

# Environmental Sustainability

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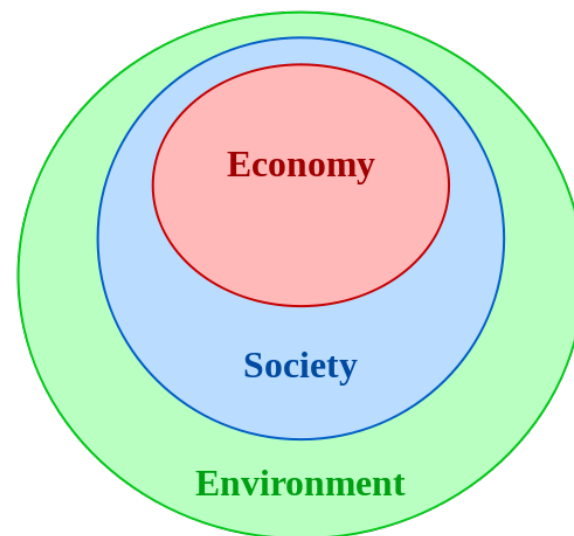
Northwest Advanced Renewables Alliance





# Define: Sustainability

- Sustainability – endurance of systems and processes
  - Economic
  - Social
  - Environment



<https://en.wikipedia.org/wiki/Sustainability>  
Scott Cato, M. (2009). Green Economics. London: Earthscan, pp. 36–37.



# Environmental Sustainability

- The rates of renewable resource harvest, pollution creation, and non-renewable resource depletion that can be continued indefinitely



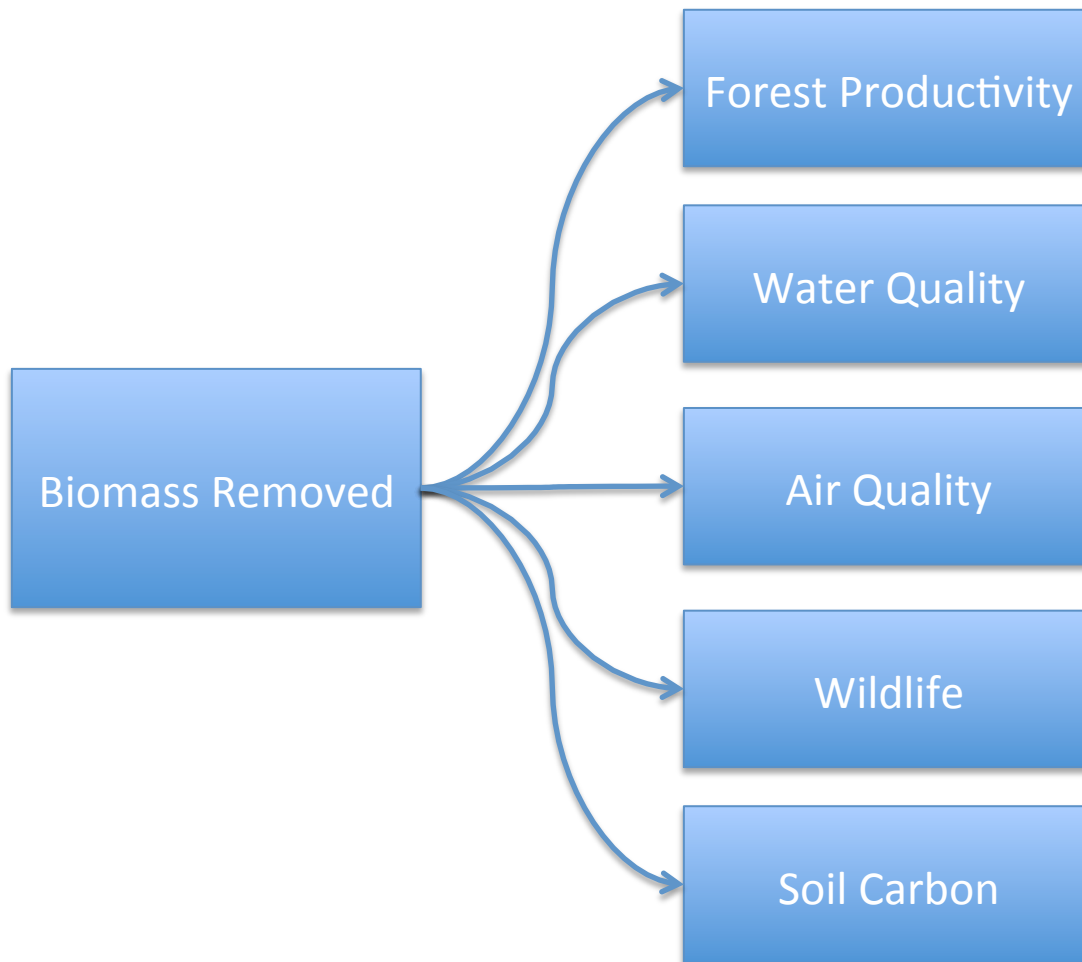
# Environmental Sustainability

- What are the impact of forest residual harvesting on the environment?
  - Long-term Forest Productivity
  - Water Quality
  - Air Quality
  - Soil Carbon
  - Wildlife



