Can forest carbon be optimized following an eastern spruce budworm outbreak?

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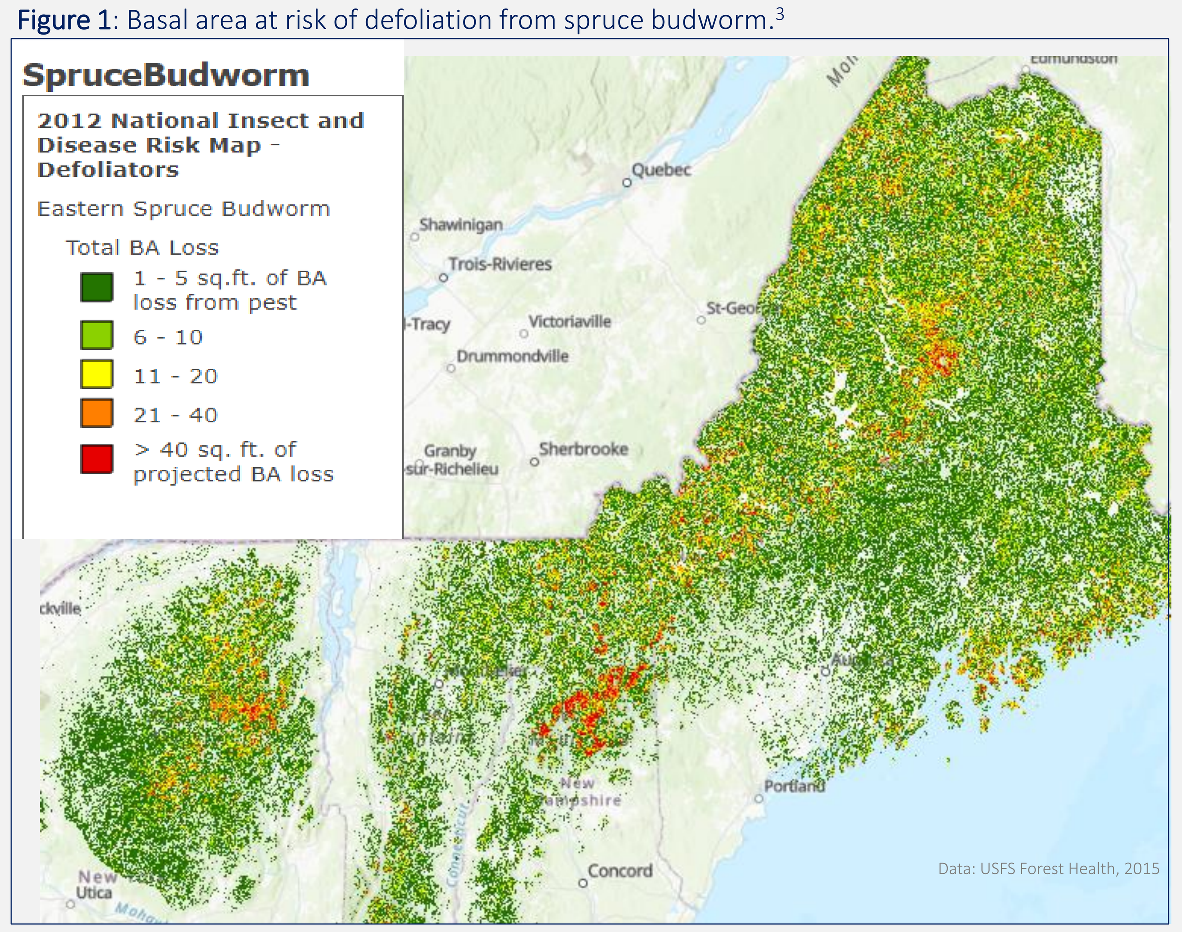
INTRODUCTION

Eastern spruce budworm

(*Choristoneura fumiferana*)

4.7 million ha of spruce-fir at risk of defoliation in northern New England and New York (2x state of NH)[1]

Figure 1: Basal area at risk of defoliation from spruce budworm.[3]



Previous study by Gunn et al. 2020

- Widespread defoliation and management response (salvage dead wood) has implications for forest carbon
- In most cases, salvaging leads to net carbon emissions in years 0-20 after treatment
- Salvaging leads to a net carbon sequestration over longer time periods (years 20-40 after treatment)

RESEARCH QUESTIONS

1. Can we optimize forest carbon following a major disturbance using machine learning methods?

2. Are there stand conditions (e.g. basal area of balsam fir) where not salvaging may be preferred from a carbon perspective?

