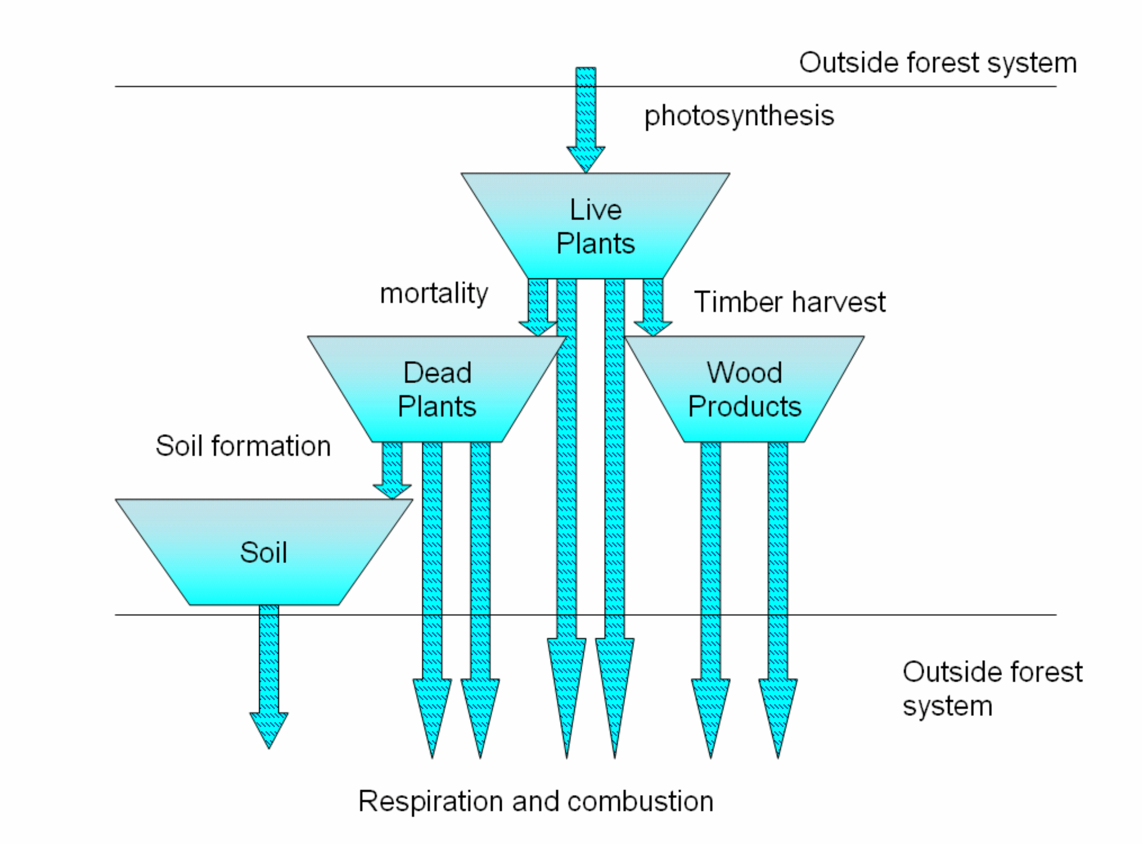

Figure 1.The forest carbon system can be envisioned as a series of leaky buckets. The amount stored in each bucket depends on the amount coming in versus the proportion leaking out. Carbon enters the forest systems via photosynthesis. Carbon leaks out via many processes, but the main ones are respiration and combustion.

