice is employed on the property.[52] Conservation easements like those used in RFLPP could be another avenue for incentivizing foresters to manage for water yield.

Agricultural BMPs are actions that landowners can take to conserve water and reduce nutrient loads on the water supply.[53] In most cases practicing BMPs is voluntary, but in some situations landowners are subject to sanctions from FDEP if they are not followed (like in RFLPP easements or in FDEP's Basin Management Action Plans).[54] FDACS adopts BMPs by rule for different types of agricultural use.[55] Filing Notice of Intent Forms and subsequent compliance with BMPs gives landowners a presumption of compliance with state water quality standards and in some cases can satisfy water management district permitting requirements.[56] FDEP has the discretion to bring administrative action against landowners who are not in compliance with the BMPs they have enrolled in, but as action is discretionary, enforcement is not guaranteed. Currently there are silvicultural BMPs that landowners can practice, but they do not include managing for water yield.[57] It is unlikely under Florida law that a BMP that is not economically feasible (like one requiring management for water yield) could be adopted.

Finally, FDACS and the Florida Forest Service (FFS) have the authority to make and adopt rules for the management of public lands.[58] Public lands must be managed for the public interest.[59] The rulemaking process could and should be used by FDACS and FFS to manage public forests for water yield. Public forest land is already managed to improve biodiversity and for other environmentally advantageous reasons, and water yield should be included among those in regions where it makes sense scientifically to do so.[60] Under *Section 373.813, Florida Statutes*, FDACS has the authority to implement new rules and BMPs to improve water quantity and quality for improving and protecting Outstanding Florida Springs.[61] Adopting rules that encourage or mandate managing for water yield on public lands, especially in regions that are home to Outstanding Florida Springs, seems an easy decision for rule makers.

Legal Issues in Paying for Water

The Public Trust Doctrine is a legal doctrine prohibiting private property rights over groundwater, *see Village of Tequesta v. Jupiter Inlet Corp*., 371 So.2d 663.[62] Put simply, "the ownership of the land does not carry with it any ownership of vested rights to underlying ground water not actually diverted and applied to beneficial use."[63] Under this precedent, it may be problematical to use water-yield incentives to compensate landowners for water to which they have no right. An exception to the rule in *Village of Tequesta* exists in *Schick v. Florida Department of Agriculture*, 504 So.2d 1318, where landowners brought an inverse condemnation action against the FDACs for negligently contaminating landowners' groundwater in privately owned wells.[64] The court distinguished *Village of Tequesta*, noting that the landowners were deprived of the use of existing water in their well and pipes.[65] Therefore, the court found that the landowners had a property right in that existing water.[66] Potential water saved by managing for water yield would not fit the exceptions to *Village of Tequesta* as it would not be contained or permitted. Any program or policy adopted would have to be done in compliance with the Public Trust Doctrine, lest it be struck down in Florida courts.

As mentioned previously, *Section 373.042, Florida Statutes*, obliges state agencies and water management districts to determine MFLs for watercourses and Outstanding Florida Springs.[67] The statute provides that the best information available should be used when determining MFLs, and in practice that includes peer reviewing the science used in making those determinations.[68] If presumptive water yields from managing forests were to be considered in the creation or re-evaluation of MFLs, [69] then the existing research and any further research into the technique should also be peer reviewed. While water management districts use peer review reports to defend their "best information available" position, [70] the legal standard against which agency action is judged is whether the rule is arbitrary or capricious.[71] In making his final order on the challenged emergency Silver River MFL, Judge E. Gary Early concluded that although reasonable minds could differ on whether the science used was the most accurate, St.

Johns River Water Management District's decisions were based on facts and logic and thus were not arbitrary or capricious.[72] If a district were to utilize water yield calculations in developing an MFL, it is likely that an administrative judge would not disturb its inclusion if the MFL were challenged. The standard for altering agency action is whether the agency acted arbitrarily or capriciously, and if managing for water yield is shown to be based on facts and logic, the action would not be disturbed.