3. How does economic discounting affect carbon optimization results? Discounting captures a preference for near-term storage and penalizes longer wait periods before sequestering more carbon with salvage logging.

METHODS

Carbon data

Gunn et al. 2020 calculated expected carbon values (Mg/ha) at 4,926 FIA plots 40 years following different management response scenarios. Carbon estimates were derived using the Forest Vegetation Simulator and a Life Cycle Assessment.

We used carbon values provided by Gunn et al. 2020. Carbon values at each FIA plot vary based on the following scenarios:

1. Salvage vs. No Salvage Response

2. Additional treatments (heavy cut, light cut, etc…)

3. Discount rate preference (0-5%)[5]

   - Discounting penalizes having to wait to receive carbon sequestration benefits and accounts for the uncertainty of new regeneration to replenish carbon stocks if wood is salvaged
   - Higher discount rates value near-term storage (years 0-20) and may favor not salvaging more often

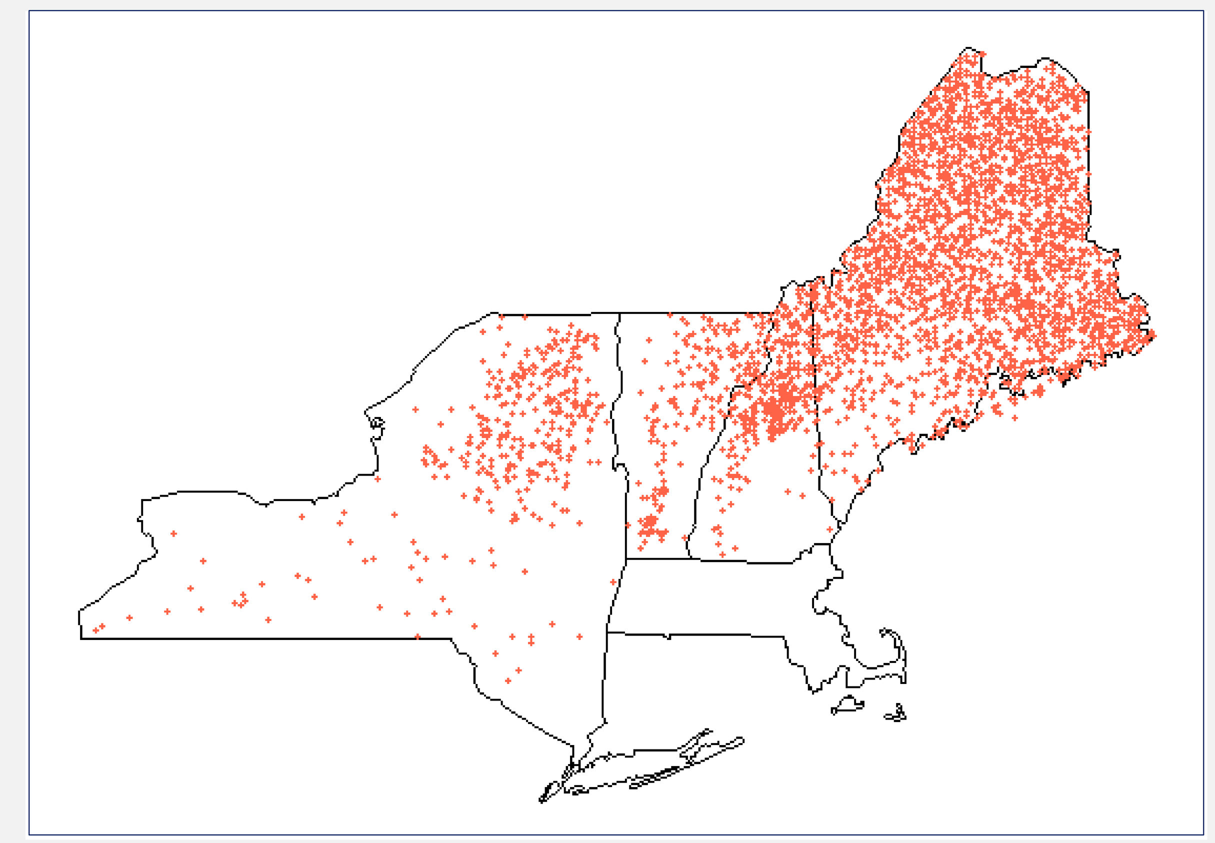
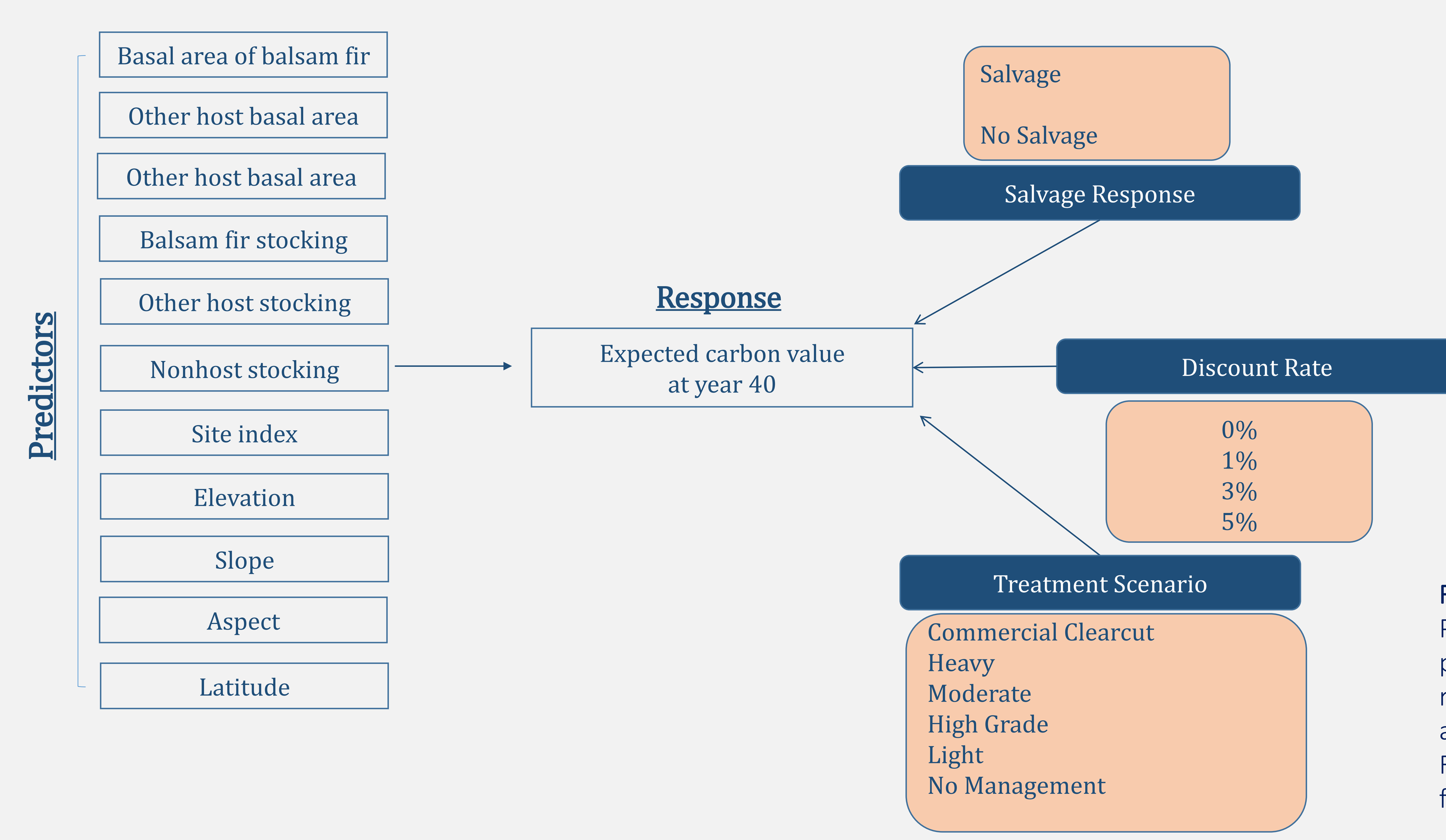


Figure 2: FIA study plots (n=4,926) where carbon values were provided by Gunn et al. 2020.