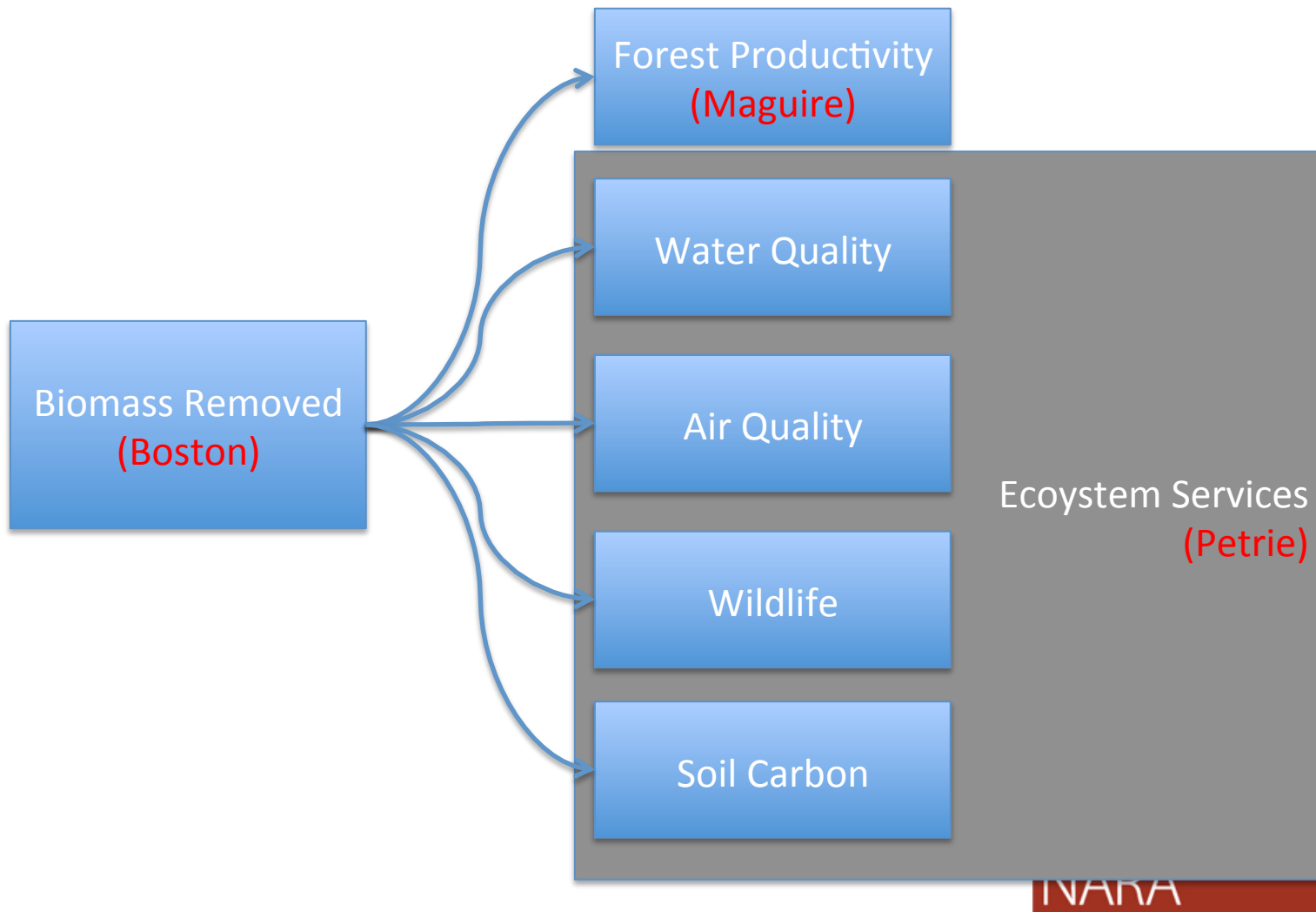


# Simplified Conceptual Model



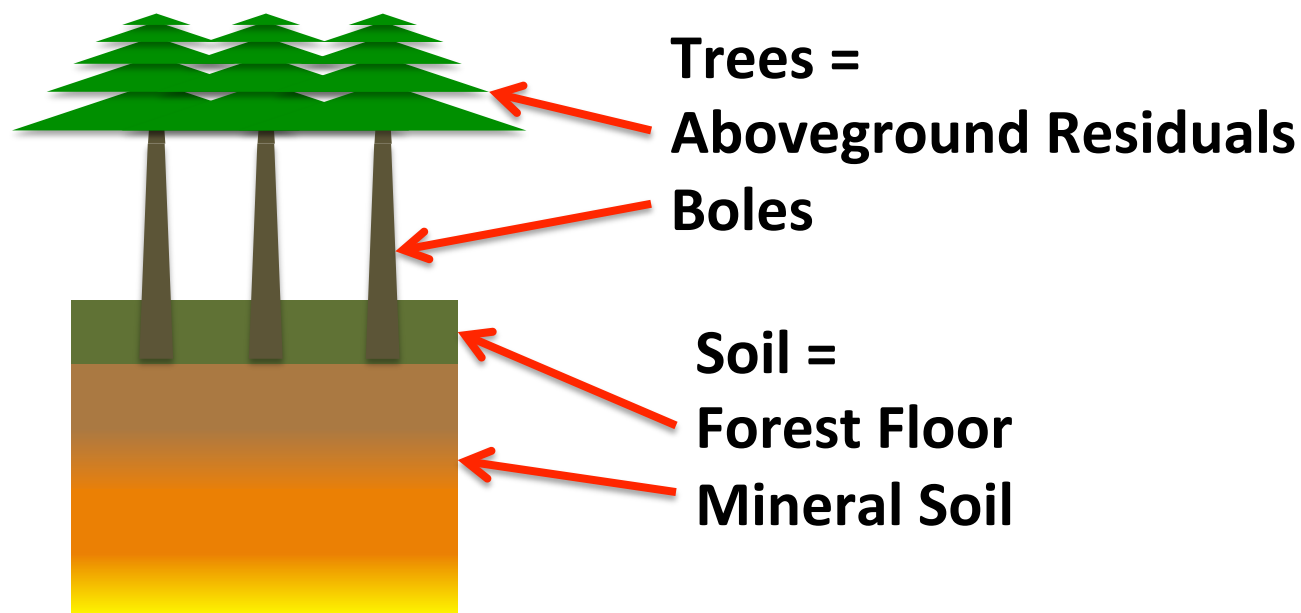


# Simplified Conceptual Model



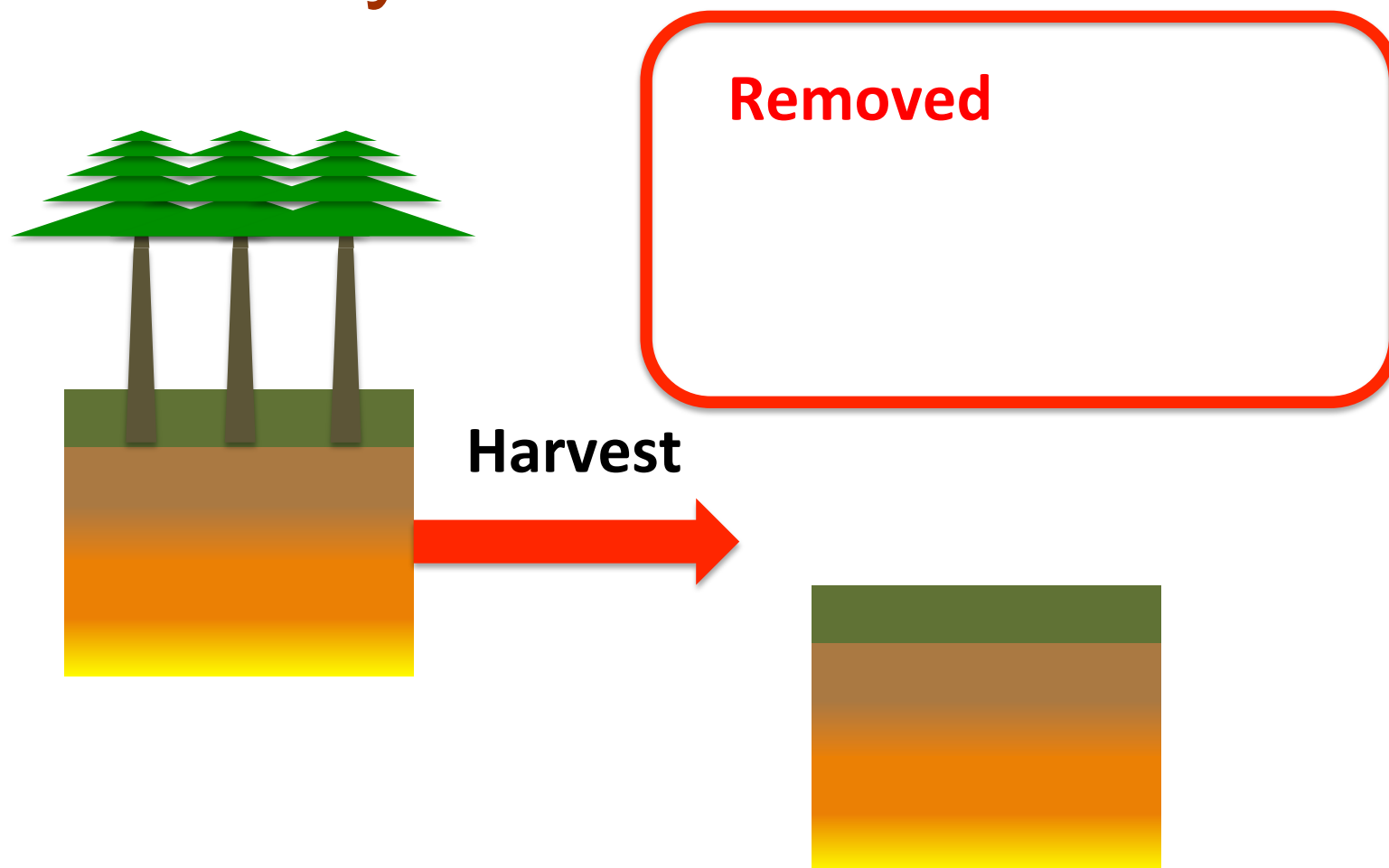


