

# **White Paper for GWNF Plan Revision**

## **Whole Tree Harvesting and Acid Deposition - Risk Assessment and Management Options to Protect Soil Productivity**

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**This white paper was prepared using pertinent, modern research literature, personal communications with soil scientists in Virginia and West Virginia, Forest Service regional air resource and geology specialists. Also, comments and concerns from public scoping were used to focus the issues. Currently we are working with Virginia Tech under agreement to resample soils which were sampled on the Forests 15-20 years ago, in areas that we think are sensitive to acid deposition. Hopefully, this will add to our knowledge of soil acidification trends and levels on our Forests. This white paper also helps us understand the issue of whole tree harvesting on the George Washington National Forest and how we may want to manage this harvesting system, especially on our most nutrient poor and acid sensitive soils. Protecting soil productivity is something we will do, as we manage for our other resource values.**

### **Summary:**

**There is much evidence now of acidic deposition occurring in and near the George Washington National Forest. This has been ongoing for decades. The Clean Air Act has reduced some components of the deposition in recent years. There is a lag time before these improvements begin to show up in the soils and water affected by this deposition. Some of the geology and soils of the Forest have low buffering capacities against the effects of acid deposition. These areas can be generally mapped using geology, water chemistry, soils and atmospheric deposition spatial and tabular data. These low buffered areas have the greatest risk of becoming increasingly acidic, having greater amounts of aluminum in rooting zones and having stressed ecosystems due to losses of beneficial plant available soil nutrients.**

**These high risk areas for soil acidification are also areas where whole tree harvesting can have the most impact on soil productivity. Whole tree and biomass removal harvests could be more in demand as bio fuels and other products that require harvesting all biomass growing on a site. This could become a desired use for some of the lower quality sites on the Forest, where total biomass removal could be more viable than a bole only product. Removal of large amounts of nutrients on these poorer sites through whole tree harvesting (biomass removal) can affect soil productivity according to some research. Soils most susceptible to impacts from whole tree harvesting are characterized by shallow depth to bedrock, low clay**

**content, drier aspects and thin organic layers on the surface. Generally, these soils have low site productivity as well.**

**Whole tree harvesting on more productive sites with more buffering capacity seems to be a lower risk for impacting soil productivity. To protect soil productivity on our high risk soils, there seems to be sufficient research support to not do whole tree (biomass) removal on where they occur. Other silvicultural treatments and firewood removal would be acceptable. Whole tree harvesting would be acceptable in other areas. Conserving nutrients on our least productive soils seems to be the correct thing to do, according to research, especially with acid deposition continuing its effect on the less buffered soils and watersheds.**

**Current Situation and decision to be made: The George Washington NF Plan currently does not allow whole tree harvesting anywhere on the Forest. The first Jefferson NF Plan had a standard of not whole tree harvesting on SI<50 sites. The new JNF Plan has no restrictions on whole tree harvesting. We probably would like both Forest Plans to say the same thing on this issue. Research shows that whole tree harvesting can be done on better sites with little effect to soil productivity.**

**Content:**

- **Evidence of Acid Deposition impacts.**
- **Review of Whole Tree Harvesting effects upon soil.**
- **Indicators of Risk**
- **Recommended management strategy and mitigations from research.**
- **Proposed management strategy and mitigations for the National Forest.**

**Evidence of Acid Deposition Impacts**

Driscoll, Charles T., et al., 2001.

- Acidic deposition has accelerated the leaching of base cations from soils, thus delaying the recovery of ANC in lakes and streams from decreased emissions of SO<sub>2</sub> (at the Hubbard Brook Experimental Forest the available soil Ca pool appears to have declined 50% over the past 50 years).
- Sulfur and N from atmospheric deposition have accumulated in forest soils across the region, and the slow release of these stored elements from soil has delayed the recovery of lakes and streams after emissions have been reduced.
- Acidic deposition has increased the concentration of toxic forms of Al in soil waters, lakes, and streams deficiencies of Ca<sup>2+</sup> and Mg<sup>2+</sup> have caused extensive mortality of sugar maple in Pennsylvania, and acidic deposition contributed to the depletion of these cations from soil.

Lovett, G.M., and T.H. Tear. 2008

- Nitrogen contributes to acidic deposition, ground-level ozone, and over-enrichment of soil and surface water. Reduces forest productivity (under high loading). Increases potential vulnerability to pests and pathogens. Causes

declines in some sensitive wetland plant populations. Alters plant species composition. Increases algal growth and reduces water clarity in some systems. Contributes to declines in dissolved oxygen and degradation of nursery habitats in estuaries.

Soil acidification:

- Enhances the mobilization of toxic aluminum from soils to tree roots.
- Increases sulfate and nitrate leaching from soils to surface waters.
- Promotes the loss of important buffering nutrients from soils.
- Reduces ecosystem productivity.