Decision tree models



Decision trees learn

1. Does salvaging or not salvaging store more carbon at year 40

2. What are the predictor values in high carbon storage scenarios

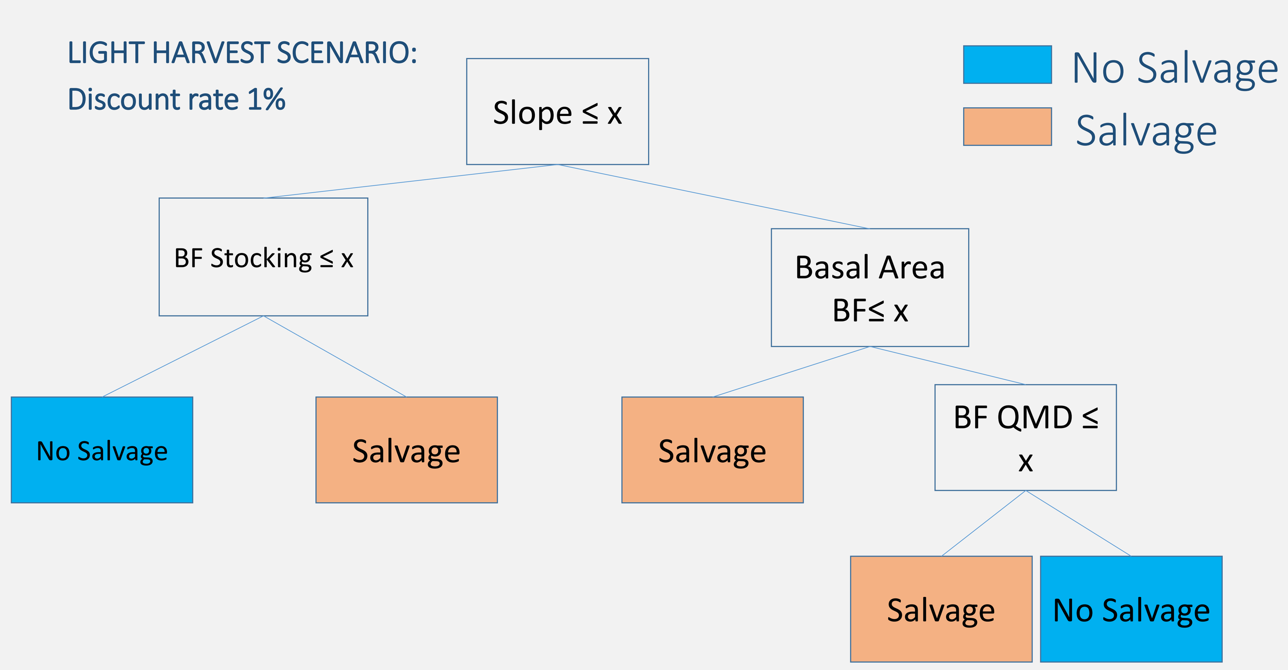
Figure 3: (Left) Conceptual diagram of decision tree model inputs. Predictor variables were calculated at each FIA plot using FIA tree, plot, and condition level data[2] and were chosen based on expected relationships to mortality from spruce budworm which is where we also expect salvaging logging to occur as a management response. Response variables were either directly retrieved from or derived from Gunn et al. 2020 carbon estimates.

RESULTS

Decision tree results

- Decision trees identify key predictors to optimize forest carbon
- Tree structure varies based on (1) treatment scenario and (2) discount rate

Figure 4: (Right) Decision tree models produce trees to optimize carbon values at each plot.[4] Branches are created from the most important predictors variables. Stand characteristics can be used to follow each branch to a decision of whether salvaging or not salvaging likely stores the most carbon at year 40.