# Biomass Removal: Components



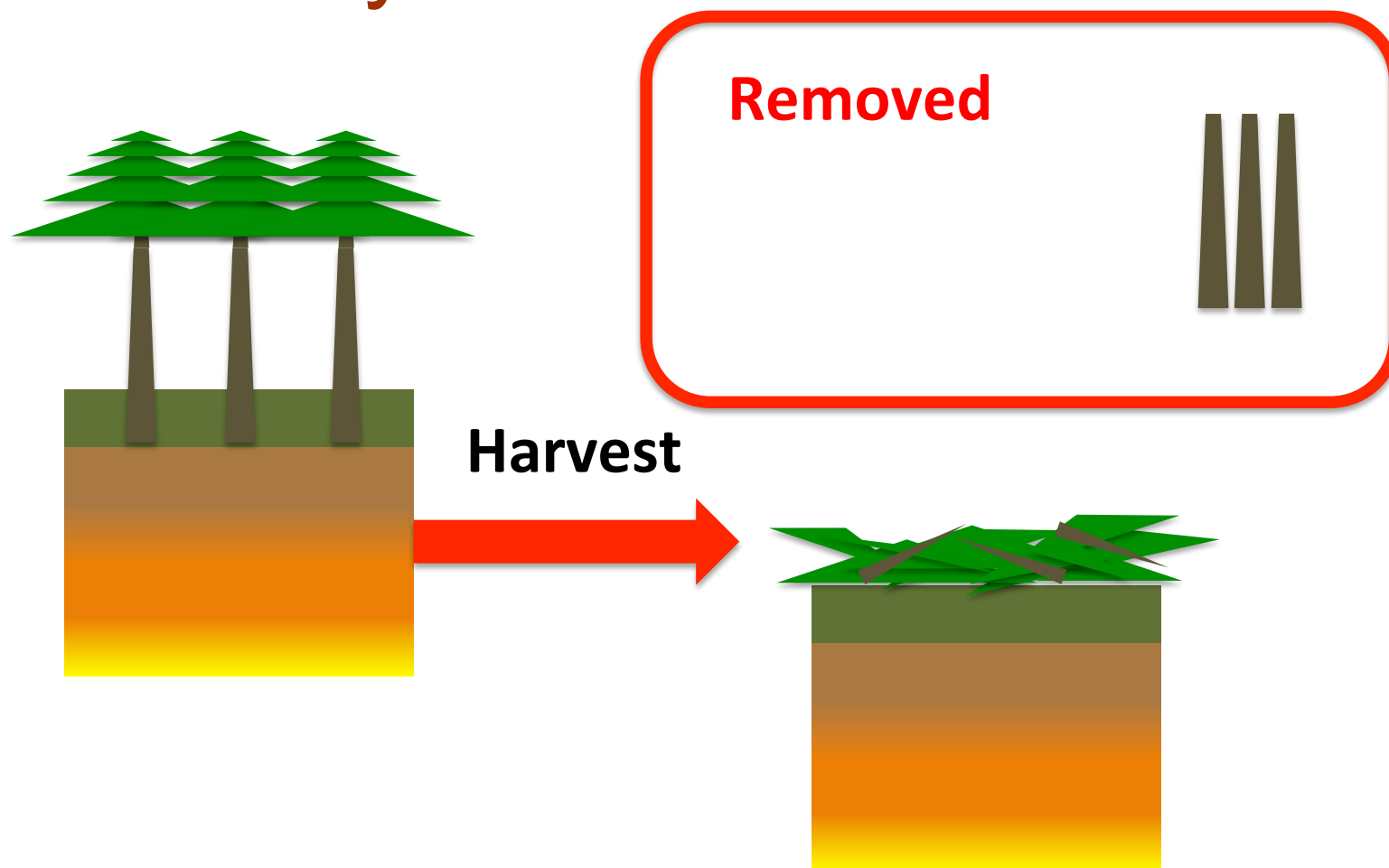


# Bole-only Harvest – “Conventional”





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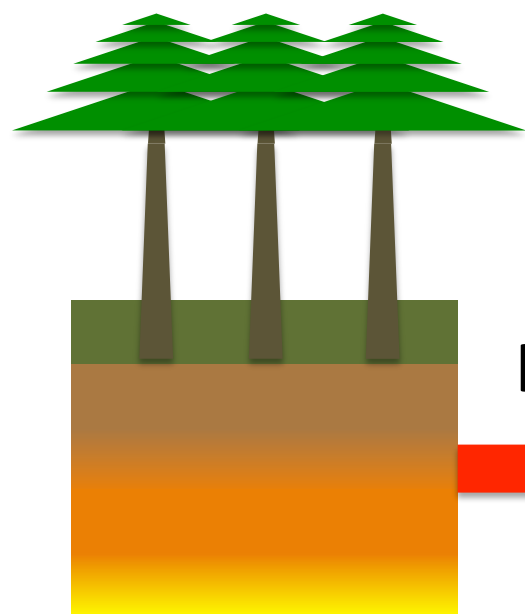


