Literature search by D Reid: 12/10/18

**Recommendations for vegetation/grass height for water quality:** need to consider environmental conditions and survival during stress such as droughts.

1. Depends on location in the watershed and land use; Best to meet multidisciplinary goals including aesthetics.
2. Lawns = Earlier recommendations for a cutting height of 1.5 inches were common. **Current** standards suggest between 2 and **3.75 inches**. Higher cut lawn grasses are more stress tolerant and have deeper more robust root systems (improving infiltration and carbon storage).
3. Typically, a grazing residue height of 3-4" in cool season perennial grasses is recommended. During times of water deficit and high temperatures, a grazing residue height of 4-4.5" would be ideal, allowing the forage to have an adequate root system to seek out the nutrients necessary for regrowth during times of stress. https://extension.psu.edu/grazing-residue-height-matters
4. https://www.sciencedirect.com/science/article/pii/S1877705816300790

Table 4: **Effectiveness of turf and prairie for runoff reduction:**

| Soil Type | Runoff reduction pre-BMP condition by turf grass (%) | Runoff reduction pre-BMP condition by prairie grass (%) |
|---|---|---|
| Loamy Sand | 57 | 98 |
| Silt Loam | 18 | 60 |
| Silty Clay | 10 | 37 |

5. The following information is taken from: “Filtering of water pollutants by riparian vegetation: bamboo versus native grasses and rice in a Lao catchment” by *O. Vigiak, O. Ribolzi, A. Pierret, C. Valentin, O. Sengtaheuanghoung and A. Noble*
    a. The effectiveness of vegetation in filtering pollutants depends on the nature of the pollutant.
    b. Vegetation mainly filters sediments through the following mechanisms:
        i. Infiltration (i.e. reducing runoff volume) and increasing surface roughness (i.e. reducing runoff velocity) with effectiveness depending on many factors, such as rainfall characteristics and riparian topography
        ii. Protecting soils from direct erosion
        iii. Filtering solid particles
        iv. Adsorbing pollutants
        v. Taking up nutrients before they reach the watercourse
    c. Density, height and type are the most important characteristics affecting the capacity of vegetation to retain sediments in riparian land (Karssies and Prosser, 1999).
    d. The density of the vegetation is important, particularly at ground surface, because the vegetation stems offer resistance to overland flow, thus reducing flow velocity and favoring particle settling. Vegetation should be uniformly dense; stoloniferous grasses (those spread by lateral stems, called stolons, which creep over the ground and give rise to new shoots along their length) and creeping grasses are the best, whereas tussocks may concentrate flow (Karssies and Prosser, 1999). A minimum of 45 percent ground cover is recommended for effective buffers. Vegetation height should be at least 10 to 15 cm; it must be high enough to avoid submergence from overland flow.
    e. The effect of vegetation type is more controversial. Grass may be more effective than woody vegetation in reducing bank erosion and trapping sediments, but grass requires active management because succession processes tend to favor woody vegetation (Lyons, Trimble and Paine, 2000). Grass filters colonize new sediments quickly so they are not removed by subsequent runoff; grass filters should be perennial, resistant to flooding and drought, able to grow after partial inundation, and not invasive of other ecosystems (Karssies and Prosser, 1999).
    f. Unless undergrowth is dense, forest is considered the least effective buffer because stems are dispersed and flow often gets concentrated into rills, thus becoming more erosive. Litter works only as a temporary store: it traps sediments, but these are flushed out by subsequent runoff (Karssies and Prosser, 1999; McKergow *et al.*, 2004). However, trees and shrubs can provide

other benefits to streams, such as shade and control of water temperature, which affect primary production and in-stream habitat (Lyons, Trimble and Paine, 2000). Forest should therefore be bordered by a grass strip to trap sediments from adjacent fields.

g. For the southeastern United States, Sheridan, Lowrance and Bosch (1999) recommended forest riparian buffers composed of three zones: a grass filter strip adjacent to fields, whose main function is to spread surface runoff as sheet flow; a first forested zone where infiltration and sedimentation occurs; and a second forested zone to protect and stabilize stream banks.