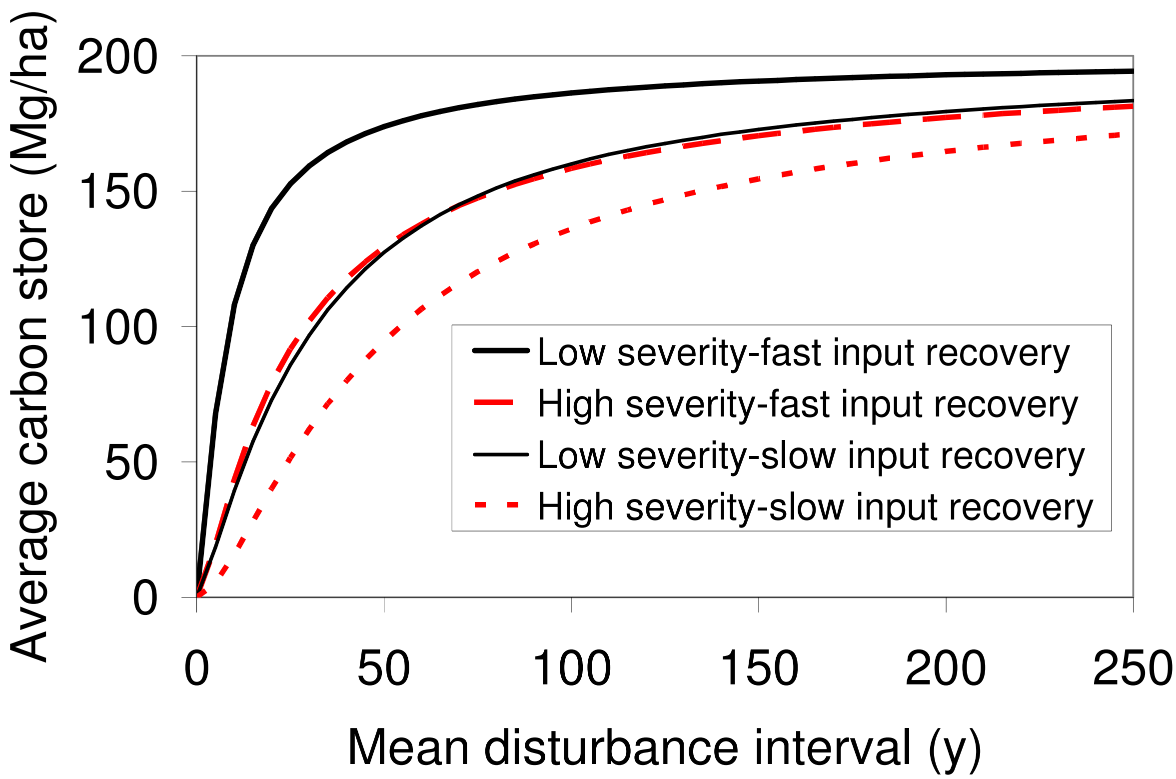

Figure 2. One can store carbon in forests even when there are disturbances. This figure shows the average amount of carbon that can be stored given various combinations of disturbance interval and severity. The low severity disturbances remove 5% of the carbon and the high severity disturbances remove 50%. This model also accounts for that fact that disturbance reduces the input of carbon via photosynthesis for a time period. Fast recovery of carbon input occurs in 5 years and slow recovery in 50 years. Notice that a low severity disturbance with a slow input recovery has about the same response to disturbance interval as a high severity disturbance with fast input recovery. Also note that as the interval of disturbance increases disturbance severity and input recovery have diminishing effects. To increase carbon stores there are multiple options: one could decrease the severity, increase the interval between disturbances, or increase the rate that carbon input recovers.