# Bole-only Harvest – “Conventional”





# NARA – Whole Tree Harvest



**Harvest**

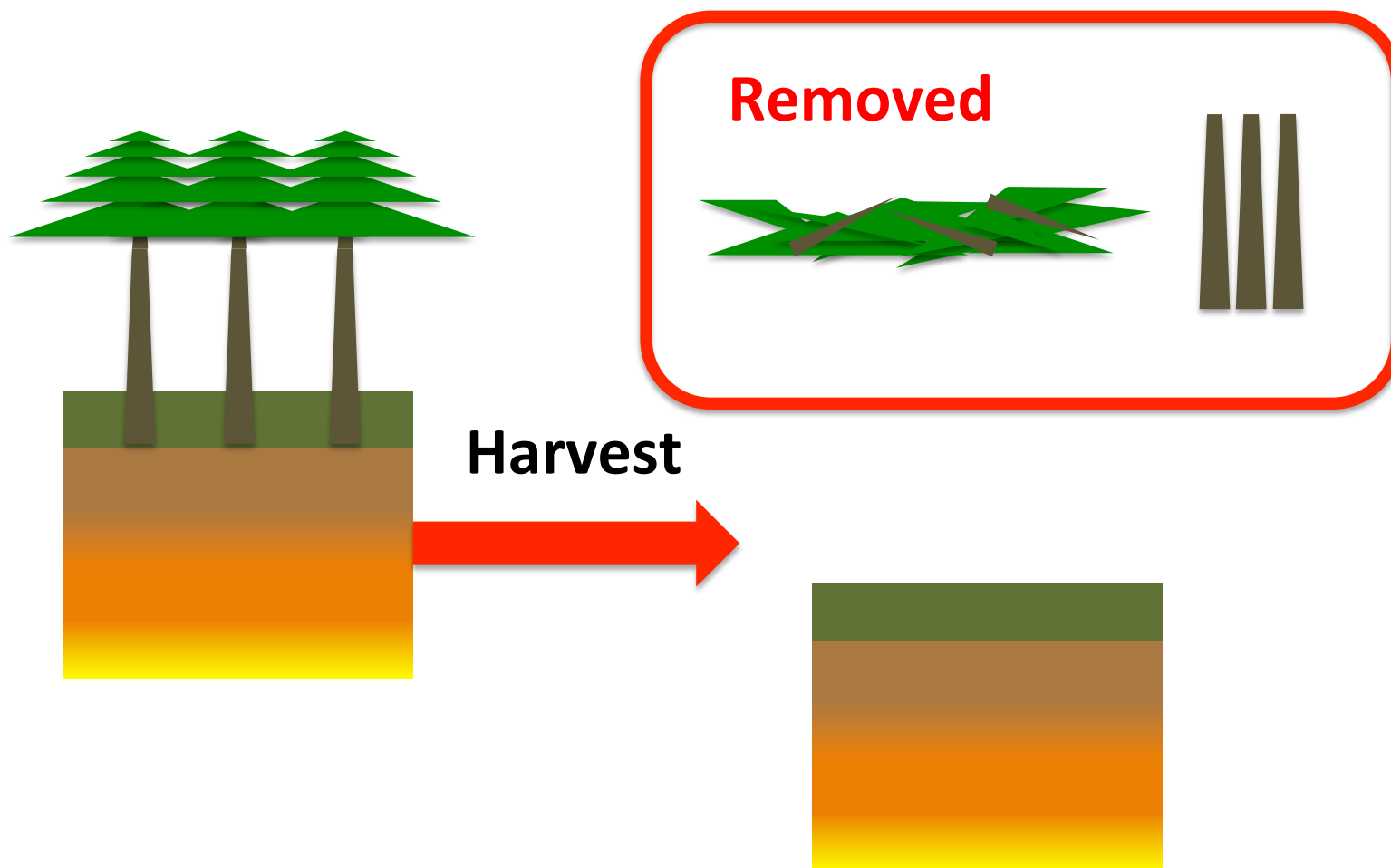


**Removed**





# NARA – Whole Tree Harvest





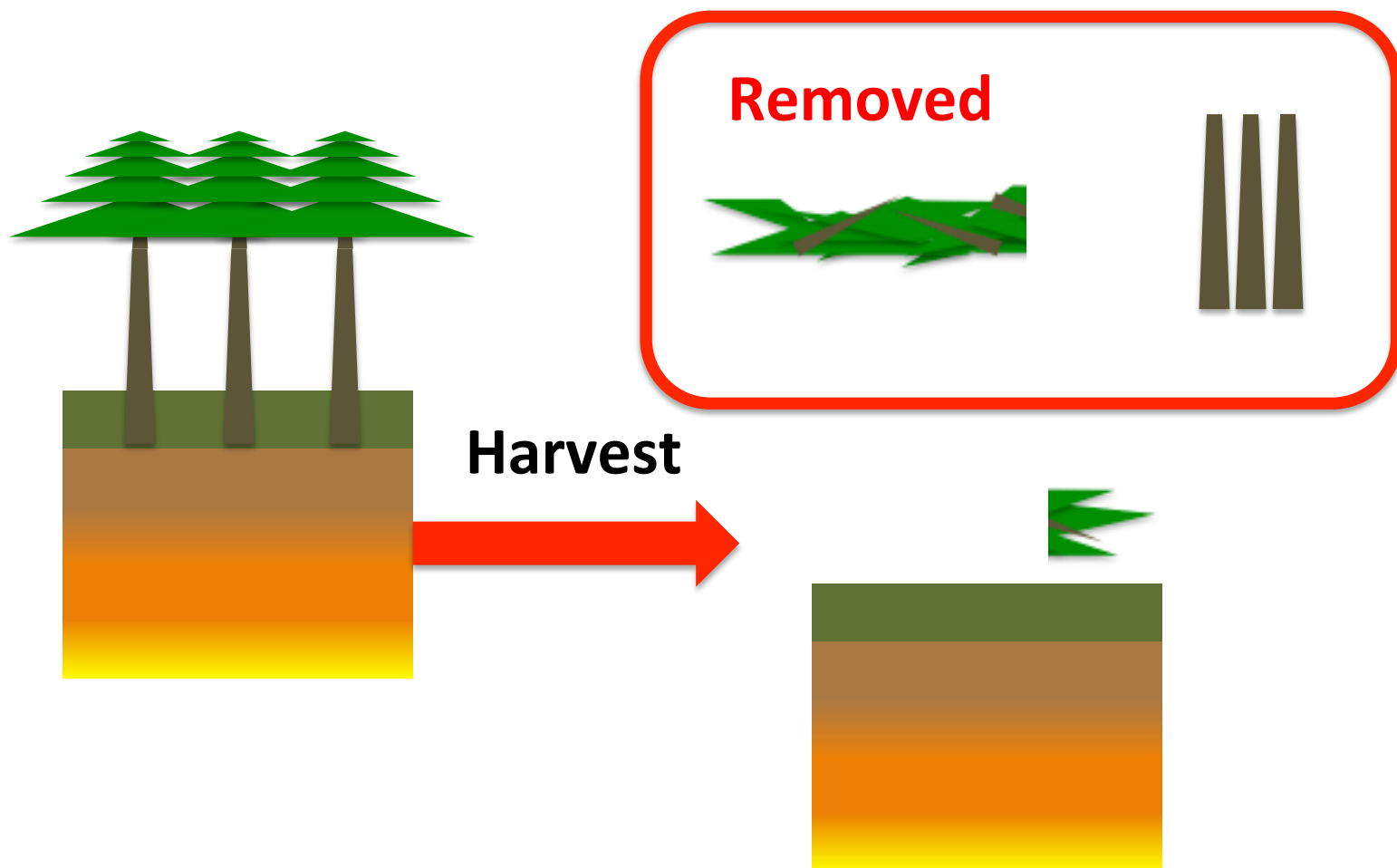


# NARA – Whole Tree Harvest



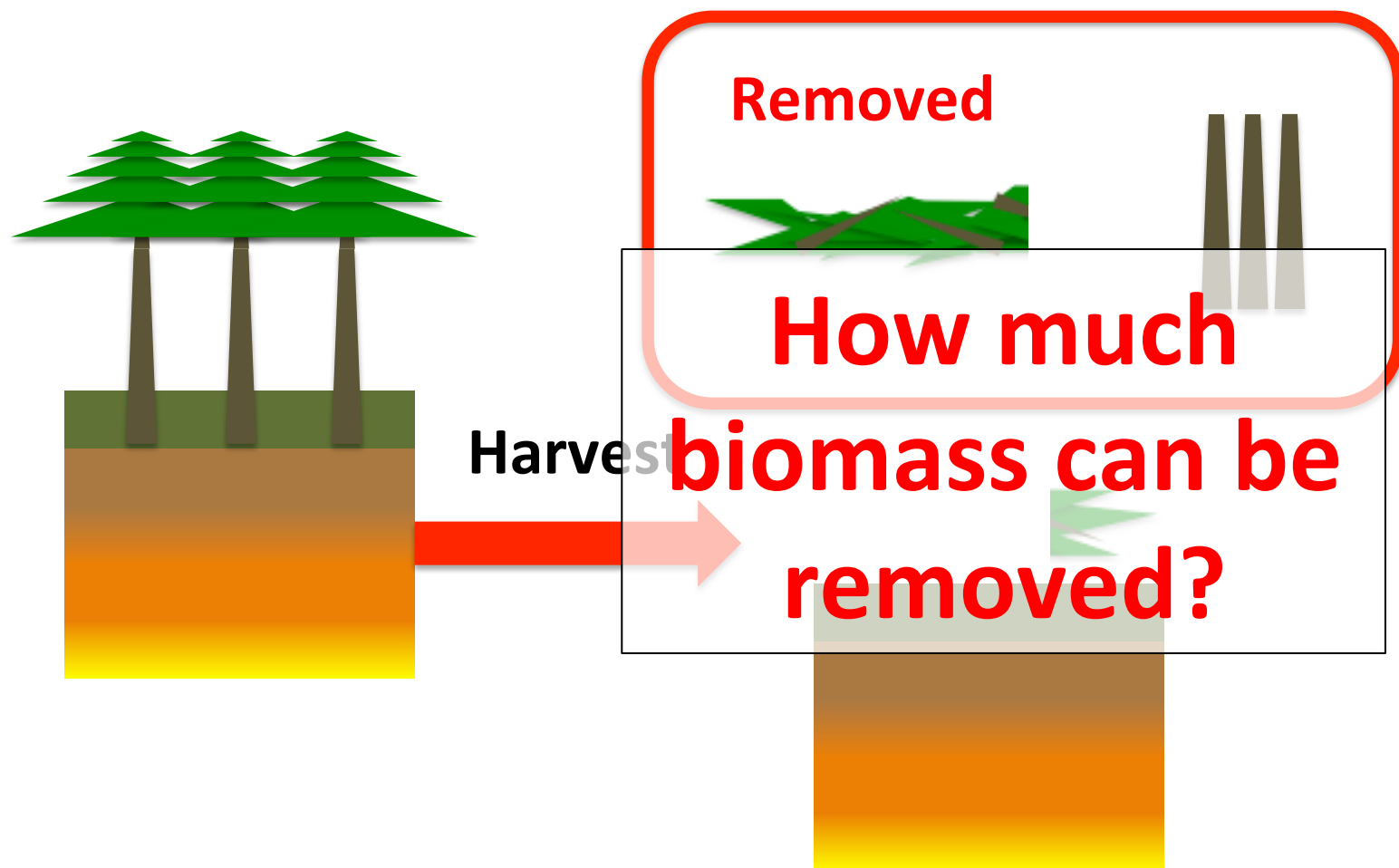


# NARA – Whole Tree Harvest





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# Constraints Presentation