Conclusion

The science behind managing forests for water yield is still in its early stages, but the data available support the premise that forests with less basal areas than traditionally managed commercial forests will yield more water to surface water bodies and groundwater.[73] Initial economic findings suggest that a program to incentivize foresters to manage for water yield would be efficient to entities making payments, and attractive to the foresters receiving them.[74] The state of Florida has options at its disposal that could incentivize or mandate management for water yield on both public and private lands. Issues remain as to how to properly monetize managing for water yield; the study by Susaeta et al posits prices for water based on the costs of pumping it from the ground, which may not be an accurate evaluation of the cost. There is also the danger of payments running afoul of the Public Trust Doctrine. These issues should not and have not discouraged the State from addressing and exploring the promise of managing forests for water-yield; currently the SRWMD has requested funding (a portion of a larger $3,000,000 request) from FDEP to monitor water yielded from commercial thinning on property in Bradford County.[75]

Managing forests for water yield has the potential to be used to the benefit of Florida's springs, and while there are still uncertainties with the associated science and economics, it should continue to be explored by state agencies and water management districts. The management technique needs to be investigated on larger scales to verify the research already done. Once the real-world results are repeatable and reasonably predictable, the State should consider using water yield from forestry in determining MFLs and other water supply calculations, but only with scientifically conservative values to account for possible errors. The existing economic analysis ought to be bolstered by real-world studies on the costs incurred by managing for water yield as well, so policymakers can better determine what foresters expect to be paid and what policymakers can or should actually pay them. If more aggressive research into managing forests for water yield determines that the program is scientifically and economically feasible, then it ought to be applied in regions where spring flows are affected the most.

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[1] "Silenced Springs" by Robert L. Knight. 2015; FLA. DEP'T OF ENVTL. PROT., FLORIDA'S SPRINGS: STRATEGIES FOR PROTECTION AND RESTORATION (2000), at p. 1.
[2] Id. at 7.
[3] Id. at 1.
[4] Robert L. Knight and Ronald A. Clarke, *Florida Springs – A Water Budget Approach to Estimating Water Availability*, 6 J. EARTH SCI. AND ENGINEERING 2, 59-73 (2016).
[5] Fla. Stat. §373.801
[6] Fla. Stat. §373.042
[7] Id.
[8] *Springs Programs*, FLA. DEP'T OF ENVTL. PROT. (2018), https://floridadep.gov/programs/Springs.
[9] Daniel L. McLaughlin, David A. Kaplan & Matthew J. Cohen, *Managing Forests for Increased Water Yield in the Southeastern U.S. Coastal Plain*, J. OF THE AM. WATER RESOURCES ASS'N (2013); MATTHEW COHEN ET AL., REPORT ON TASK 7: YEAR 3 ANNUAL REPORT, MANAGING FORESTS FOR INCREASED REGIONAL WATER AVAILABILITY, FDACS CONTRACT NO. 20834 (2017).
[10] *What is a Spring?*, SUWANNEE RIVER WATER MGMT. DIST. (2018). http://www.srwmd.state.fl.us/index.aspx?NID=56
[11] McLaughlin, *supra* at 1.
[12] Basal density is defined as the cross sectional area of a single tree at breast height; *see* ALA. COOP. EXTENSION SYS., BASAL AREA: A MEASURE MADE FOR MANAGEMENT (2012) at p. 1.
[13] Id. at 2.
[14] Cohen, *supra* at 2.
[15] Id.
[16] Roche, JW, Goulden, ML, & Bales, RC. (2018). Estimating evapotranspiration change due to forest treatment and fire at the basin scale in the Sierra Nevada, California. *UC Merced*. http://dx.doi.org/10.1002/eco.1978 Retrieved from https://escholarship.org/uc/item/71f611j4

[17] Id.
[18] Andres Susaeta, Jose R. Soto, Damian C. Adams & Derek L. Allen, *Economic Sustainability of Payments for Water Yield in Slash Pine Plantations in Florida*, WATER, MDPI (2016) at 2.
[19] Telephone Interview with Damian Adams (February 20, 2018).
[20] Matzdorf, B., Biedermann, C., Meyer, C., Nicolaus, K., Sattler, C., Schomers, S. (2014) *Paying for Green? Payments for Ecosystem Services in Practice. Successful examples of PES from Germany, the United Kingdom and the United States*.