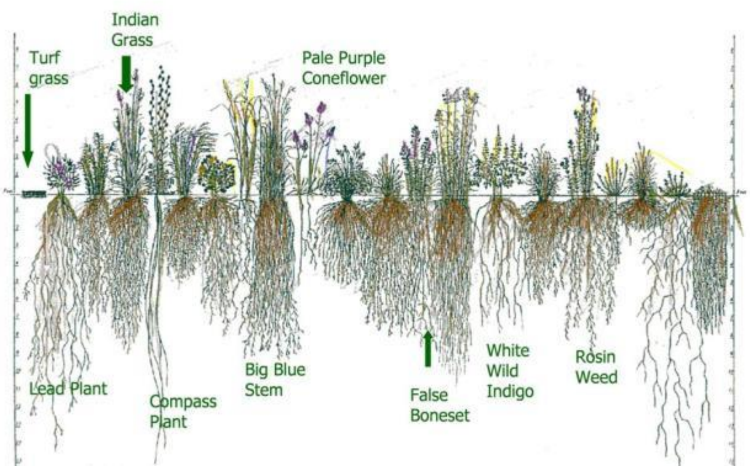
6. A **soil** surface exposed to rainfall is subjected to processes of wetting and **drop impact** which can lead to the formation of a seal during the rainfall, reducing infiltration and increasing erosion by increasing runoff (Ramos and Pla, 2003). *https://www.sciencedirect.com/science/article/pii/S0048969717300797*
7. Vegetation effectiveness is dependent on slope, soil texture and vegetation mix; Structurally diverse riparian buffers, those that contain a mix of trees, shrubs and grasses, are much more effective at capturing a wide range of pollutants than a riparian buffer that is solely trees or grass. Removal efficiencies range from 61% of the nitrate, 72% of the total phosphorous and 44% of the orthophosphates from grass buffers to 92% of the nitrate 93% of the total phosphorous and 85% of the orthophosphates from combined grass and woody buffers. Jontos 2004 **Table 1:** Estimated reduction of nutrient loads from implementation of riparian buffers

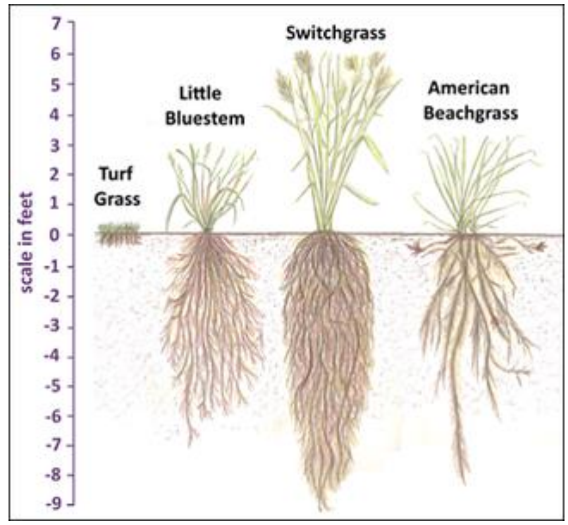
| **Buffer Type** | **Nitrogen** | **Phosphorus** | **Sediment** |
|---|---|---|---|
| - Forested | 48-74% | 36-70% | 70-90% |
| - Vegetated Filter Strips | 4-70% | 24-85% | 53-97% |
| - Forested and Vegetated Filter Strips | 75-95% | 73-79% | 92-96% |