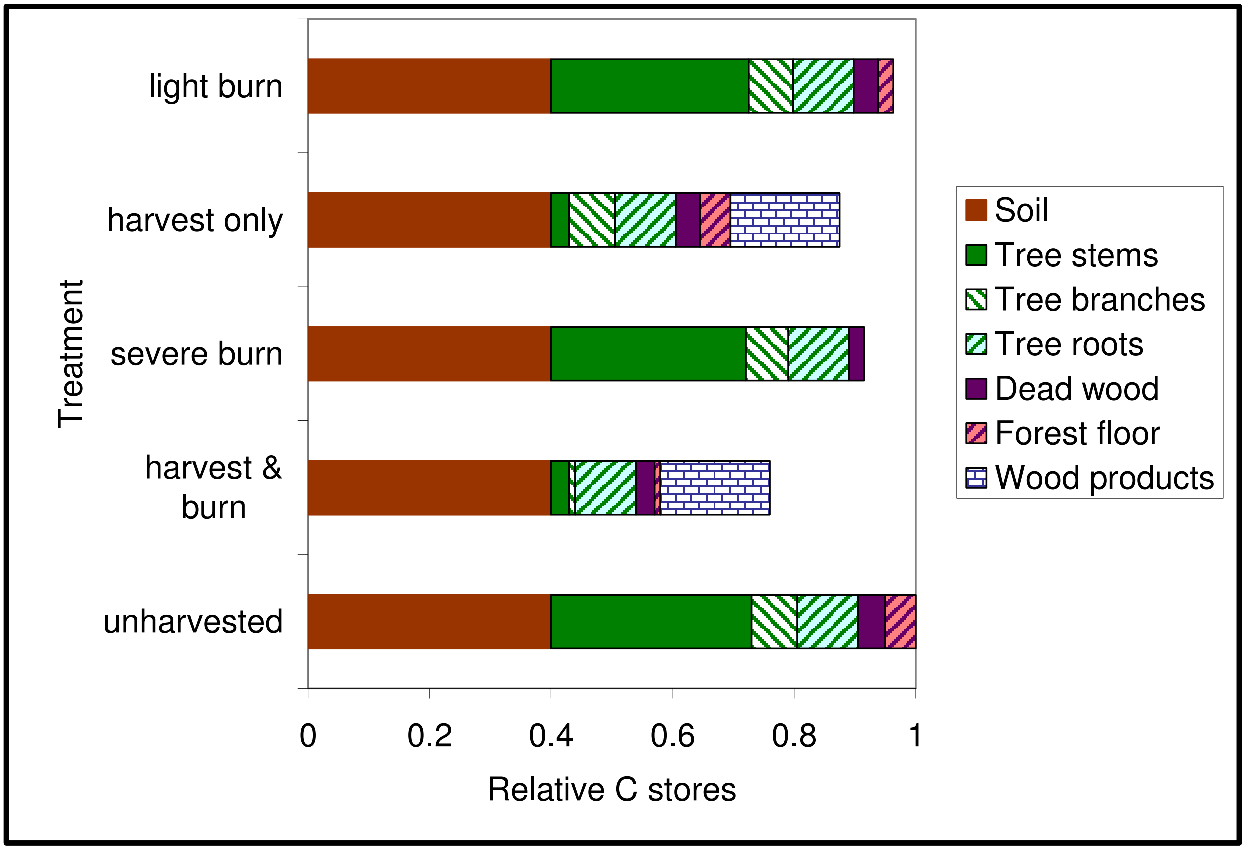

Figure 3. Hypothetical stores in forest system after wildfires and timber harvest with and without site preparation fires. None of these treatments is assumed to influence carbon stores belowground. The conversion rate from harvested carbon to wood products carbon is assumed to be 60%. Severe wildfires are assumed to consume the entire forest floor and 45% of the dead wood. Light wildfires are assumed to consume 50% the forest floor and 10% of the dead wood. Fires associated with site preparation are assumed to be intermediate in their effects on these pools.

