## Fire simulation results.

### Purpose

Here we examine how fire might affect landscape characteristics in terms of 1) spatial scale, 2) temporal scale, 3) topographic position, and 4) spatial and temporal variability.

### The fire model.

We are modeling stand-resetting fires. Numerous smaller, less intense fires may also occur in the landscape, but are not represented in this model. Stand age over the 1300-km$^2$ study area is set everywhere to the mean recurrence interval at the beginning of the simulation. A 2000-year warm-up period is then run to initialize stand ages. The remaining 3000 years of simulation are used for the results presented here. Figure 2 shows the sequence of fires (in terms of size) generated over the 5000-year simulation.

### Stand age.

*Spatial Scale*

The spatial mosaic of forest ages varies considerably over time. Figure 3 shows stand-age maps at three different times during the simulation. Figure 4 presents histograms (using 50-year bins) showing the distribution of stand ages found within polygons of varying size at these same times. The largest sampled area (1000 km$^2$) shows the greatest range in stand age, and the least variability over time. In Figure 5 I show the mean of the age distribution sampled over three different areas for each simulation year. Histograms and cumulative frequency plots are shown in Figure 6.

*Topographic position*

Because fires (and the fire model) respond to topography (i.e., south aspects tend to burn more frequently; fires tend to spread upslope), fire regime can be characterized in terms of topographic position. The study area is delineated into valley bottoms, midslopes, and ridge tops. Mean stand ages over time for each topographic position over various areas are shown in Figure 7. Cumulative frequency plots for three spatial scales are shown in Figure 8. Topographic position has a distinct influence on the frequency of fire. We can also express this effect in terms of recurrence interval.

Figure 9 shows fire recurrence interval maps resulting from two separate 5000-year fire simulations, each with a mean recurrence interval (averaged over the entire area) of 220 years. The mean of these two simulations was used to examine fire recurrence as a function of topographic position. Figures 10 and 11 examine topographic aspects and fire recurrence over two 200-km2 basins (the Tilton and Mineral drainages) and three 25-km$^2$ sub-basins of the Tilton (all delineated in Figure 1). For each case I show cumulative frequency distributions for elevation, position in local relief (0=valley floor, 1=ridge top, over a circular area of 1.8km diameter), and fire recurrence interval. Distributions are shown for 1) the total area, 2) all landslide source areas identified from the DEM, 3) all “colluvial” channels, defined here as any channel delineated from the DEM with a drainage area > 0.008 km2 and < 0.8 km2, and 4) “fluvial” channels, defined as any channel delineated from the DEM with a drainage area > 0.8 km2. These plots show how different landscape features (landslide source areas, small channels, larger channels) tend to be positioned at different topographic locations. Because fire occurrence is also influenced by topography, these landscape features also tend to experience distinctly different fire regimes. Landslide source areas are burned more frequently than channels; small channels tend to burn more frequently than larger channels. Because fire recurrence, and consequence stand-age distributions, exert strong controls on sediment flux and wood recruitment to stream channels, such topographic controls on disturbance regime may play a large role in setting channel characteristics over space and time.

Note also in Figure 10 and 11 distinct differences between basins in the topographic distribution of landscape features. This results in distinct differences in the fire regime for different landscape features between basins. Such variation may produce distinct differences in, say, the distribution of channel characteristics found within these basins.

**Summary**

These results illustrate several important aspects of fire “disturbance” and its affect on forest stand-age characteristics:

1) The range of stand ages at any time increases with increasing area sampled (Figure 4)

1) Temporal variability in stand-age distribution increases with decreasing area sampled (Figures 5 and 6).

1) The frequency of fire occurrence varies with topographic position, being least frequent along large valley floors and most frequent along ridge tops.

1) The topographic distribution of landscape features varies between basins, resulting in distinct differences in the effects of fire between basins.

These factors have important consequences in interpretation of “natural disturbance”. For example, the stand-age distribution estimated for some particular point in time (100 years ago say) is only one out of a range of potential stand-age distributions, and the characteristics of this “range of distributions” is a function of the area over which the age distribution is determined. “Disturbance regime” must be characterized over a large range of spatial scales to be fully meaningful. Fire regime must also be resolved over topographic position and the effects of fire must be interpreted in light of the distribution of landscape elements (e.g., landslide source areas, debris-flow prone channels, fluvial channels) over the topography. Because of variation in the distribution of landscape elements, the “fire regime” and consequences of the fire regime may vary between neighboring basins.