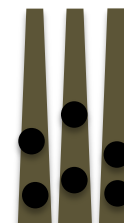
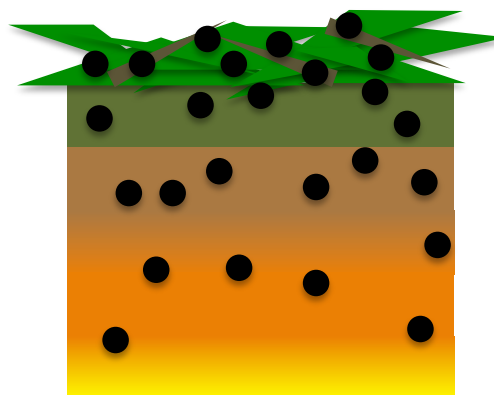
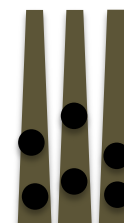
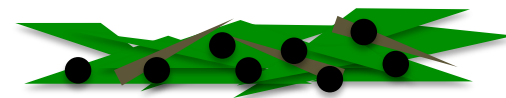
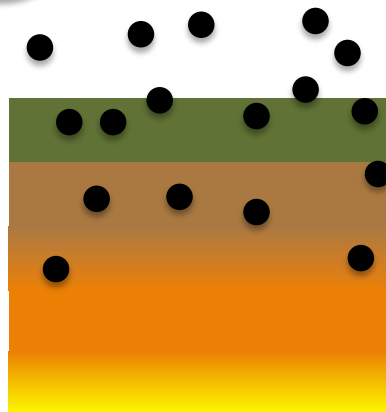
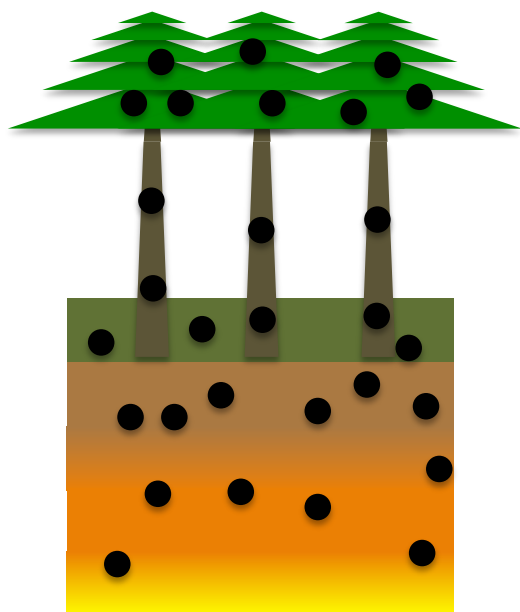
# Long-Term Nutrient Balance May Limit Forest Growth

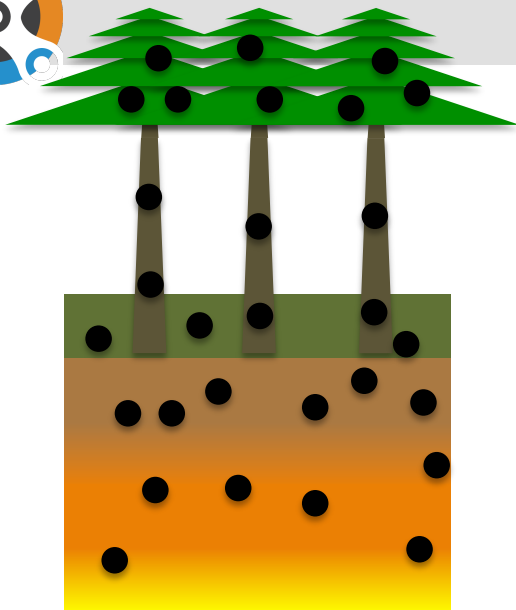
- Growth limiting factors
  - Water
  - Light/Space
  - Nutrients



