How is local, regional, and global hydrology impacted by forest restoration?

Forest restoration and hydrology

Citation Jones, J., Ellison, D., Ferraz, S., Lara, A., Wei, X., & Zhang, Z. (2022). Forest restoration and hydrology. *Forest Ecology and Management* 520, 120342. https://doi.org/10.1016/j.foreco.2022.120342

How does forest restoration impact ecosystem services, including hydrologic processes?

A significant proportion of global forestland has been converted to alternate uses and many restoration projects are undertaken each year to increase forest cover, habitat, and ecosystem services. Different restoration goals and management approaches have differing impacts on forest system hydrology and water services. This review paper is designed to provide a conceptual framework, summarize current knowledge on how restoration impacts hydrology, and determine the effects of restoration type on water storage and cycling as well as tradeoffs between management goals and hydrology changes.

What is forest restoration and how has it been done historically?

- The authors define restoration as management actions intended to increase cover, function, composition, or structure of forest and may be focused on impacts at the level of stream, watershed, or forest, or on overall biodiversity.
- Early restorations focused on forestation with native or non-native species in areas that had been used for other purposes. In later efforts, focus shifted to restoring previously forested areas and included the use of managed plantations. Most recent efforts focus on restoration to recover the native forest state.

Do outcomes differ when using different approaches to forest restoration?

- Different restoration approaches and goals will have different impacts on hydrology because in forests water either goes to evapotranspiration or soil and stream storage. How water is partitioned or allocated depends on the species composition and stand age.
- Large scale use of managed plantations may increase water availability in some areas and decrease it in others, with a global overall decrease.
- Reforestation can alter water cycling, including precipitation and cloud cover patterns. Impacts of forest restoration will differ among climate types and in dry areas water availability may decrease with forest increases.

What is the status of our understanding of hydrological processes related to restoration approaches and in light of changing climate conditions?

- The impacts of reforestation on regional hydrological and climate processes are not well understood. While current research indicates that more mature forests and forests with more native species provide better balance between traditional restoration goals and hydrologic benefits, additional research is needed.
- Canopy cover, which is often a goal of reforestation, can increase the interception of precipitation that otherwise would reach the soil and streams causing some water to be lost

through evaporation. Intercepted water can also become throughfall and stemflow, increasing soil moisture.
- Forest vegetation and tree root systems can limit evaporation and increase percolation and infiltration. However, these affects may differ with forest maturity stage. More research is needed to understand impacts of forestry practices on hydrology over ecological time scales.

Does the type of forest restoration impact hydrologic processes? In what ways can forest restoration projects cause changes in water availability?

- Forest management practices also determine hydrologic impacts. Increasing the proportion of native species in restored or managed forests increases hydrologic benefits.
- The impact of reforestation on streamflow differs depending on whether native or non-native forest species are grown. While non-native forestation decreases streamflow, native forestation maintains streamflow and can increase streamflow when replacing non-native forest.

How can managers and scientists incorporate hydrology into forest restoration projects and research?

- Goals of reforestation and forest restoration projects should include hydrologic processes and consistent water yield. Geography, ecology and past land use are important considerations. Management and restoration approaches will differ based on hill slope position, possible soil profile truncation, and vegetative cover.
- The most important information to be gained from future research is how water inputs will be divided between evapotranspiration and streamflow under current and possible future conditions. Forest researchers and managers should partner with hydrologists on project design and data analysis.

Research Approach/Methods

- This review paper synthesizes a large body of research on forest hydrology in relation to three forest conditions: mature old-growth forest, managed forest plantations, and early stages of native forest regrowth.
- Before this discussion, they describe the historic patterns of reforestation and review impacts of different approaches on a regional, continental, or global scale.