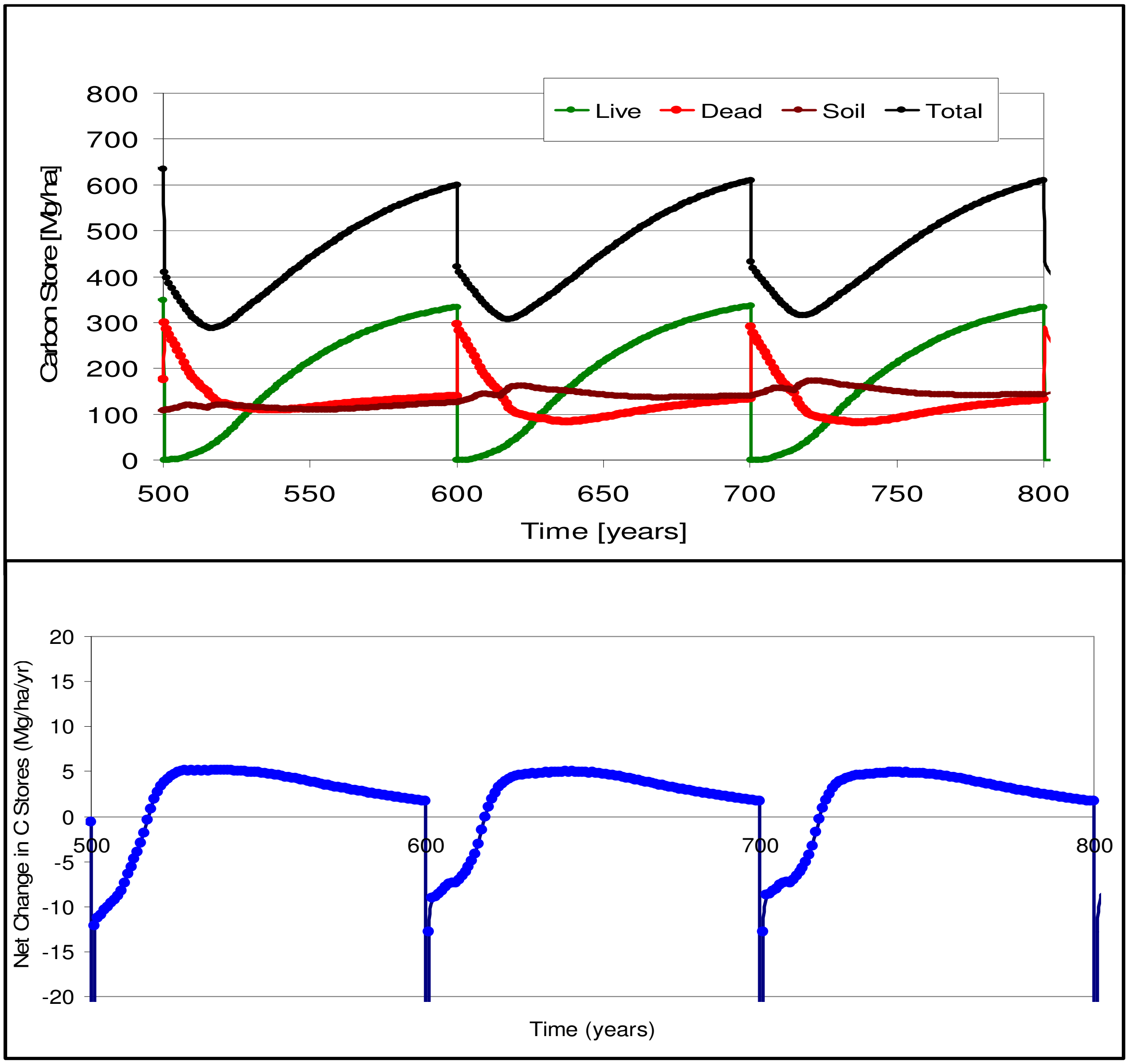

Figure 4. The divergent dynamics of live trees and dead plant material is the key to understanding distinction between optimal management for timber production and the optimal management for carbon stores on forest land. This figure shows the change in carbon stores following a hypothetical timber harvest (upper panel). The live carbon drops to 0 once the trees are cut, then increases. The rate of live carbon accumulation slows in part because more and more carbon is to replacing trees and tree parts that die. The other major stores not change in sync with tree biomass. Dead biomass receives an input of material following harvest. This dead store loses carbon gradually over many years and decades; the dead store increases again as dead plant inputs from the new stand exceed losses from respiration. The Soil carbon pool changes over time as well, but those changes are relatively minor and its peaks lag behind the dead pools which form its source. The total carbon stores decline for about 20 years following disturbance; this means that the forest is a source of carbon even as a new generation of trees actively accumulates carbon. The net change in all the carbon stores in the forest over time changes from a source to the atmosphere (negative sign) to a sink (positive sign) from the atmosphere (lower panel).