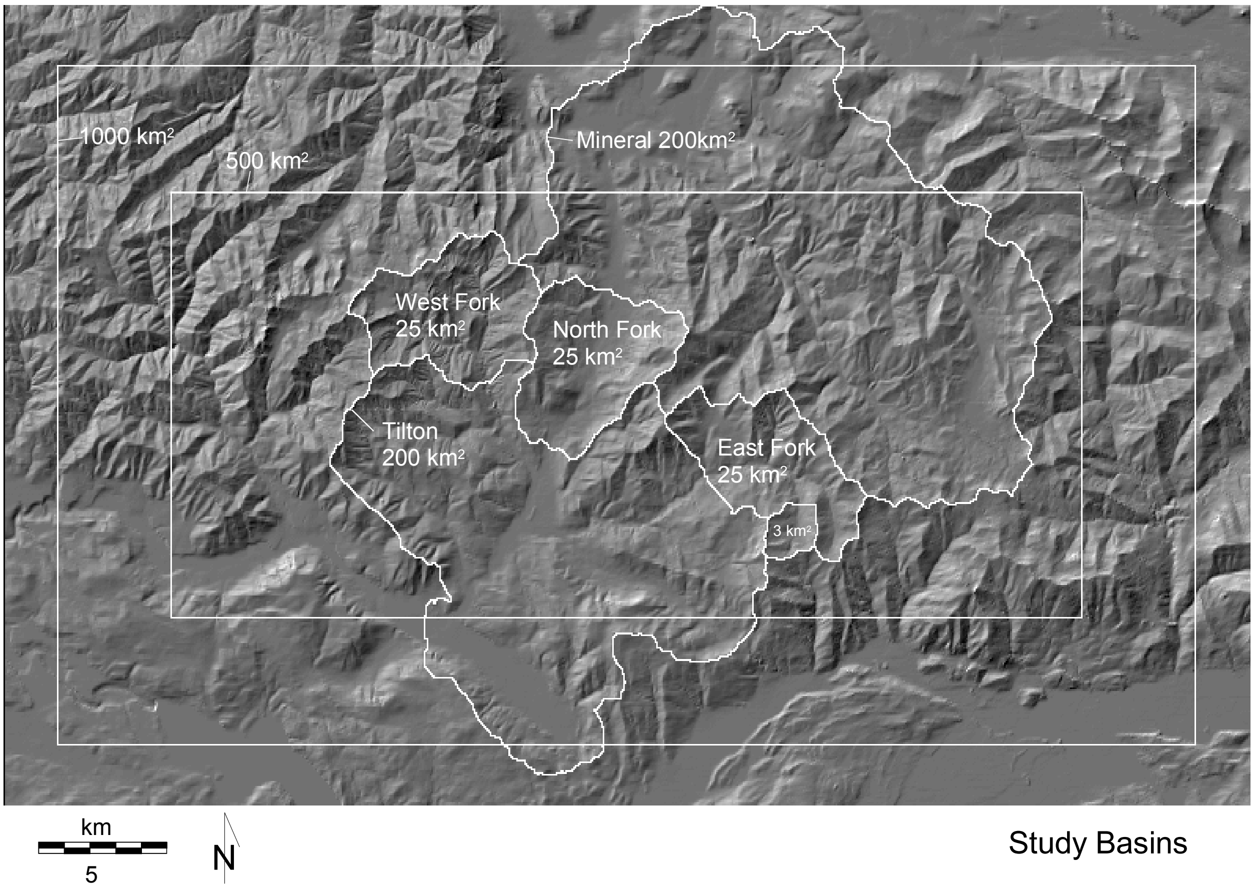



**Figure 1. Study area and sub-basins used for analysis.**

The Tilton River is a tributary to the Cowlitz