Keywords mature and old growth forests, native forest restoration, managed forest plantations, practical forest restoration approaches, tradeoffs among multiple objectives

Images

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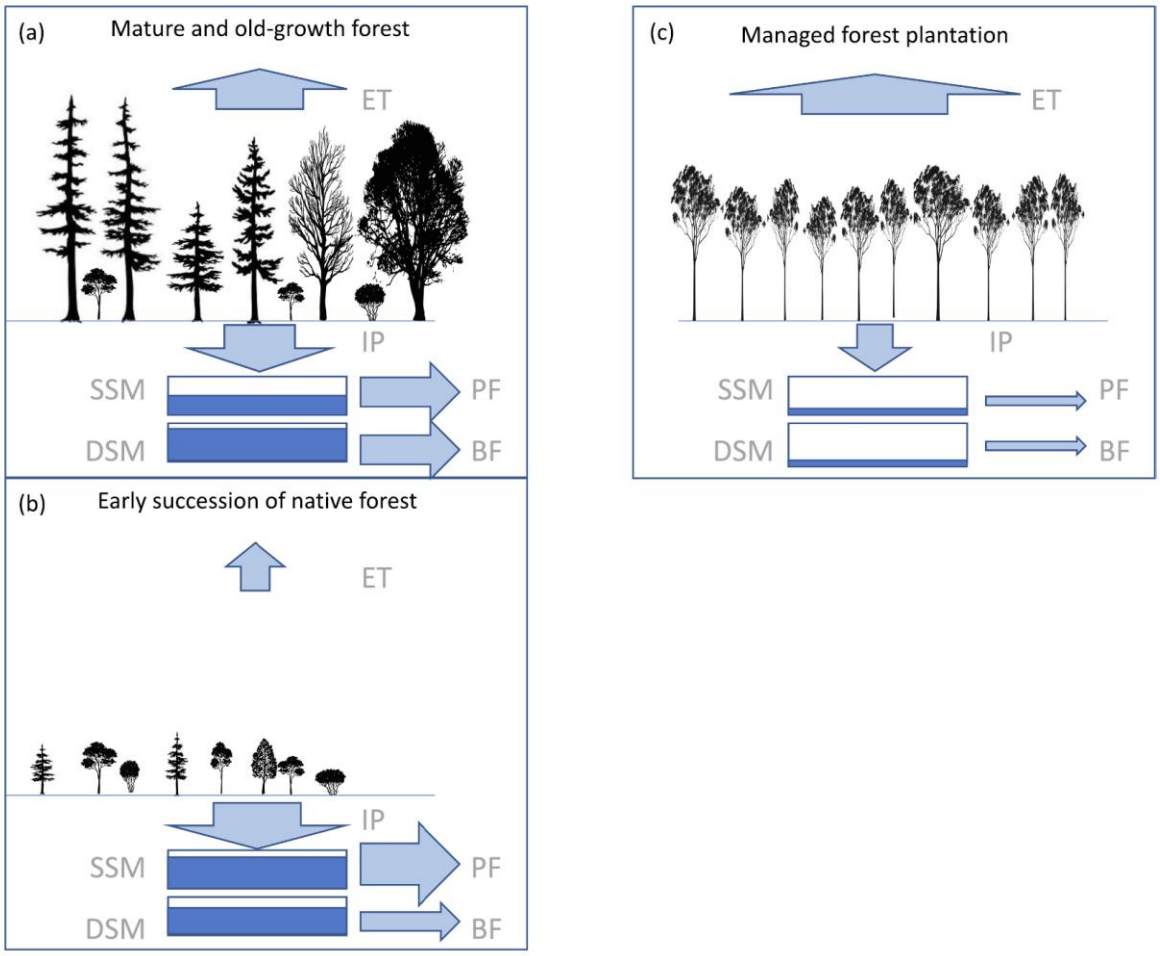

Figure 2 in Jones et al. 2022. Generalized stand structure diagrams and associated components of the water budget at event to interannual time scales in three forest types that are relevant to restoration: (a) mature and old-growth forest, the reference model for ecological restoration, (b) early native forest succession, an increasingly popular, ecologically-oriented approach to forest restoration, and (c) managed forest plantation, characteristic of early efforts for forest restoration. Arrow thickness indicates magnitude of a process. ET = evapotranspiration (transpiration and evaporation from the canopy and soil), including of water intercepted by the canopy, IP = infiltration and percolation into the soil, SSM = shallow soil moisture in the rooting zone, DSM = deep soil moisture/ shallow groundwater, PF = peak flows, BF = base flow. Managed forest plantations (both native and non-native species) have higher ET, lower IP, and lower SSM, DSM, PF, and BF than mature and old-growth forest (evergreen or deciduous, broadleaf or needleleaf). Early stages of native forest succession may have lower ET, higher IP, SSM, and PF, and lower DSM and BF than mature and old-growth forest, but higher IP, SSM, DSM and BF than managed forest plantations.