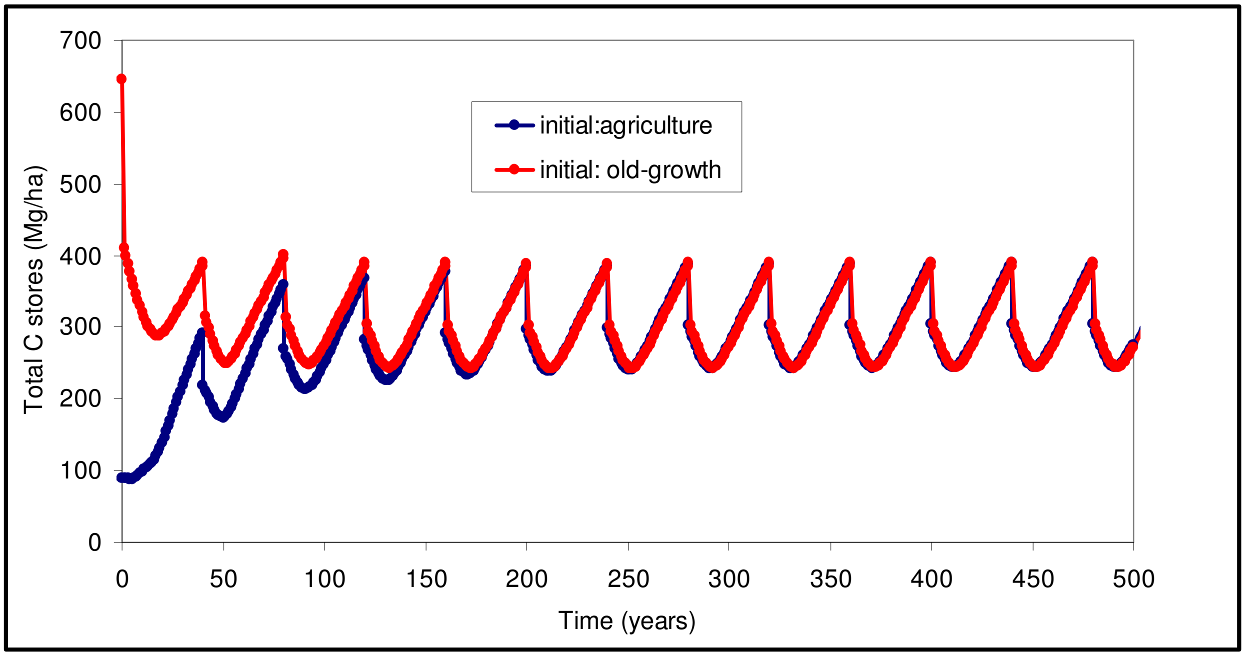

Figure 5. It is important to consider the starting as well as the end point when evaluating policies. In both cases above there is conversion to a plantation forest that is harvested every 40 years. Starting from an agricultural field there is a net gain carbon. Starting from an old-growth forest there is a net loss of carbon. Notice that in time the plantation forest is the same regardless of the starting point.