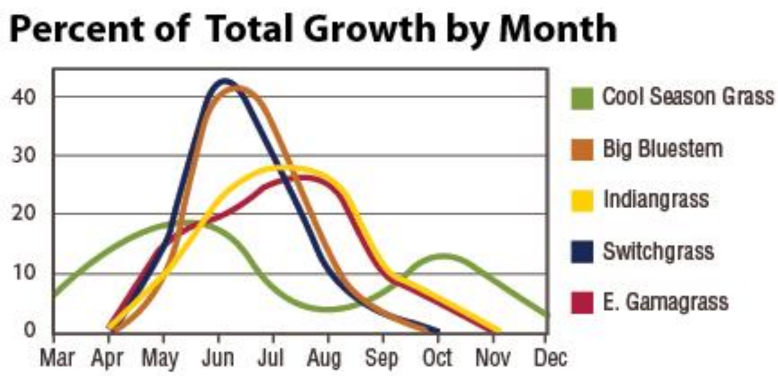
8. Delaware Department of Natural Resources and Environmental Control: Riparian buffers are widely recommended as a tool for removing nonpoint source pollutants especially those carried by surface runoff. A field plot study was conducted to determine the effectiveness of an established multi-species buffer in trapping sediment, nitrogen, and phosphorus from cropland runoff during natural rainfall events. Triplicate plots were installed in a previously established buffer with a 4.1 by 22.1 m (14 × 73 ft.) cropland source area paired with either no buffer, a 7.1 m (23 ft) switchgrass (*Panicum virgatum* L. cv. Cave-n-Rock) buffer, or a 16.3 m (53.5 ft) switchgrass/woody buffer (7.1 m switchgrass/9.2 m woody) located at the lower end of each plot. The switchgrass buffer removed 95% of the sediment, 80% of the total-nitrogen (N), 62% of the nitrate-nitrogen ($NO_3$-N), 78% of the total-phosphorus (P), and 58% of the phosphate-phosphorus ($PO_4$-P). The switchgrass/woody buffer removed 97% of the sediment, 94% of the total-N, 85% of the $NO_3$-N, 91% of the total-P, and 80% of the $PO_4$-P in the runoff. There was a significant negative correlation between the trapping effectiveness of the buffers and the intensity and total rainfall of individual storms. **While the 7 m (23 ft) switchgrass buffer was effective in removing sediment and sediment-bound nutrients, the added width of the 16.3 m (53.5 ft) switchgrass/woody buffer increased the removal efficiency of soluble nutrients by over 20%.** Similar or even greater reductions might have been found if the 16.3 m (53.5 ft) buffer had been planted completely to native warm-season grasses. **In this buffer, combinations of the dense, stiff, native warm-season grass and woody vegetation improved the removal effectiveness for the nonpoint source pollutants from agricultural areas.**
9. That vegetation is a product of the soil is generally understood; that soil is likewise a product of vegetation is not so widely comprehended. A soil covered with its natural mantle of climax vegetation represents conditions most favorable to maximum absorption of rainfall and maximum erosion control. Vegetation profoundly affects soil structure, that is, the arrangement of the individual grains and aggregates that make up the soil. The structure of a soil determines its porosity. http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1010&context=agronweaver
10. Turfgrasses (2-3 in ht) can play a significant role in reducing runoff and pesticide and nutrient leaching.(44,57) Water volumes running off natural groundcover areas may be as little as 10 percent of rainfall, compared to 55 percent from mostly paved areas. A thick and carefully managed turfgrass allows 15 x less runoff than does a lower quality lawn.(29) A healthy, dense stand of turfgrass can reduce runoff volume to almost zero.(57,60) An average golf course of 150 acres can absorb 12 million gallons of water during a 3-inch rainfall.(29) Research has shown the infiltration rate on dense, sodded slopes is about 7.6

inches per hour. On slopes with less cover, the water penetrates at about 2.4 inches per hour.(44) Turf grass also produces, with every 25 square feet, enough oxygen for one person for one day. http://cues.cfans.umn.edu/old/extpubs/5726turf/DG5726.html