River; Mineral Creek flows to the Nisqually River, southwest Washington.

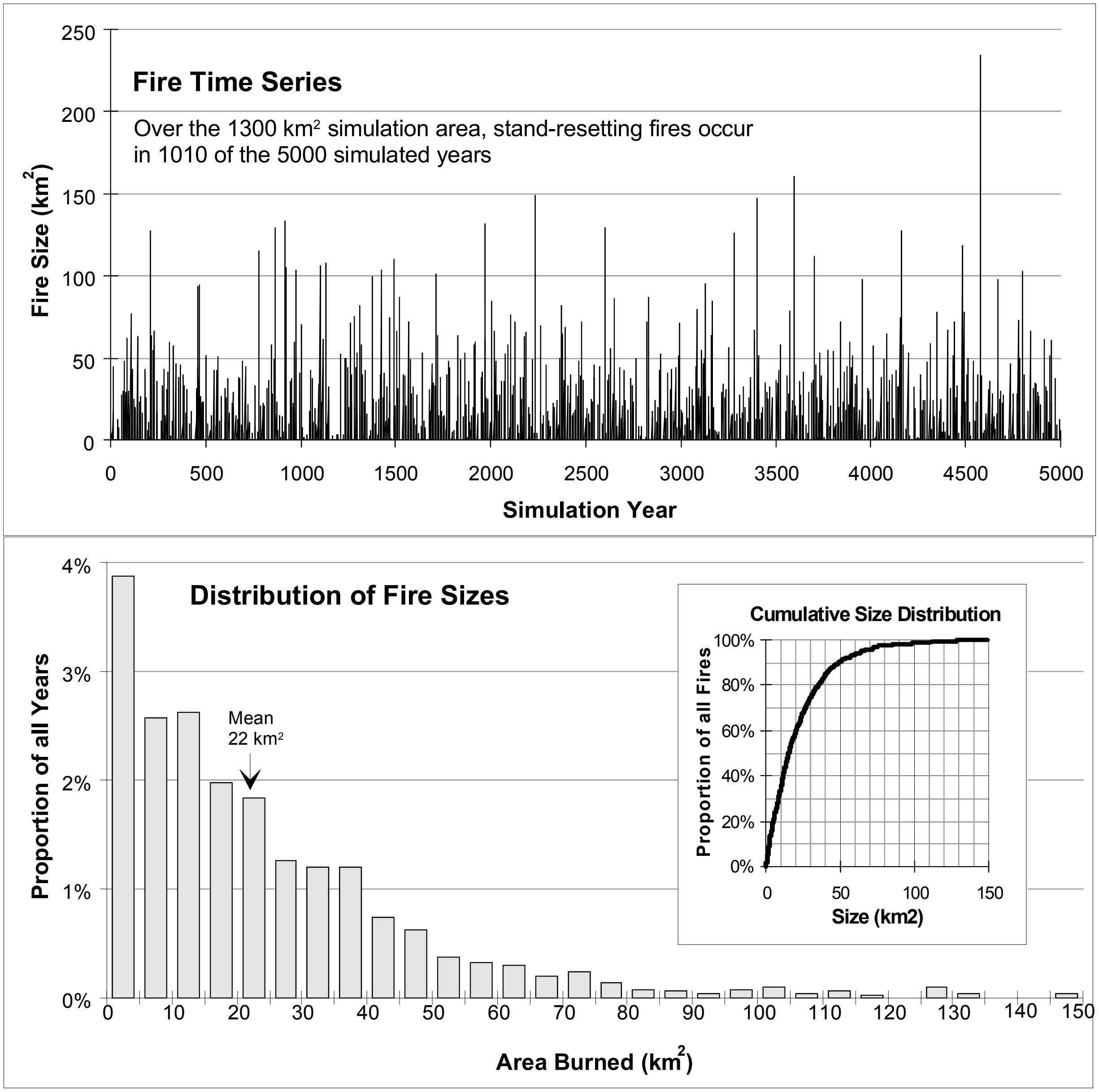
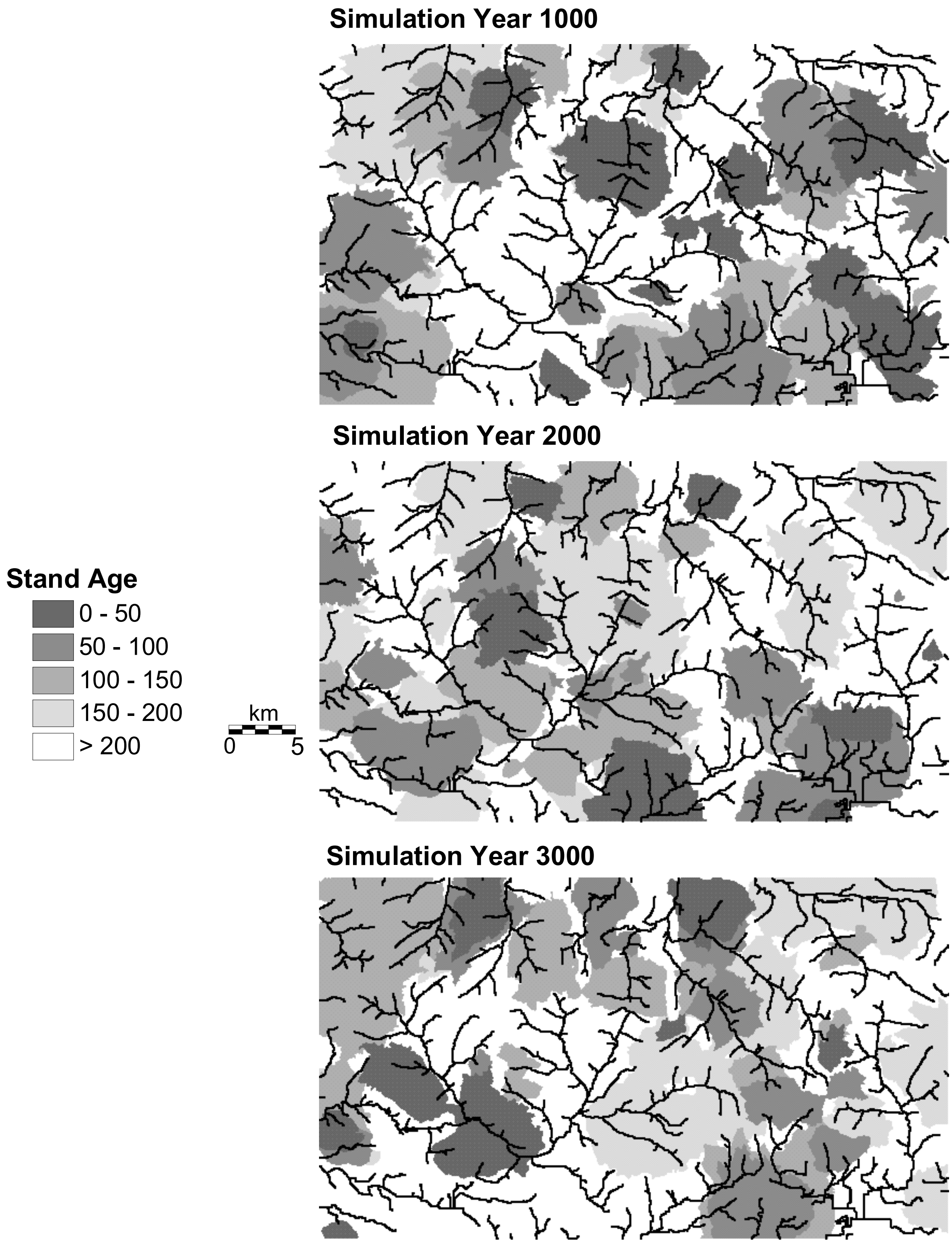