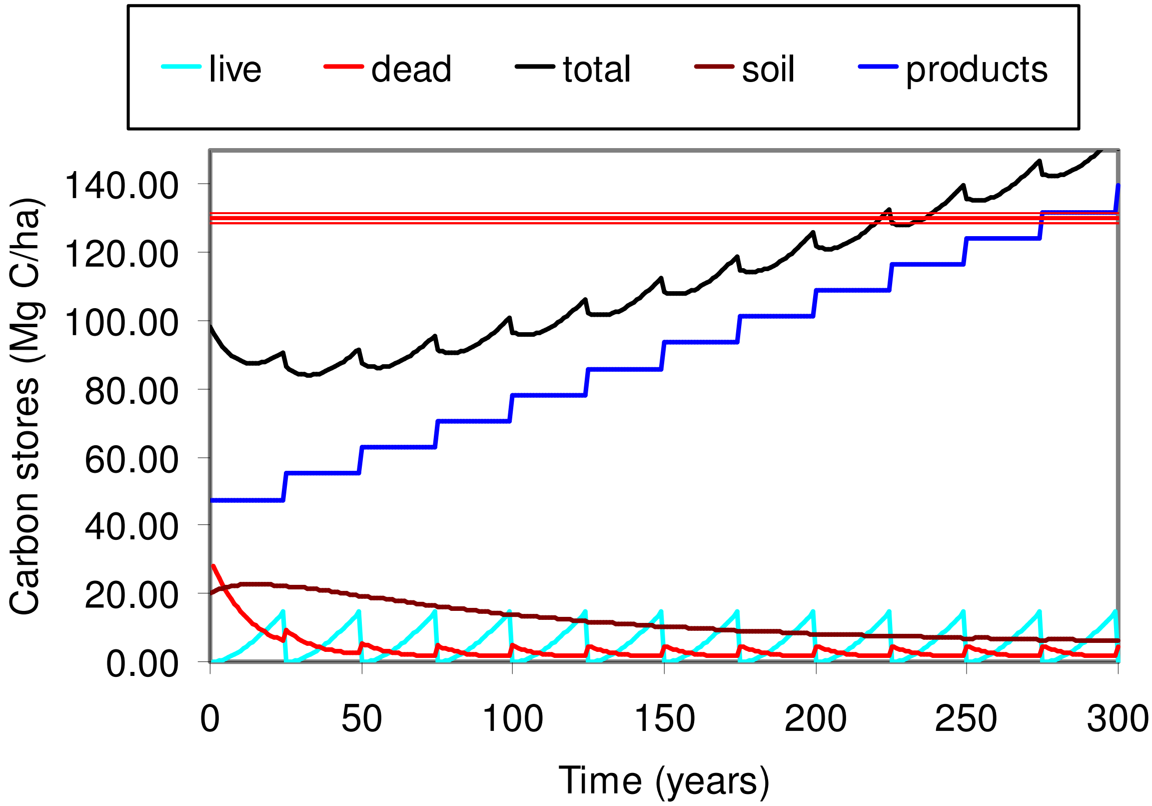

Figure 6. Forests can be slow to respond to changes in management. In this example, the gains from biomass energy harvesting may not be immediate for several reasons. When biomass energy offsets are being claimed, one needs to be aware that energy and not carbon is being substituted. In this hypothetical case an older forest was converted to a biomass plantation with a 25 year harvest interval. It is assumed that 80% of the live carbon is harvested, and none of the dead biomass is harvested. The energy content of wood is assumed to be 2/3rds that of fossil fuels. The horizontal red line indicates the starting store that was contained within the old-growth forest. Note that it could take hundreds of years before there is a net gain. If the net energy content of biomass fuels is lower, it will take even more time.