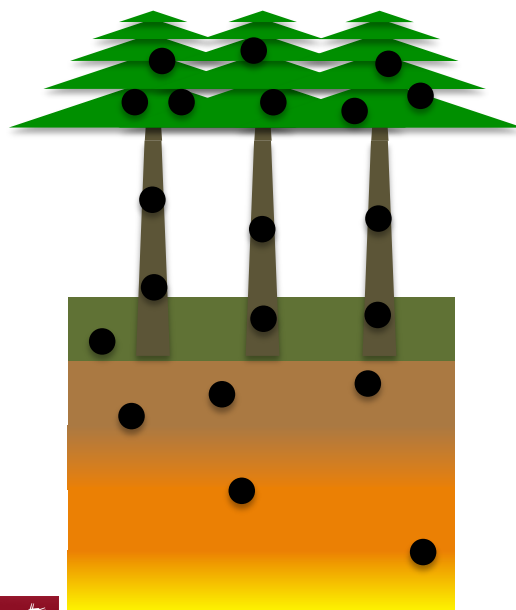
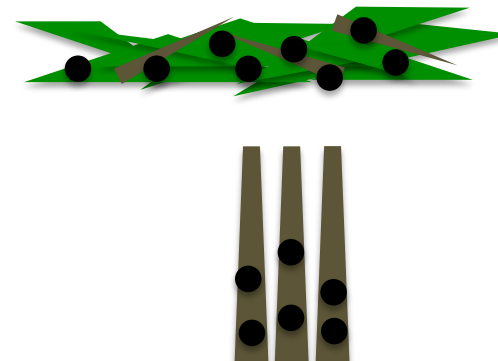
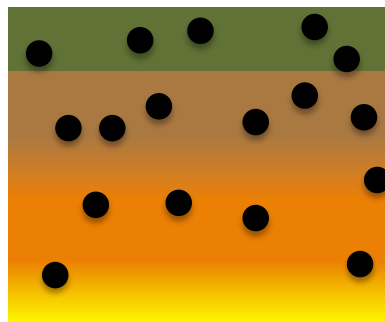
# Biomass Harvest = Nutrient Harvest

- The amount of biomass removed will dictate the quantity of nutrients removed
- The long term balance of nutrients will influence long-term site productivity

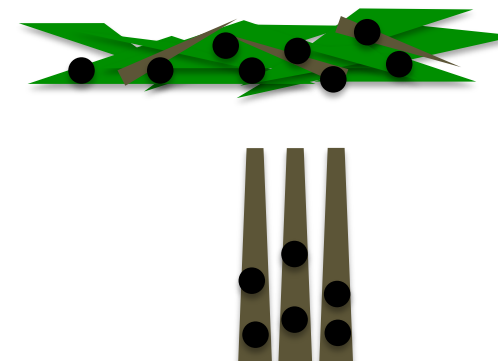
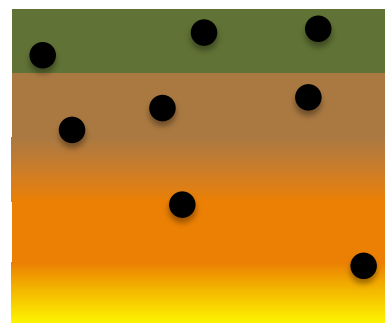