S. W. Bailey, S. B. Horsley, and R. P. Long, 2005

- At all four sites there were significant decreases in exchangeable Ca and Mg concentrations and pH at all depths. Exchangeable concentrations increased at all depths at all sites, however increases were only significant in upper soil horizons. There were long-term decreases in pH, exchangeable Ca, and exchangeable Mg concentrations and increases in exchangeable Al concentration at all depths between two sampling periods separated by 30 yr.
- Acidic deposition endangers forest health by depleting available calcium in the soil system. Between 1967 and 1997 acidic deposition caused significant decreases in exchangeable soil calcium at all of four study sites on the Allegheny Plateau in Pennsylvania.

Cronan and Schofield, 1979;

- These observations indicate that calcium may become a limiting resource for the growth of forested ecosystems, ultimately predisposing forests to health problems such as increased mortality due to reduced resistance to pests and pathogens

Federer et al., 1989,

- Along with base cation leaching, another consequence of soil acidification is increased solubility and mobility of aluminum in forested ecosystems

### **Whole Tree Harvesting Effects Upon Soil**

Katherine J. Elliott, Jennifer D. Knoepp, 2005.

- Methods that remove excessive amounts of organic material (branches, leaves, tree crowns), such as whole-tree harvesting, have more detrimental effects on nutrient availability than stem-only removal methods that leave more organic material at the harvest site.

United States Department of Agriculture Forest Service Pacific Northwest Research Station General Technical Report, PNW-GTR-222, March 1989.

- In conventional harvesting, where only the bole or stemwood is removed, nutrient losses tend to be low.
- Stemwood and bark of most temperate forest trees account for about 65 to 85 percent of the total biomass but only 25 to 50 percent of the total nitrogen in the trees (Marion 1979).

- Natural inputs of nutrients will often compensate for losses of this magnitude, resulting in no loss of long-term productivity potential.
- On nutrient poor sites having a high percentage of total nutrients stored in the trees, productivity potentials could be lowered.
- Whole-tree harvests can increase average nitrogen-removal rates in some temperate coniferous forests by 100 percent and in some temperate broadleaf forests by as much as 215 percent (Marion 1979). The actual increase in nutrient losses brought on by whole-tree harvesting varies greatly with species, age, and site productivity, but harvest methods removing more than just the stem result in substantially greater nutrient losses (Morrison and Foster 1979).
- The absolute amounts removed are less important than the time required for the site to replace the lost nutrients.
- If revegetation of the site is rapid, the accelerated leaching losses usually last for only a few years. Even with immediate revegetation of the site, however, a lag of at least one year occurs in which more nutrients are mobilized than can be taken up by the vegetation (Bormann and Likens 1979). The nutrients released through decomposition of the forest floor and increased nitrification can enhance the growth of regeneration on the site.

#### **Other whole tree harvest research**

1. Due to low soil Ca content and high Ca content in woody tissues, whole-tree harvesting depleted total ecosystem Ca to a much greater extent than N, P, or K. Soil reserves and atmospheric inputs may be adequate to sustain total N, P, and K supplies with whole-tree harvesting, but soil amendments may be necessary to sustain Ca supplies.
2. Regardless of the intensity of forest harvest, the quantity of nutrients lost from the site by soil erosion or rainwater leaching was small compared to amounts removed in harvested wood. Nutrients removed in harvested wood were potentially large enough to reduce subsequent forest growth at some sites.
3. The combination of leaching loss and whole-tree harvest at short (40-year) rotations apparently could remove roughly 50% of biomass and soil Ca in only 120 years.
4. Calcium and Mg concentrations at the clearcut site were 88 and 75% higher than the levels at the whole-tree site 5 years after harvest. The increased soil fertility observed could provide a valuable nutrient supply to the succeeding forest stand, but net nutrient outputs through harvest and burning could also eventually reduce the already low productivity of these sites.
5. Full tree harvesting removes substantially more nutrients from the site than tree length harvest methods due to the high concentration of nutrients in the branches and foliage (Maliondo et al. 1990). The possible effects of this nutrient removal include a decline in soil fertility (Wells and Jorgensen 1979, Perala and Alban 1982, Silkworth and Grigal 1982), loss of organic matter and a potential increase in site acidification (Maliondo et al. 1990).

6. The decomposition of logging slash is an important source of N for the next tree crop, especially on nutrient poor sites. With full tree harvesting there is often very little remaining debris (Gordon 1983), and this may lead to a N deficiency.
7. Theoretically, site acidification is thought to result from the removal of positive ions or cations (K, Ca, Mg and sodium (Na)) normally present in the branches and foliage of trees (Foster and Morrison 1987, Maliondo 1988). These cations normally buffer acid inputs from precipitation and from the decomposition of organic matter (Maliondo 1988).
8. Organic matter decomposition releases organic and inorganic acids as well as cations and may be accelerated after full tree harvesting due to increased soil temperature and moisture availability (Maliondo 1988).