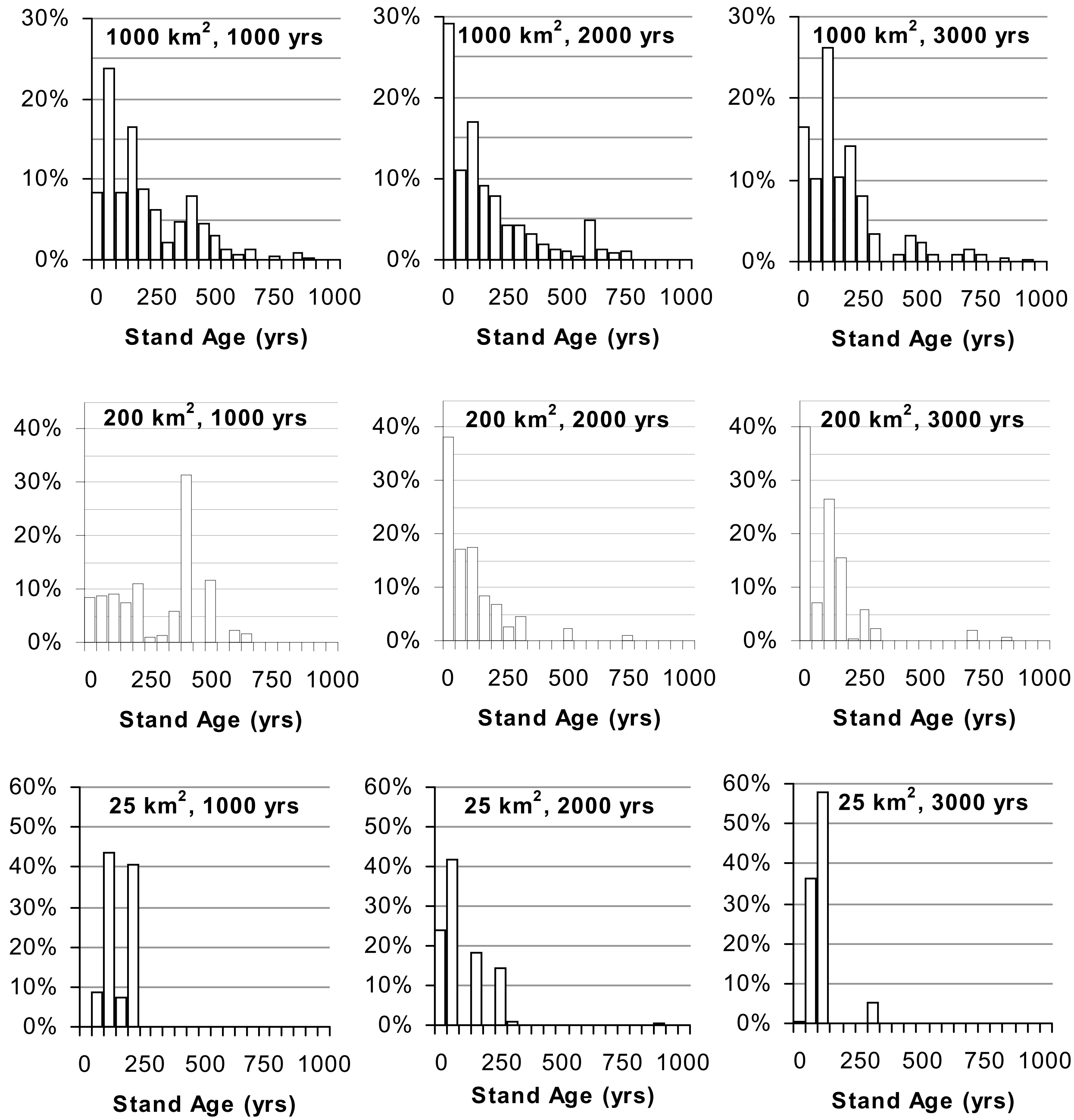

**Figure 2. Time series of simulated fires and distribution of fire sizes.**

The model used an ignition probability of 0.00017 ignitions per square kilometer per year. Ignition locations and timing were assigned randomly. Fire size for each ignition was sampled from a negative exponential distribution. Most fires are small, although rare, large fires do occur. The largest fire during this simulation was 235 square kilometers.



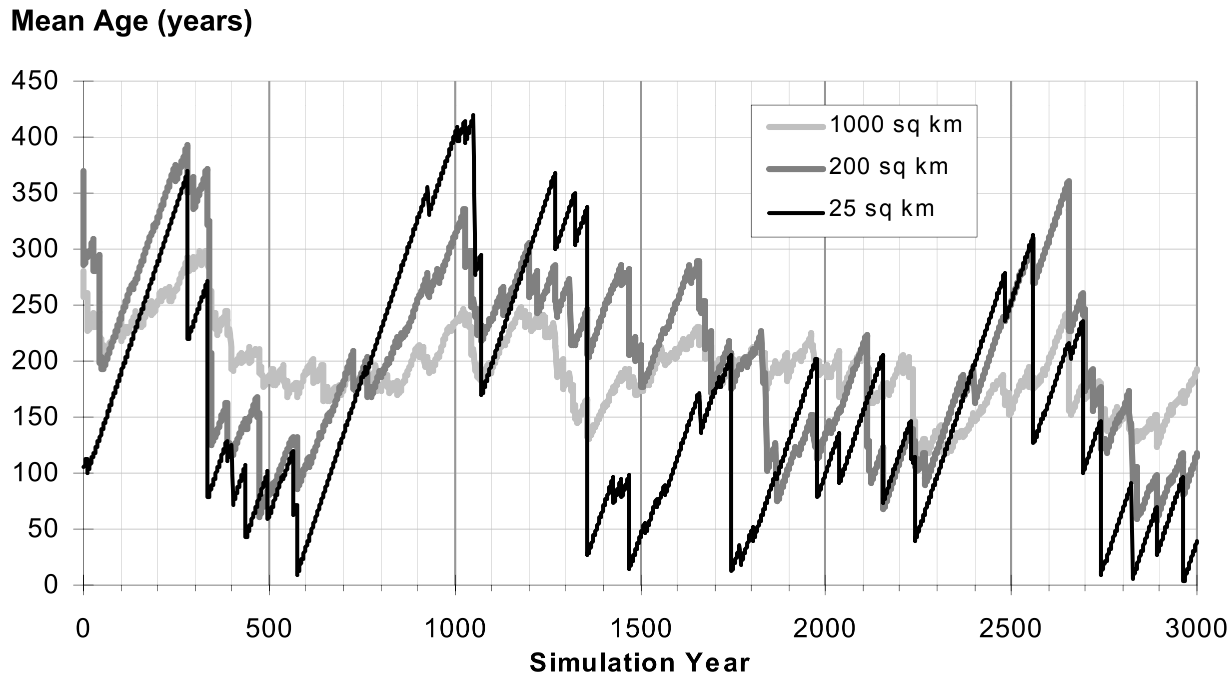

## Figure 3. Mosaics of Forest Ages.

The sequence of fires creates a patchwork of stand ages that varies over time. These images show stand age at three different points in time during the simulation.




## Figure 4. Stand-age histograms.

The distribution of stand ages varies over time and the shape of the histogram is dependent on the size of the area sampled. Large basins include a sufficient number of different stands to define the exponential shape of the distribution. Small basins may have the majority of their area in stands of a single age.




## Figure 5. Temporal variability in mean stand age.

Mean stand age is calculated each year of the simulation for basins of differing size. Mean age varies over time within a basin as stands age and as occasional fires kill a portion of the standing trees. Note that variability over time increases with decreasing basin size. The smaller the basin, the more likely it is that a large fire will burn a large proportion of the area. Indeed, at times during the 3000-year simulation the 25-$km^2$ basin is completely burned over, setting mean stand age to zero. Likewise, long periods may go by during which a small basin is missed by major fires, leading to very old mean ages. Histograms and cumulative distribution plots for these time series are shown in Figure 6.