MÜNCHEBERG. 208 pages. At p. 8.

[21] Telephone Interview with Bob Palmer (April 25, 2018).
[22] McLaughlin, *supra*, at 1.
[23] Id.
[24] Id. at 3.
[25] Id. at 2.
[26] Id. at 3.
[27] MATTHEW COHEN ET AL., REPORT ON TASK 7: YEAR 3 ANNUAL REPORT, MANAGING FORESTS FOR INCREASED REGIONAL WATER AVAILABILITY, FDACS CONTRACT NO. 20834 (2017).
[28] Id.
[29] Id.
[30] Cohen, *supra*, at 13-15.
[31] Id at 2.
[32] Id at 1.
[33] Id. at 3
[34] Id.
[35] Id.
[36] Susaeta, *supra*, at 1.
[37] Id.
[38] Id at 6.
[39] Id.
[40] Id. at 12.
[41] Email from Bob Palmer, Board Member, Florida Springs Institute, to author (May. 2, 2018, 16:35 EST) (on file with author).
[42] Email from Carol Brown, Senior Professional Engineer, St. Johns River Water Management District, to author (Feb. 20, 2018, 10:58 EST) (on file with author).
[43] *Fla. Stat. § 373.801-13*.
[44] Cohen, *supra*, at 2.
[45] Matzdorf, *supra*, at 8.
[46] Dispersed Water Management & Treatment Interagency Team Meeting, S. FLA. WATER MGMT. DIST. (2013).
[47] Id at p. 8.
[48] Id.
[49] This program was subject to controversy, and Governor Rick Scott vetoed some $34 million in payments that were to be used to support it. https://www.tcpalm.com/story/news/local/indian-river-lagoon/politics/2016/03/15/scott-plans-to-veto-money-for-water-storage-torrey-pines/89328314/
[50] *Conservation Easements*, THE NATURE CONSERVANCY. (2018). https://www.nature.org/about-us/private-lands-conservation/conservation-easements/what-are-conservation-easements.xml
[51] Id.
[52] Id.

[53] *Agricultural Best Management Practices*, FLA. DEP'T OF AGRIC. AND CONSUMER SERVS. (2018). https://www.freshfromflorida.com/Business-Services/Water/Agricultural-Best-Management-Practices
[54] Id.
[55] Id.
[56] Id.
[57] FAC 5I-6.002 (2017).
[58] Fla. Stat. § 589.12.
[59] Fla. Stat. § 589.21.
[60] Telephone Interview with Keith Fountain, Conservation Advisors LLC, (January 30, 2018).
[61] Fla. Stat. §373.813.
[62] *Village of Tequesta v. Jupiter Inlet Corp*., 371 So.2d 663 (Fla. 1979).
[63] Id. at 667
[64] *Schick v. Florida Department of Agriculture*, 504 So.2d 1318 (Fla. 1st DCA 1987).
[65] Id.
[66] Id.
[67] Fla. Stat. §373.042.
[68] Id.
[69] Presumptive water yields could conceivably be used in Regional Water Supply Plans, which are described in *Chapter 373, Florida Statutes*.
[70] EDWARD J. BUSKEY ET AL., MINIMUM FLOW CRITERIA FOR THE CALOOSAHATCHEE RIVER ESTUARY, FINAL PEER REVIEW REPORT, S. FLA. WATER MGMT DIST. https://www.sfwmd.gov/sites/default/files/documents/cre_mfl_peer_review_report.pdf.
[71] *St. Johns Riverkeeper, Fla. Defenders of the Envt., Silver Springs Alliance, and Alice Gardner v. St. Johns River Water Mgmt. Dist*., Case No. 17-2543RE, Fla. Div. of Admin. Hearings.
[72] Id. at 34.
[73] Cohen, *supra*, at 2.
[74] Susaeta, *supra*, at 1.
[75] Telephone Interview with Bob Heeke, Senior Project manager, Suwannee River Water Mgmt. Dist. (April 4, 2018).