### **Indicators of soil acidification risk**

- The calcium/aluminum (Ca/Al) molar ratio of the soil solution provides a valuable measurement endpoint or ecological indicator for identification of approximate thresholds beyond which the risk of forest damage from Al stress and nutrient imbalances increases. The Ca/Al ratio can also be used as an indicator to assess forest ecosystem changes over time in response to acidic deposition, forest harvesting, or other processes contributing to acid soil infertility.
- Based on a critical review of literature on Al stress, we estimate that there is a 50:50 risk of adverse impacts on tree growth or nutrition when the soil solution Ca/Al ratio is as low as 1.0, a 75% risk when the soil solution ratio is as low as 0.5, and nearly a 100% risk when the soil solution Ca/Al molar ratio is as low as 0.2.
- The Ca:Al ratio of soils can be used to guide the location of soil disturbing activities and determine harvest method and rotation length.
- According to White and Harvey (1979), timber harvesting should be avoided on sites with very shallow to bedrock soils and marginal fertility. A significant proportion of the nutrients are contained in the above ground biomass and the limited productivity of the site is maintained by the nutrient cycle.
- Sites sensitive to nutrient depletion as a result of full tree harvesting include those with medium to coarse textured soils and little humus, and sites with shallow soils.
- Bailey et al. (2004, 2005) propose that calcium levels below 2% in the B horizon is a threshold below which forest health will become susceptible to decline.
- Because of these biological responses to changes in the soil system, aluminum contents in biomass can be used to classify the health of forested ecosystems (Cronan and Grigal, 1995; Johnson et al., 1982)
- Forests on deeper soils are generally less susceptible to nutrient depletion from full tree harvesting than stands on shallow soils (Timmer et al. 1983). This is, in part, related to the absolute soil volume differences between the two soil depths and the associated differences in aeration, water retention and movement. On poor quality sites, in which a large proportion of the nutrient capital of the site is

contained in the crown components, full tree harvesting may be more detrimental to long-term productivity.

### **Possible management options and mitigations for reducing nutrient loss and soil acidification.**

- Soil pH increased after fire and thinning+fire
- Timber harvesting practices may be modified in areas with low pH and low Ca:Al ratios because harvest methods can differentially affect nutrient cycling of the forest floor.
- As much as possible, all organic material should be left after any harvesting method to maximize the potential for re-supplying nutrients to the soil. Rather than clearing or removing downed trees, standing dead trees, and debris for firewood, it would be better to leave this material on the ground to decompose.
- Whole-tree harvesting after leaf fall reduced the potential drains of N, P, K, and Ca by 7, 7, 23, and 5%, respectively, compared with potential removal by harvesting during the growing season.
- Three measures are possible to mitigate Ca depletion reduction of acid deposition to pre-industrial levels, restrictions on short-rotation whole-tree harvesting, and liming of vast forest areas on a scale similar to liming agricultural crops. . Large-scale liming, perhaps at the same time as harvest, may be required if forest productivity is to be maintained at present levels.
- Full tree harvesting of hardwoods after leaf fall will remove less nutrients and in different proportions than harvesting when the trees are in full leaf. Removal of N, P and K would be halved, and most of the Ca and Mg would remain on the site (Freedman 1990) owing to the nutrient resorption characteristics of some hardwood species.

As a result of this paper, internal discussion, further literature review and public comment, the George Washington National Forest has established a strategy and a standard to address the issue of using biomass for energy production. We will no longer use the term whole tree harvesting and will not allow it on the Forest. Instead we will use the term Small Diameter Utilization (SDU).

Currently we allow material down to 4 inch diameter to be harvested in timber sales. These are harvest sites on soils with moderate to high potential for tree growth. If SDU is proposed for harvest in areas with moderate to high productivity we would allow material down to 2 inch diameter to be harvested. If SDU harvest were ever proposed for low productivity sites, the harvest would be a thinning, on a longer rotation and material down to only 4 inch diameter would be allowed to be taken. More slash would be left on the sites with less productivity.and more trees left standing. These criteria would help protect soils with lower productivity from being impacted from the harvest.

No below ground biomass is allowed to be harvested. Only material from harvested trees. Areas on the Forest most at risk for nutrient depletion are identified and mapped by using geology, water chemistry, soil survey and acid deposition spatial

data. We feel we can address the national need for alternative/renewable fuel sources and protect our soils as well with this direction in our Forest Plan.

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