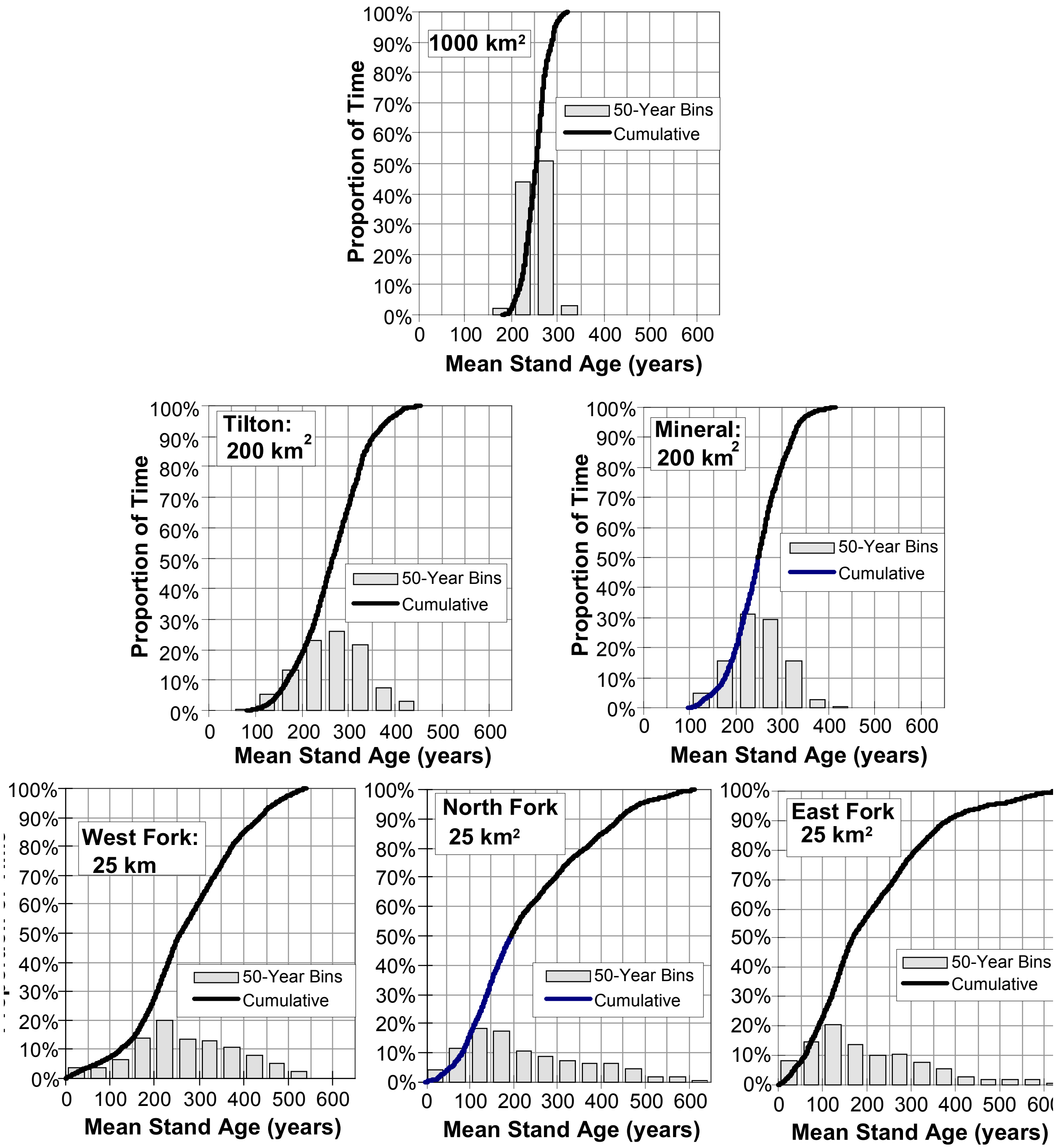



**Figure 6. The distribution of mean stand age as a function of spatial scale.**

The stochastic nature of fire occurrence, in both space and time, creates a distribution of mean ages for any basin. This distribution becomes more symmetric and exhibits less variance as the area examined increases. Subtle differences in the distributions for basins of the same size reflect both the random nature of fire occurrence and distinct differences in the hypsimetric curves for different basins.