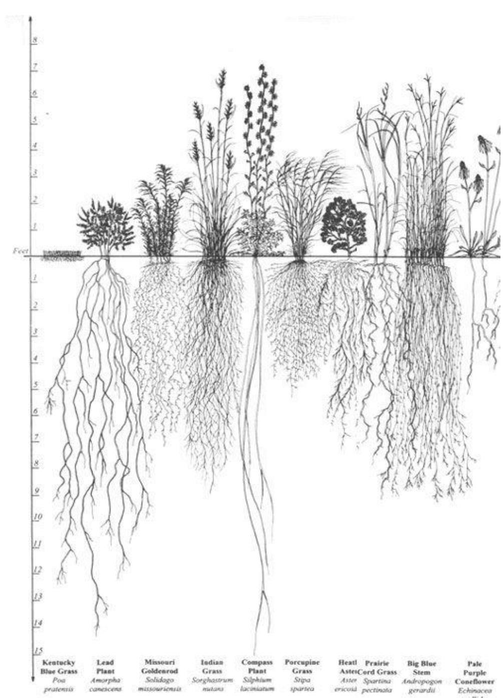
**Images showing the extent of root systems for native grasses and plants versus turf grasses**



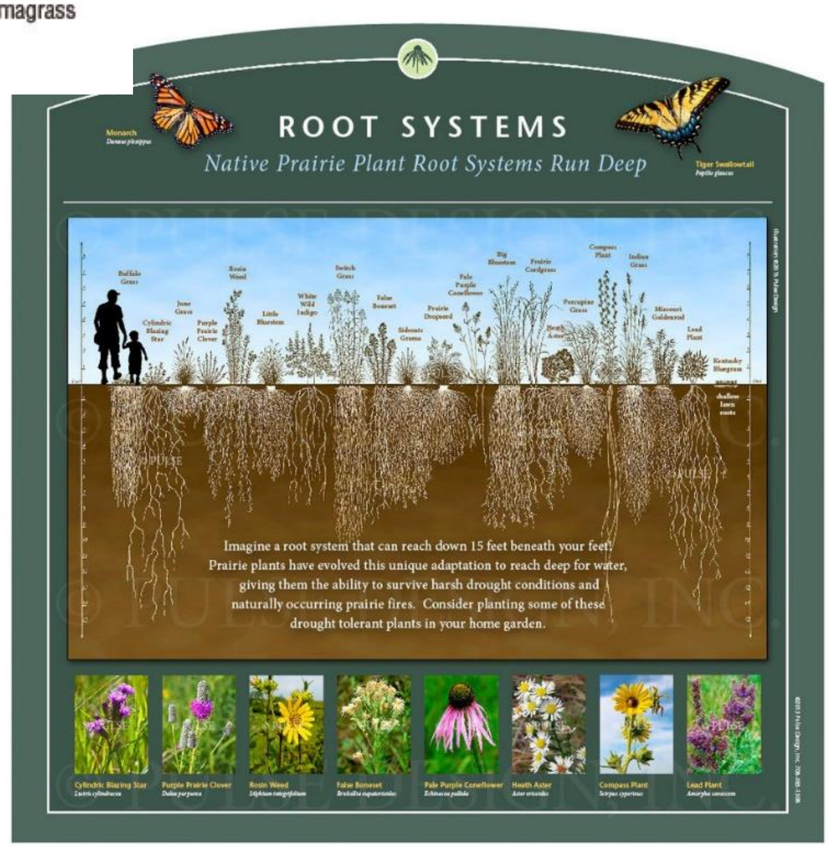




Native grasses and wildflowers have more robust root systems than turf grasses. Over-grazing and/or mowing too low, reduces plant vigor and increases stormwater runoff and soil erosion.