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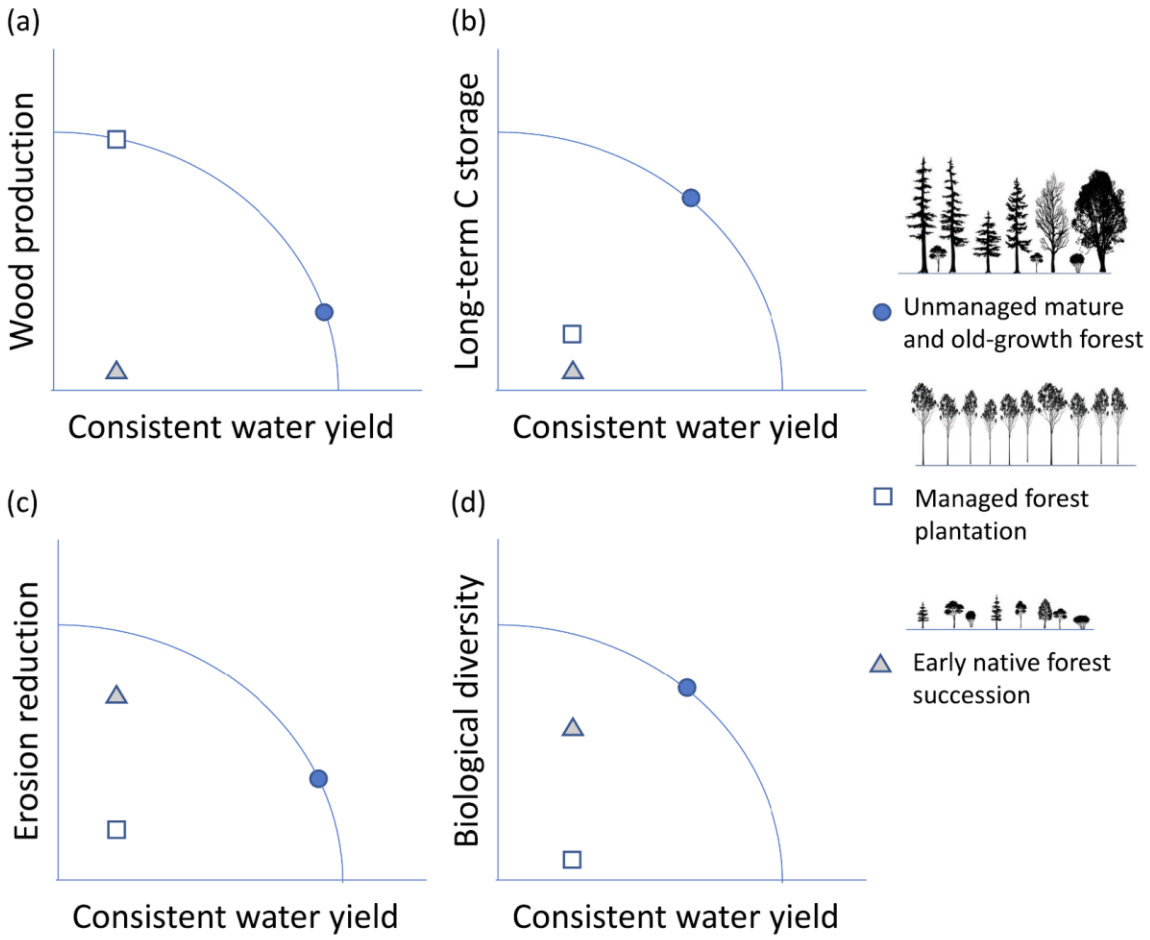