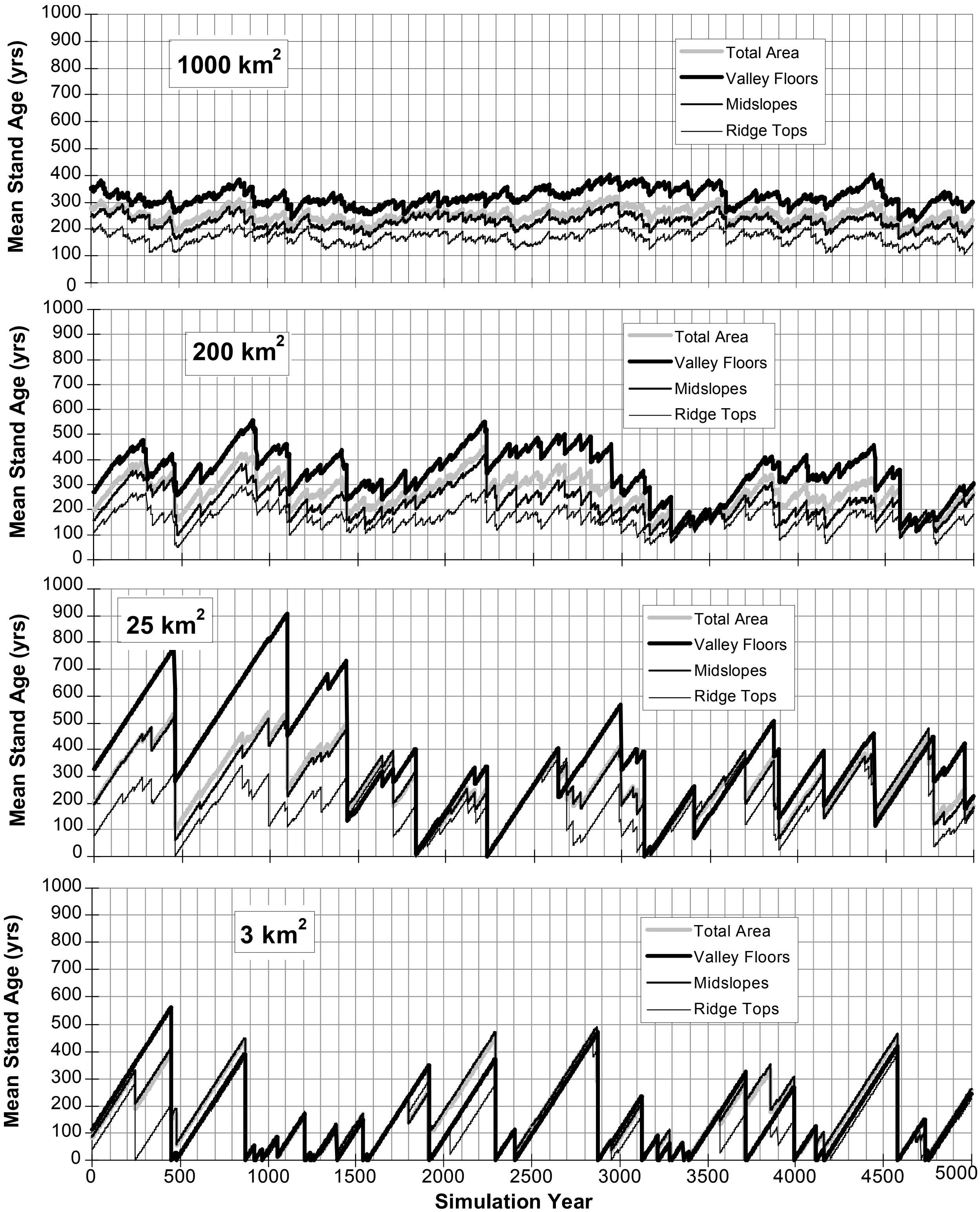



**Figure 7. Mean stand age as a function of topographic position.**

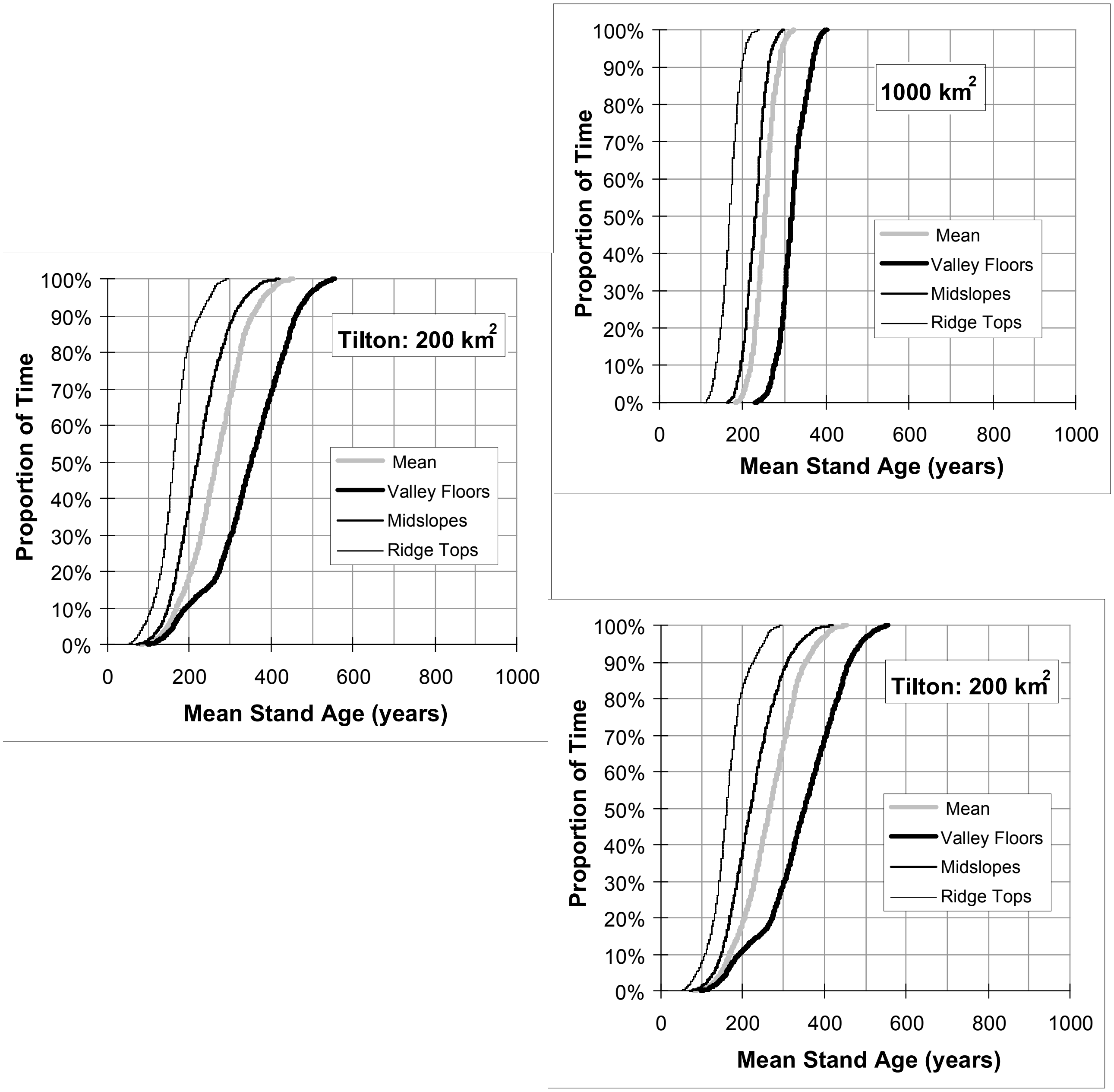



**Figure 8. Topographic control on stand age distribution.**

Fires tend to spread upslope, causing different parts of the landscape to experience distinctly different fire regimes, even within the same basin. Valley floors generally burn least frequently, resulting in older mean stand ages, whereas ridge tops tend to burn most frequently, resulting in generally younger mean stand ages, relative to valley floors and midslopes. Not also the reduction in the range of mean stand age over time as the size of the basin examined increases.