## Harvest 1



## Harvest 2



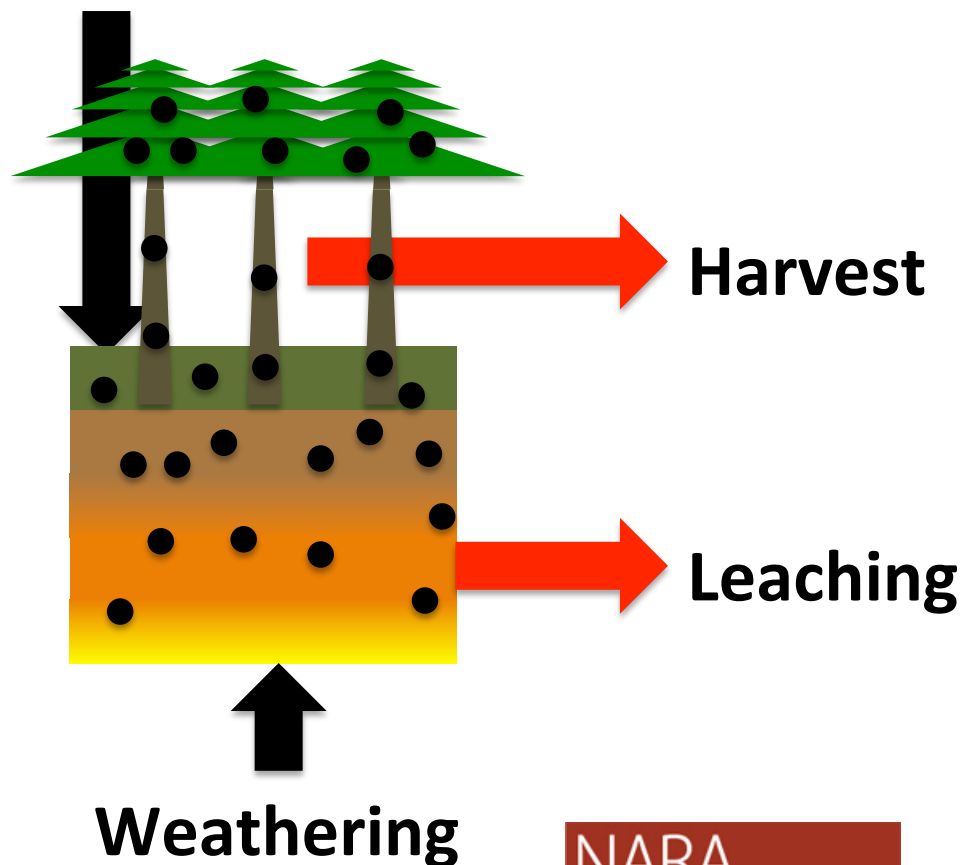




# Balance of Nutrients is Key

- Soils are not static
- Inputs include:
  - Atmospheric deposition
    - Dust, Pollution, Lightning fixed N, etc.
  - Weathering
    - Rocks dissolve
- Outputs include:
  - Leaching
  - Harvesting