Figure 3 in Jones et al. 2022. Idealized, hypothetical tradeoffs for three different forest types between consistent water yield and other forest management objectives including (a) wood production, (b) long-term carbon storage, (c) reduction of erosion or reduced sediment production, and (d) biological diversity. All values are estimated as averages over time scales of decades to centuries under a given management regime, based on literature reviewed. Consistent water yield is defined as moderate peak flows and sustained base flow. Wood production refers to commercial production of timber and pulp. Long-term carbon storage is defined as the amount of carbon stored in live and dead wood and soils. Erosion reduction is defined as the decrease in sediment production from exposed soil, forest roads, and logging activities, relative to severe and frequent soil disturbance such as cultivation. Biological diversity is defined as the number of species present. Arc indicates a hypothetical "production possibility frontier", i.e., the maximum potential joint production of the two values being traded off. The shape of these frontiers is unknown, and more research is needed to identify them.

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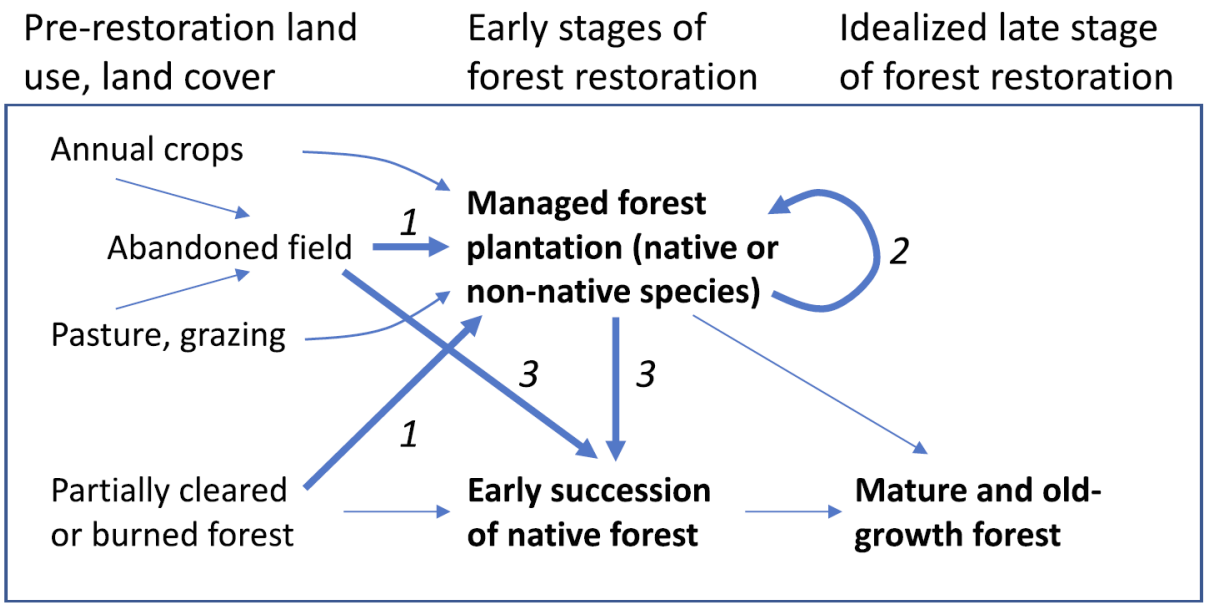

Figure 1 in Jones et al. 2022. Forest restoration (indicated by arrows) is defined for purposes of this paper as forest management activities whose objective is to increase forest cover, structure, and/or species composition, through treatments involving tree regeneration and removal (see Table 1). Forest restoration may involve establishment of forest plantations (path 1), including managed forest plantations that are harvested and replanted (path 2), or it may involve establishment of native forest (path 3). Bold font indicates forest types and bold arrows indicate forest restoration efforts whose hydrological properties have been well studied and form the basis for this review of forest restoration effects on hydrology.