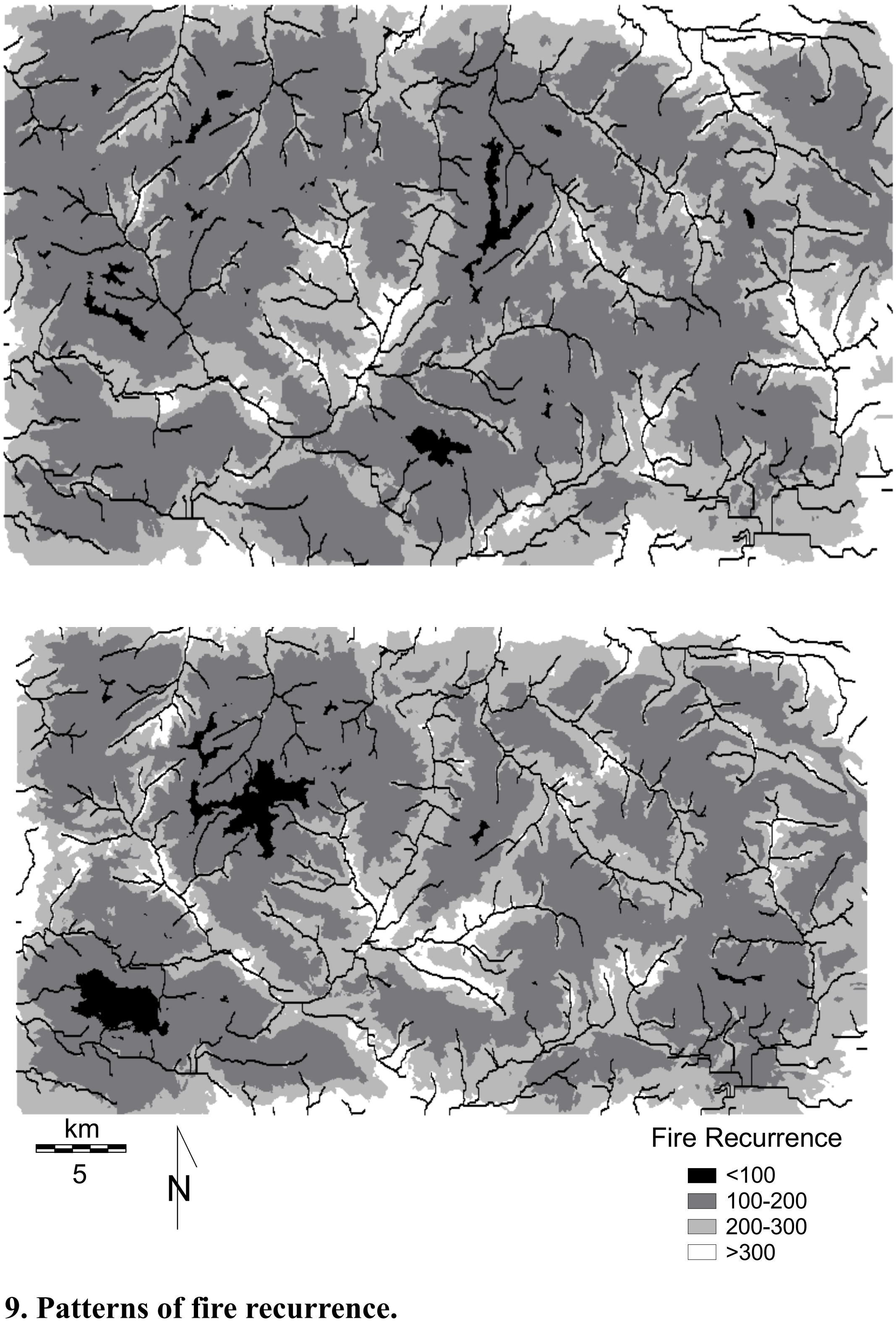
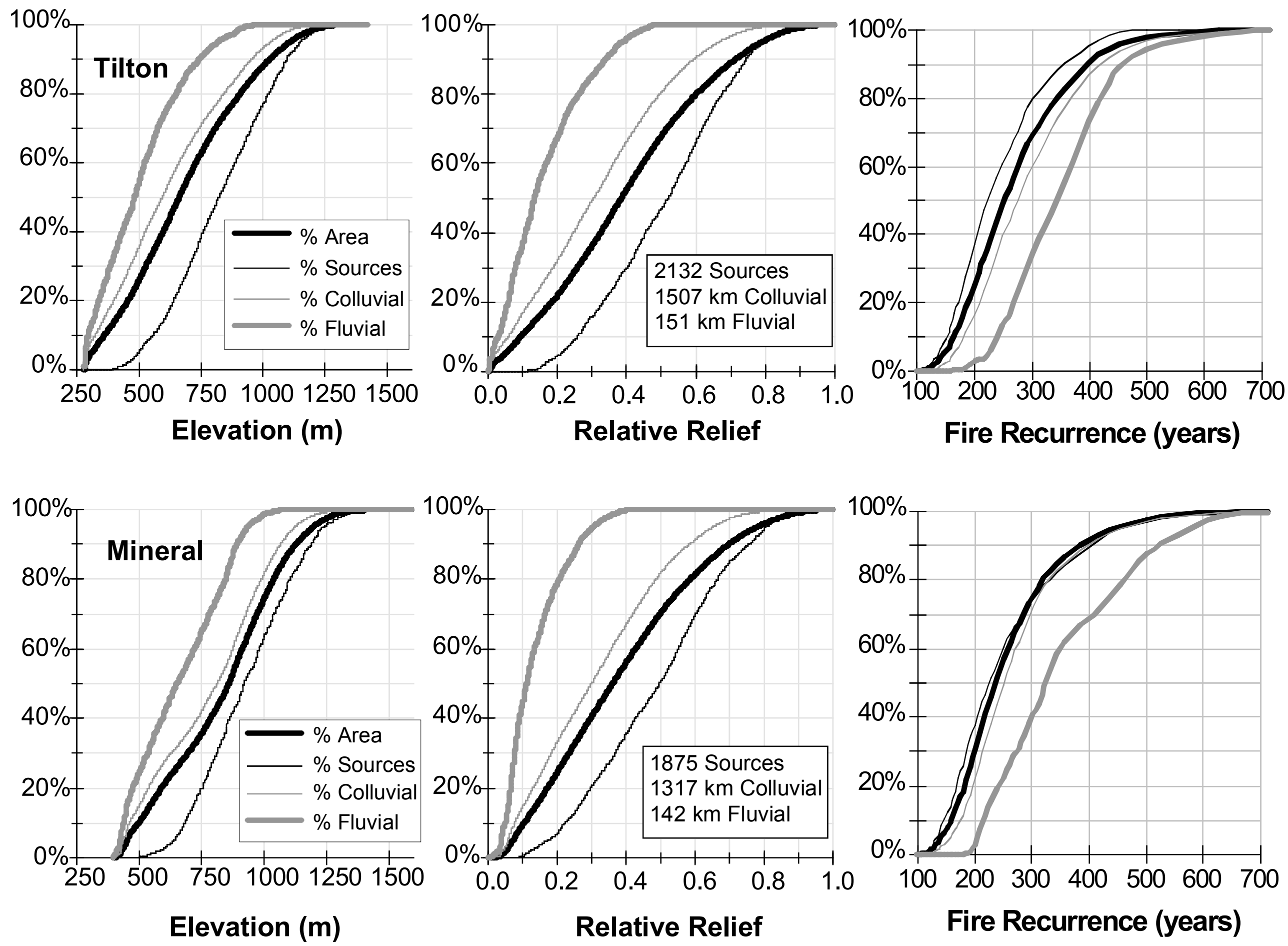