RESULTS

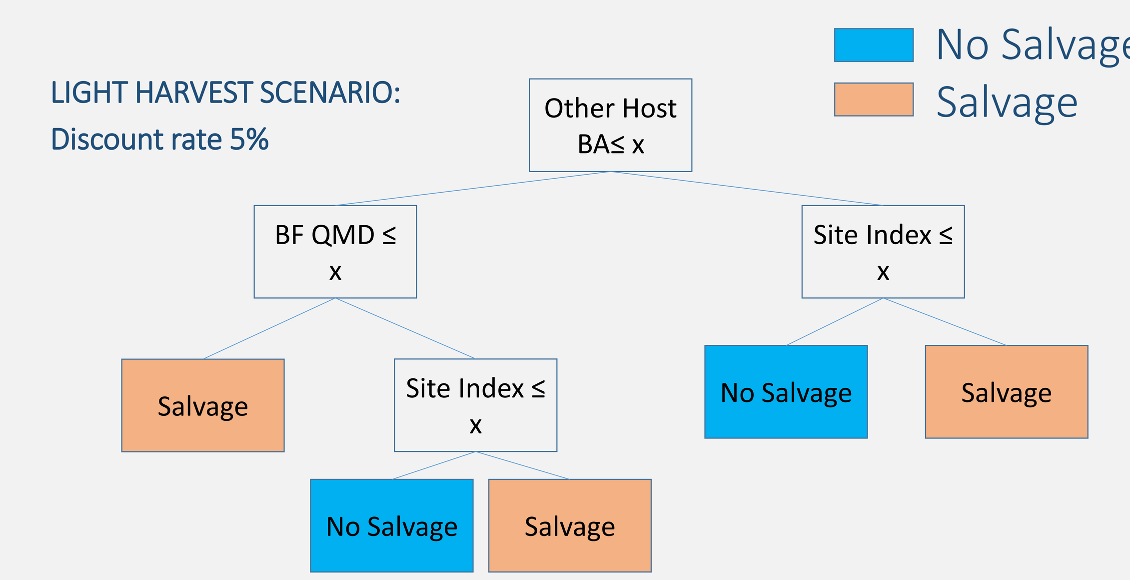


Figure 5: Decision tree branches (important predictor variables) change based on harvest scenario and discount rate scenario. In this figure a discount rate of 5% generates models with different tree branches compared to figure 4 that shows a discount rate of 1% scenario.

CONCLUSIONS

Stand characteristics:

•Higher basal area of host species (balsam fir and spruce species) and larger host trees (higher QMD) could suggest not salvaging may be preferred

Discounting:

Higher discount rates (valuing near-term storage) suggests salvaging less often may be preferred

General

More volume removed from salvaging = greater swings in forest carbon budget

If there is a lot of wood salvaged, and you care about GHG emissions, choose to not salvage or salvage less

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REFERENCES

1. Gunn, J. S., Ducey, M. J., Buchholz, T., & Belair, E. P. (2020). Forest Carbon Resilience of Eastern Spruce Budworm (Choristoneura fumiferana) Salvage Harvesting in the Northeastern United States. Frontiers in Forests and Global Change, 3, 1–2. https://doi.org/10.3389/ffgc.2020.00014
2. Gray, Andrew N., Brandeis, Thomas J., Shaw, John D., McWilliams, William H., Miles, Patrick D. (2012). Forest Inventory and Analysis Database of the United States of America (FIA). In: Dengler, J., Oldeland, J., Jansen, F., Chytry, M., Ewald, J., Finckh, M., Glockler, F., Lopez-Gonzalez, G., Peet, R. K., Schaminee, J .H. J., eds. Vegetation databases for the 21st century. Biodiversity and Ecology. 4: 225-231.
3. Krist, Frank J., Jr., Ellenwood, James R., Woods, Meghan E., McMahan, Andrew J., Cowardin, John P., Ryerson, Daniel E., Sapio, Frank J., Zweifler, Mark O., Romero, Sheryl A.(2014). 2013-2027 National Insect and Disease Forest Risk Assessment. FHTET-14
4. Quinlan, J. R. (1990). Decision trees and decision-making. *IEEE Transactions on Systems, Man, and Cybernetics*, *20*(2), 339–346. https://doi.org/10.1109/21.52545
5. Timmons, D. S., Buchholz, T., & Veeneman, C. H. (2015). Forest biomass energy: assessing atmospheric carbon impacts by discounting future carbon flows. *GCB Bioenergy*, *8*(3), 631–643. https://doi.org/10.1111/gcbb.12276