## Atmospheric Deposition





# Productivity Presentation

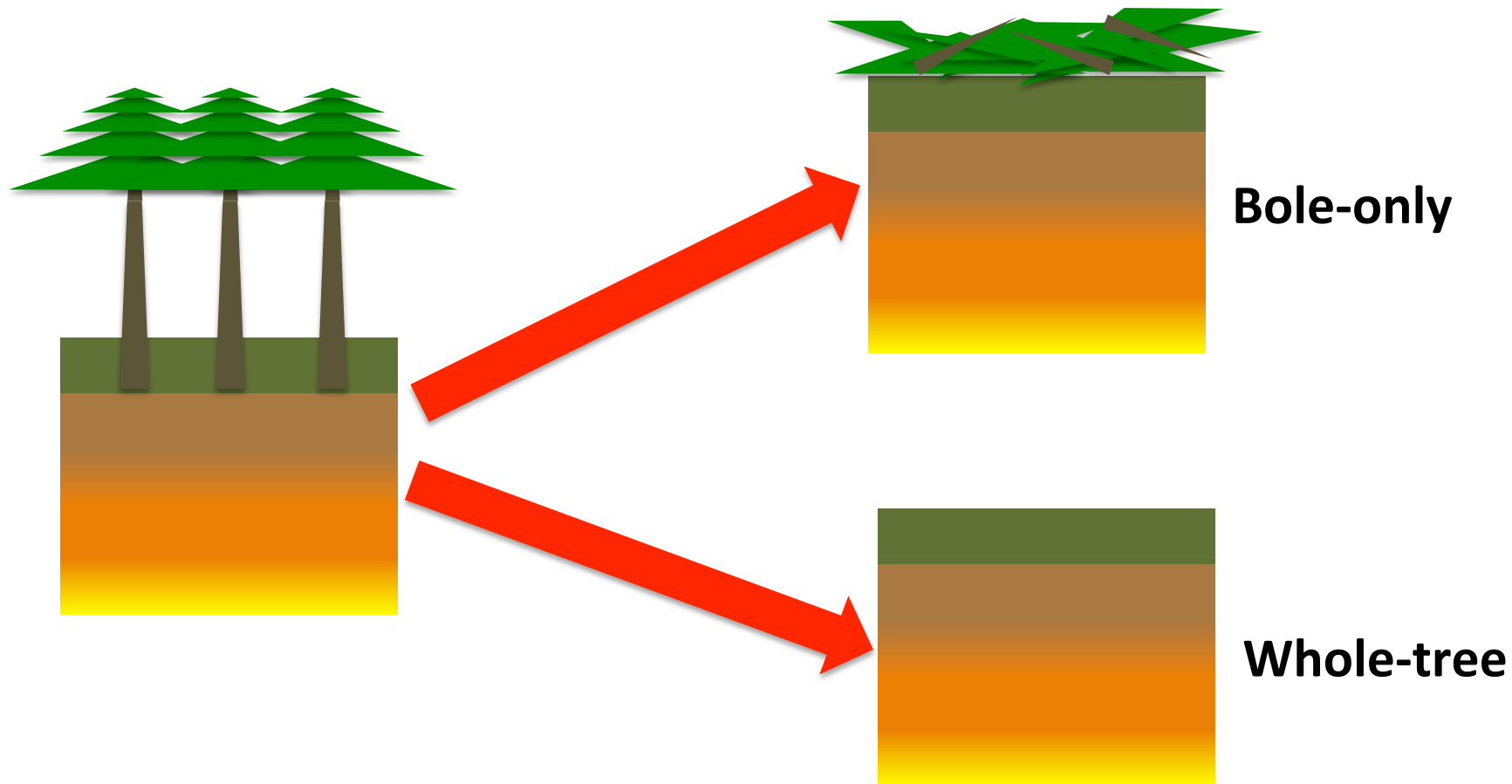


# Ecosystem Services

- Air Quality
- Water Quality
- Soil Carbon
- Wildlife/Pollinators

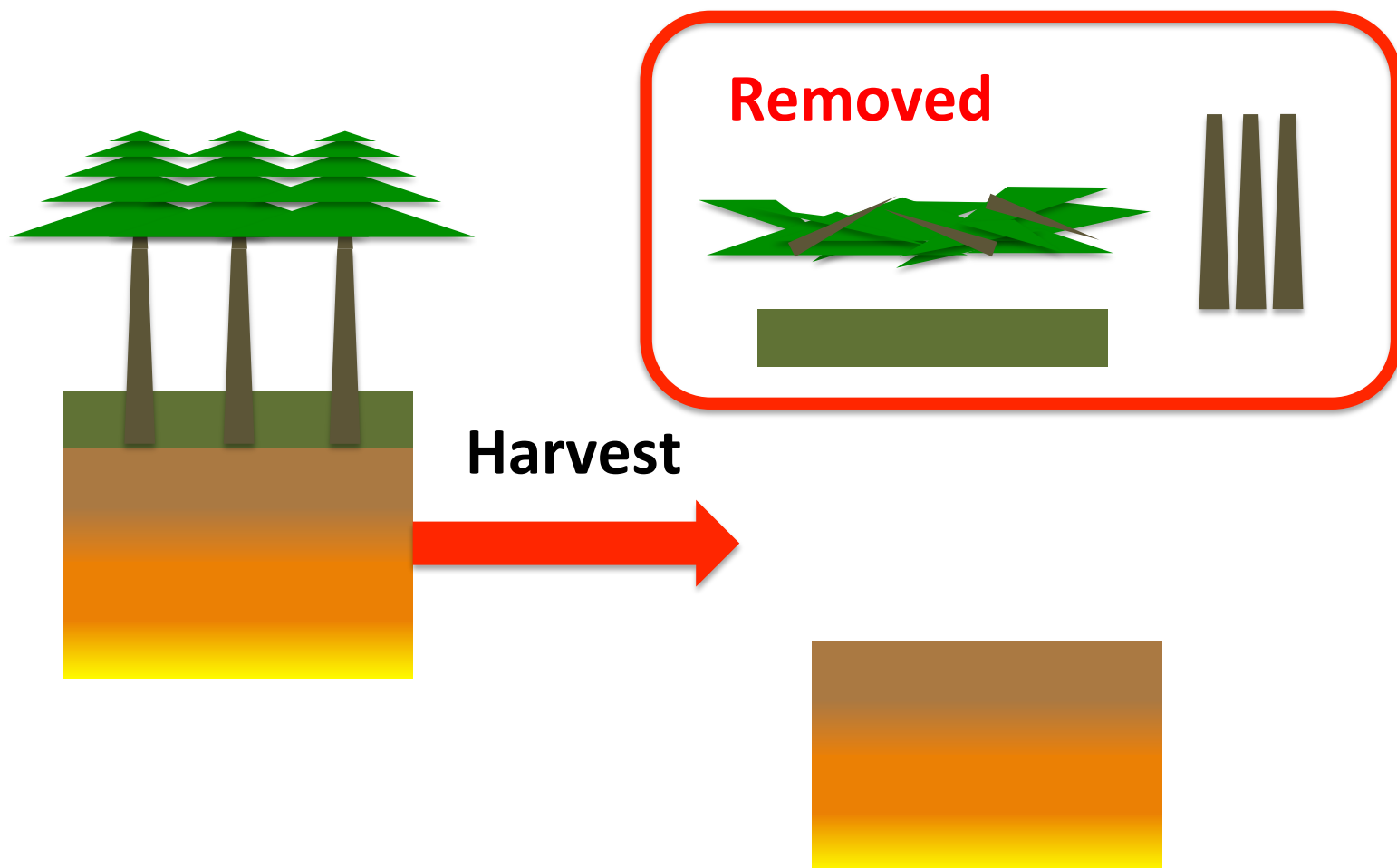


# Two Harvest Scenarios





# Whole Tree Harvest + Forest Floor



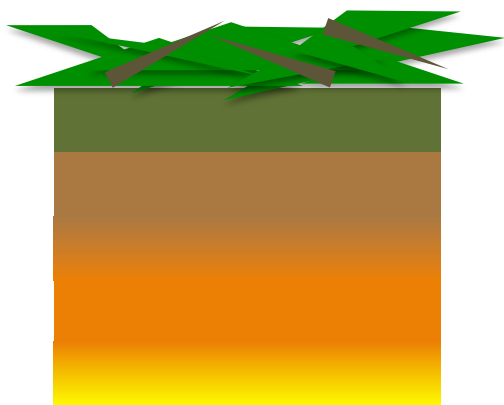


# Whole Tree Harvest + Forest Floor





# Three Experimental Harvest Scenarios



**Bole-only**



**Whole-tree**



**Whole-tree +  
Forest Floor**

**These experimental treatments bracket the potential post-harvest conditions and allow us to interpolate reality**



# Air





# Soil



# Water



# Wildlife



# Complications

- Spatial distribution of residuals
  - Affect variability of productivity across stand
    - Soil resources depleted where residuals removed
    - Piles concentrate soil resources
  - Affect wildlife
    - Relationship to roads
    - Piles? Scattered? Burned?
  - Water quality
    - Disturbed near roads, roads have ditches, ditches are problem areas in forests
- Residuals  $\neq$  Non-bole aboveground components
  - Stumps and roots may be important for site nutrition as well as soil carbon



# Feedbacks





# Complications

- Change in techniques
  - Harvesting
  - Harvesting BMPs
  - Site Prep/Regeneration
  - Fertilization
  - Mid Rotation Treatments
- Change in technology
  - Harvesters
- Productivity scenarios account for this by showing worst/best/NARA
- ?



# Conclusions

- Not logistically or economically feasible to harvest all residues
  - May change as technique and technology changes
- Whole-tree or NARA harvesting scenarios have a low risk to deplete nutrients
  - Probably little short-term impact on productivity
  - Long-term may need BMP, mitigation, or change in technique
- Harvest impact could affect soil physical environment and heterotrophic activity
  - Decrease soil carbon?
  - Increase available nutrients?
  - Role of stumps and roots?
- Costs and benefits to wildlife depending on the approach (winners and losers)
  - Balance should be a goal
    - If you manage everything to be old growth, you'll lose habitat for early seral species
- Increase in sediment flux which may impact water quality
  - Potentially mitigated with BMPs adapted to biomass harvesting
- Some improvement in air quality as result of fewer piles burned





Questions?