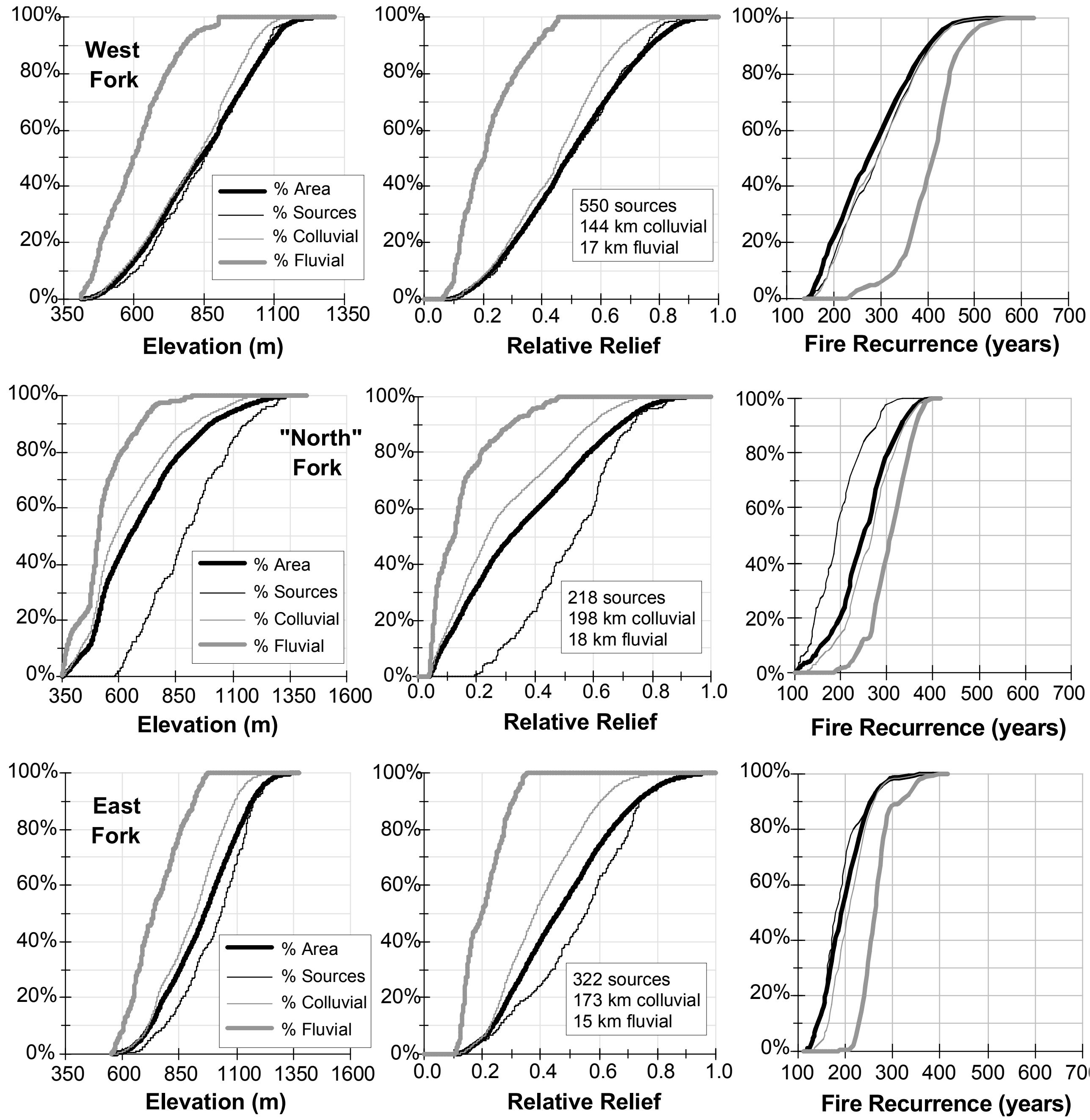

**Figure 9. Patterns of fire recurrence.**

These images show the spatial distribution of fire recurrence intervals based on two separate simulation runs. The stochastic nature of the simulation produces different results in each run, but the overall, topographically controlled patterns are the same




## Figure 10. Topographic control on fire recurrence.

Fires tend to spread upslope as they burn, a behavior mimicked within the fire model. This results in more frequent burning of upslope areas. Landslide source areas and different types of channels tend to be located within certain portions of the landscape topography: hollows and small colluvial channels are found over the midslopes, fluvial channels are found along the valley bottoms. Fire regime may therefore differ for these different landscape features, with landslide source areas (hollows) burning more frequently than riparian areas along valley floors. The median recurrence interval for both basins overall shown here is about 250 years. Riparian zones of fluvial channels, however, because of their location along valley floors, have an overall greater recurrence interval, with a median exceeding 300 years.




## Figure 11. Topographic control on fire occurrence; 25-square-km sub-basins of the Tilton.

Even within a single drainage, topographic variation can produce distinct differences in fire regime between individual sub-basins.