Root Systems of Prairie Plants

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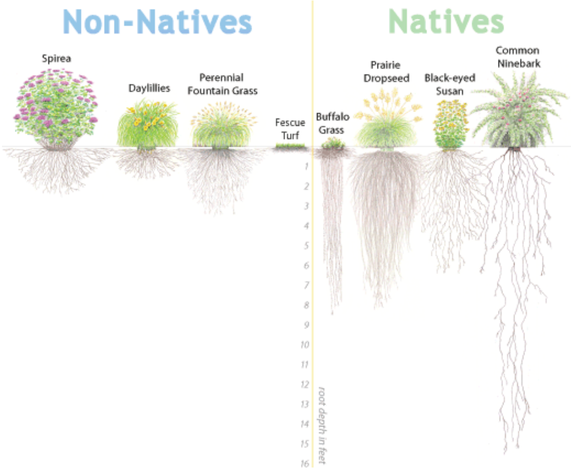
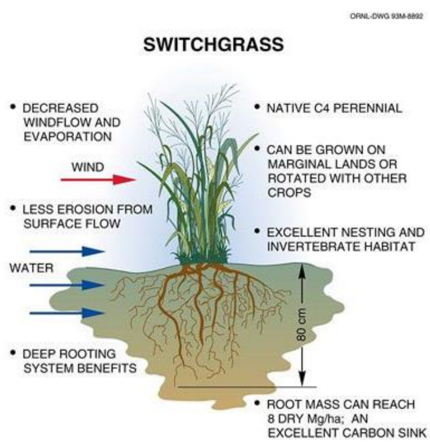



Using this information for interpretive signage will go a long way in assisting residents to accept more natural landscapes that are “less” maintained as long as they have a clear zone of a minimum 3’ along pedestrian accesses.

https://static1.squarespace.com/static/560b2e0ee4b040a6eb9ec078/56129842e4b00b12a2416d9f/5891539115d5dbb9c9d752cd/1528991731512/Pulse-Design-Nature-Sign-030-1414-01A-1000-72mw.jpg?format=1000w

**Stormwater mgt efforts can also mitigate GHG emissions. This illustrates how much more organic matter can be accumulated below ground in root systems; a 1:3 ratio of above ground to below ground**.




And when this is combined with soil macro and microorganisms such as mycorrhizae the potential for sequestering carbon dioxide is enhanced. Research indicates that tree seedlings inoculated with mycorrhizae sequestered 17% more $CO2$ than controls. https://www.nature.com/articles/srep34336

**Note: The image below illustrates the impact of mowing or not, on root systems.**

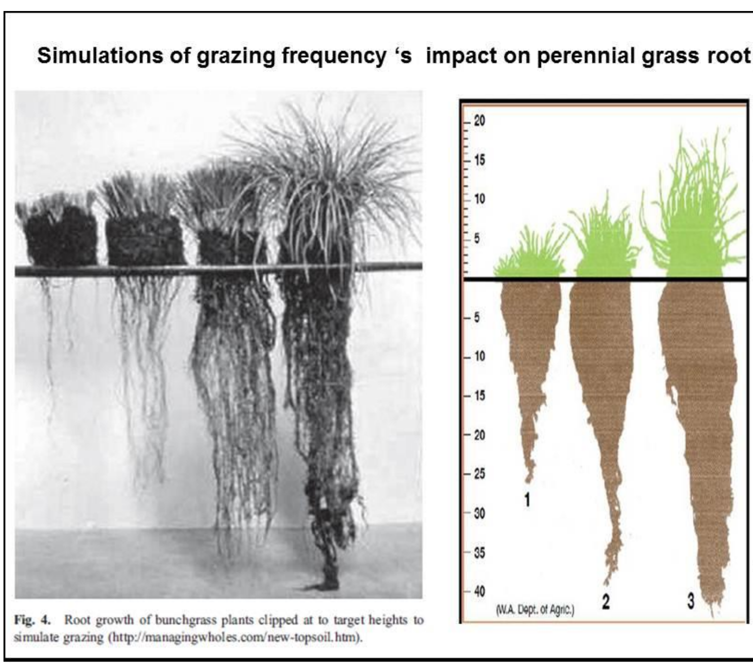


Fig. 4. Root growth of bunchgrass plants clipped at to target heights to simulate grazing (http://managingwholes.com/new-topsoil.htm).

**By reducing mowing and increasing mowing heights, a more vibrant turf or ground cover can be achieved that will:**

1. Increase removal of stormwater pollutants including sediment from erosion.
2. Increase infiltration of stormwater into soils thus decreasing runoff/flooding.
3. Increase organic matter within soils (1% increase in soil OM will hold an additional 20,000 gal of stormwater/ac).
4. Improve air quality directly by reducing emissions from equipment.
5. Improve air quality indirectly by increasing CO2 sequestration within the soil.