Small bacterial and archaeal genomes provide insights into the minimal requirements for life and seem to be widespread on the microbial phylogenetic tree. However, the precise environmental pressures and ecological processes that constrain genome size in free-living microorganisms are not understood. A recent study including isolates has shown that bacteria with high optimum growth temperatures, including thermophiles, often have small genomes. It is unclear how well this relationship may extend generally to microorganisms in nature, and in particular to those microbes inhabiting complex and highly variable environments like soil. To understand the genomic traits of thermally-adapted microorganisms, we investigated bacterial and archaeal metagenomes from a 45°C gradient of temperate-to-thermal soils overlying the ongoing Centralia, Pennsylvania (USA) coal seam fire. There was a strong relationship between average genome size and temperature: hot soils had small genomes relative to ambient soils. There was also an inverse relationship between soil temperature and cell size, providing evidence that cell and genome size in the wild are together constrained by temperature. Notably, hot soils had different community structures than ambient soils, implicating ecological selection for thermo-tolerant cells that had small genomes, rather than contemporary genome streamlining within the local populations. Hot soils notably lacked genes for described two-component regulatory systems and antimicrobial production and resistance. Our work provides field evidence for the inverse relationship between microbial genome size and temperature requirements in a diverse, free-living community over a wide range of temperatures that support microbial life. These findings demonstrate that ecological selection for thermophiles and thermo-tolerant microorganisms can result in smaller average genome sizes *in situ*, possibly because they have small genomes reminiscent of a more ancestral state.