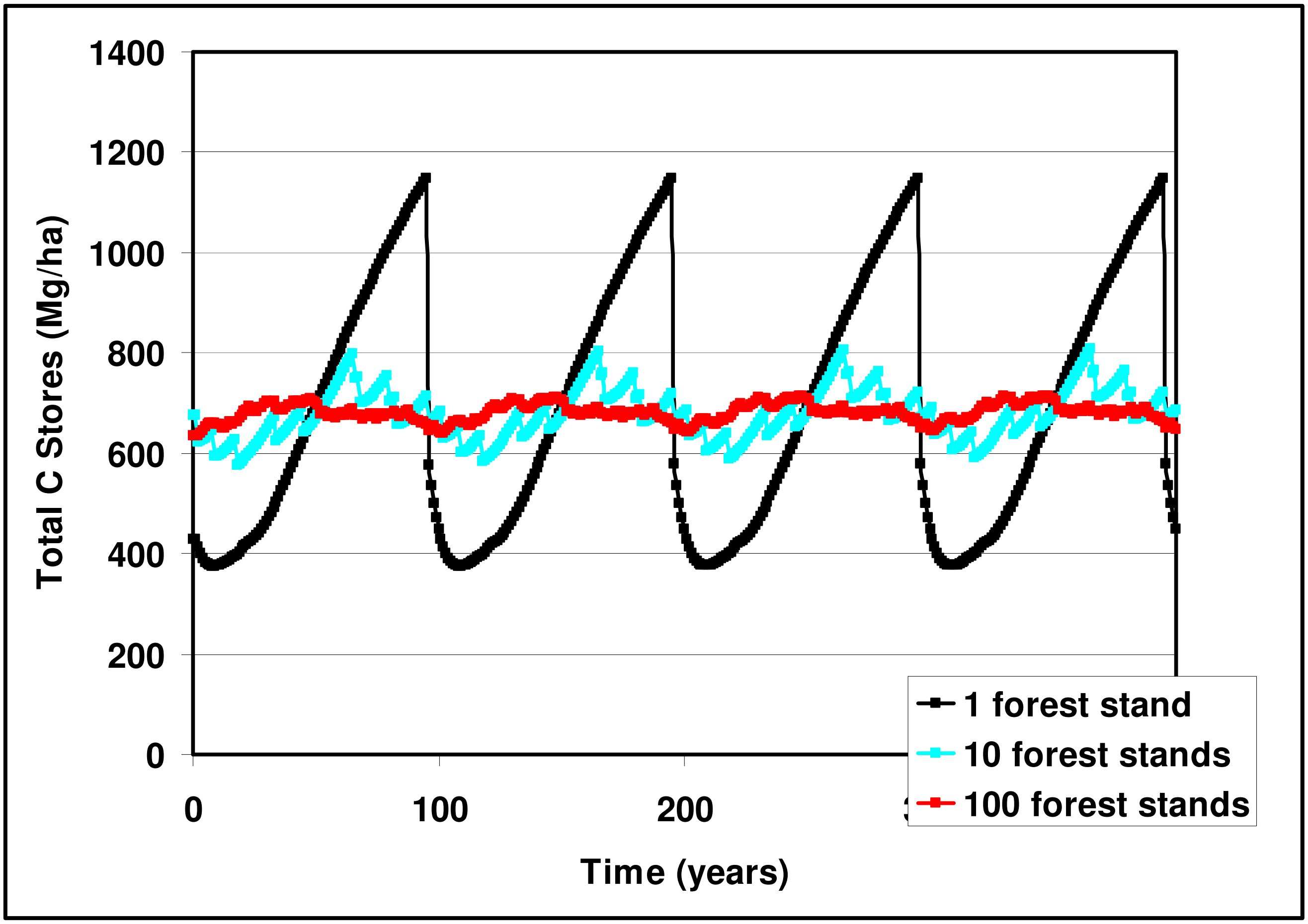

Figure 7. It is essential to examine management actions at the relevant time period and areal extent. This illustrates how the behavior of carbon stores changes as one includes more stands in the analysis; essentially increasing the area of forest being considered. As the number of stands increases, the gains in one stand tend to be offset by losses in another and hence the flatter the carbon stores curve becomes. The average carbon store with a large number of stands is controlled by the interval and severity of disturbances as shown in Figure 2. That is, the more frequent and severe the disturbances, the lower the average becomes.

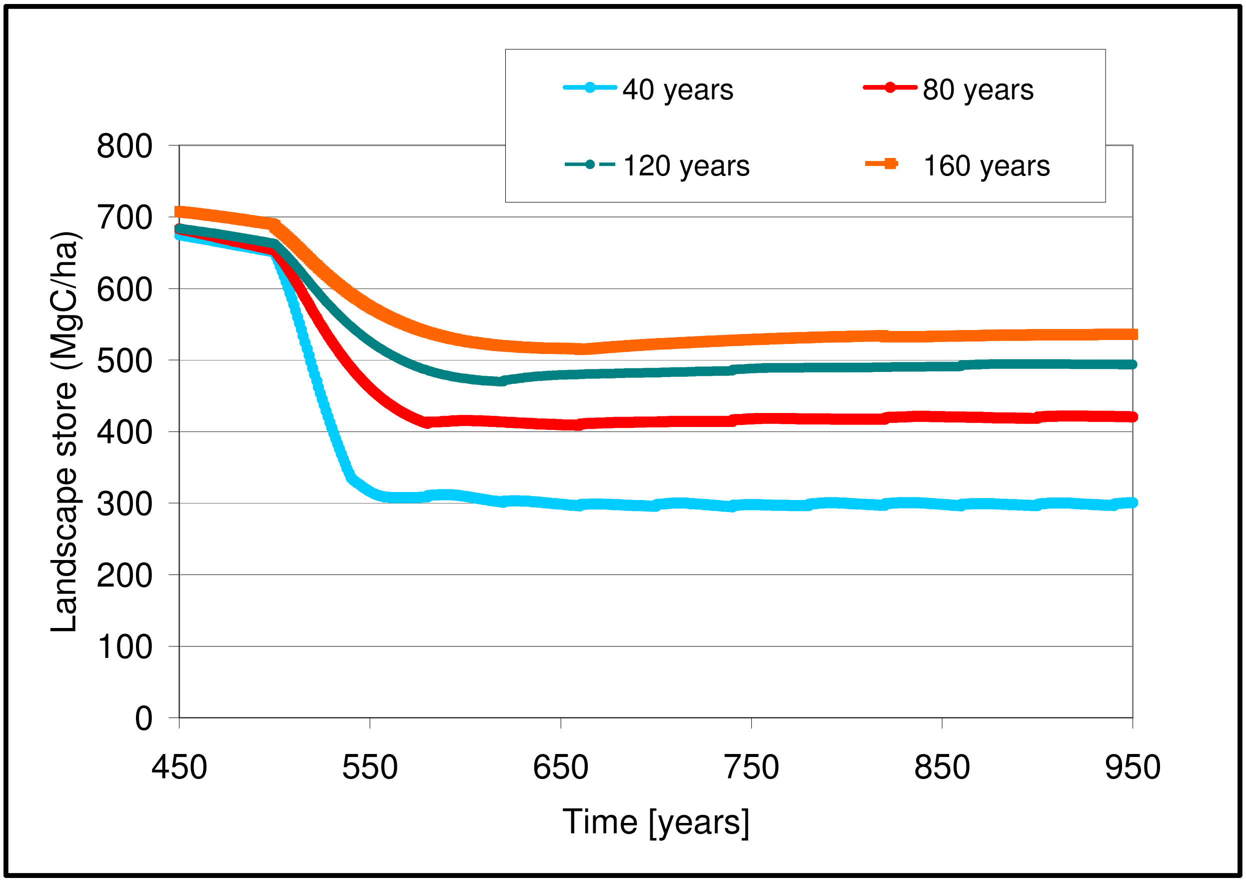

Figure 8. Converting old-growth forests in productive forests such as those in the Pacific Northwest is highly unlikely to result in the forest storing more carbon. In this series of simulations old-growth forest landscapes are converted to plantation forest landscapes with differing intervals between harvests. As the interval between harvests is shortened, the lower the carbon store becomes. The gains in wood products stores do not fully offset this loss.

Table 1. Summary of possible actions to increase carbon stores in forests. For those actions with large ranges, the underlying factor causing the range is noted.

Action	Odds of Positive Result	Potential Area Involved	Pairs Best with	Trades off with
1. Slow deforestation	High	Low to Moderate	3, 4	7, 8, 9
2. Afforestation on former forest lands	High	Moderate	7, 8, 9	6
3. Lengthen interval between harvest	Moderate to High Depends on time added	Moderate to High	1, 2, 4	7, 8, 9
4. Reduce amount harvested	Moderate to High Depends on degree	Moderate to High	1, 2, 3	7, 8, 9
5. Increase growth of trees	High	High	3, 4, 7, 8, 9	
6. Fuel reduction on wildlands	Low	Moderate	7	3, 4
7. Wood-based Biomass energy	Low to High Depends on starting point	Moderate	2, 5	1, 3, 4
8. Wood products	Low to High Depends on starting point	Moderate	2, 5, 9	1, 3, 4
9. Substitution of wood for other materials	Uncertain	Moderate	2, 5	3, 4