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Key Points

- Climate conditions after a nuclear war may cause most forests to die. Widespread fires may then destroy remaining forest resources.
- In a post-catastrophe world, wood may be the one easily accessible resource available for smaller communities and family groups.
- The decomposition rates of wood across the globe would decrease to varying degrees due to decreased precipitation and temperature.

Abstract

A global, sun-blocking catastrophe like nuclear war, an asteroid strike, or super volcano eruption spells disaster for most aspects of life as we know it. There have been many studies on how differing magnitudes of sun-blocking catastrophes would affect the global climate, and many mention the effects of this cold, dark climate on forests and cropping systems. However, few studies have solely focused on the effects of nuclear winter on forests in terms of food, resources, and decomposition. Forests already provide over a billion people with food and fuel for their livelihoods. In this review we connect how prehistoric catastrophes affected the world's forests to how a current day catastrophe may affect forest health, forest resource availability, and wood decomposition rates. We briefly discuss how forest resources may be used in this post-catastrophe climate for food and fuel in an energy and fuel depleted world. We use this information to make policy and education suggestions to prepare for future catastrophes, build resilience from smaller local disasters, prepare for the many effects of climate change, and discourage nuclear weapon stockpiling.

Index Terms:

4327 Resilience, 4333 Disaster Risk Analysis, 4312 Catastrophe, 1630 Impacts of global change, 0468 Natural Hazards

Key Words:

Nuclear Winter, Catastrophe, Human-Forest interactions, wood fuel, wood decomposition

1.1 Introduction

Sun-blocking, global catastrophes pose unique problems to many areas of human health and survival. Soot lofted into the atmosphere by explosions and fire from nuclear war, a large meteor impact, or super volcano eruption would result in extreme global climate change (Denkenberger & Pearce, 2014b; Toon et al., 2014). The most likely of these scenarios is nuclear war which has an estimated likelihood range from 0.01% – 1% of occurring each year (Barrett et al., 2013; Denkenberger & Pearce, 2014c). As the Russia-Ukraine War escalated in early 2022 and Russian nuclear forces were put on high alert, nuclear war has again become a tangible threat since the end of the Cold War (Helfand et al., 2022). As historical near-miss events have taught us, mistakes and false alarms could be the only needed prerequisite for a global nuclear war (Barrett et al., 2013; Helfand et al., 2022).

Models of the earth's climate after a large nuclear war between the U.S. and Russia project dismal outcomes. Such a nuclear war would change the global climate drastically for at least 10-15 years with deep freezes across most temperate latitudes, substantial blockage of sunlight from soot, increased UV radiation, and decreased precipitation worldwide (Coupe et al., 2019; Denkenberger et al., 2017; Mills et al., 2008). City infrastructures in warm areas, such as waterlines, are not designed with deep freezes in mind, so freezes would inevitably cause severe infrastructure damage because of frozen waterlines (Pericault et al., 2017). Electricity and many fuel delivery services would likely not be available either. This is in addition to the political-, infrastructural-, and medical-trauma that would be caused by nuclear war.

Although the entire Earth's climate would be affected by a large sun-blocking catastrophe event, not all areas would be affected equally. For instance, models from Coupe et al. (2019) predict that a large nuclear war would result in most of North America, Europe, and Asia experiencing hard freezes year-round for approximately 3 years, while some tropical and mid-latitude coastal areas only have temperature changes of a couple degrees Celsius. Although the same models predict that there would be less severe temperature reductions near the tropics, within a few years of a nuclear catastrophe large portions of tropical rainforests could see annual precipitation levels decrease by 90% and decreases in sunlight below 40% of normal light levels. The cumulative effects from these environmental conditions would have detrimental consequences on the world's agricultural systems (Denkenberger et al., 2017). In addition to decimating agricultural production, sun-blocked conditions would likely affect natural systems across the planet, disrupting ecosystem function in most habitats.

1.2 The modern importance of forests

Of those habitats, forests are arguably the most important, making up 80% of the world's biomass (Kindermann et al., 2008) and 31% of the Earth's land area (FAO, 2020). Whether for non-timber forest products (NTFPs), ecotourism, or ecosystem services, forests are a particularly important habitat which approximately 1.6 billion people directly depend on for their livelihoods (Chao, 2012). Timber and NTFPs harvested from forests are an essential resource for many communities across the world in our current, non-catastrophe environment (Sreevani, 1992). However, it is unknown how a nuclear winter would affect forest health and concomitantly its resources. In this paper, we seek to determine what the direct and indirect effects of a sun-blocking catastrophe on global forest health would be and to determine availability of forest resources for human use after such a catastrophe. We will discuss impacts on food and fuel production, along with resource use and availability.

The world's total yearly roundwood production, about 4 billion m^3, is almost evenly split between fuelwood and industrial roundwood (all other wood products not used as fuel) (Food and Agriculture Organization of the United Nations, 2019). This has been true of global wood production since 1961 at the earliest, and only since 2017 has industrial roundwood production exceeded fuelwood (Food and Agriculture Organization of the United Nations, 2019). It is important to note that temperate areas produce around twice as many industrial wood products as tropical areas (Food and Agriculture Organization of the United Nations, 2019). Additionally, some wood resources are more often gained from plantations than from natural forest. Half of these plantations are located in the tropics or subtropics (Ghazoul, 2013). For example, 70% of industrial roundwood is produced from plantations, however, only 7% of fuelwood is produced in plantations (Penna, 2010). Usually these plantations are not very biodiverse and the majority grow solely pine (*Pinus* spp.), China-fir (*Cunninghamia* spp.), poplar (*Populus* spp.) and/or eucalyptus (*Eucalyptus* spp.) (Bauhus et al., 2010).

In developing countries, wood is most commonly used for fuel (Knight & Rosa, 2012). For example, wood is a main fuel source for two thirds of households in Africa for heating, cooking, and industry (FAO, 2017). Less fuelwood is used as households transition to more 'modern' cooking fuels such as electricity and gas (Knight & Rosa, 2012). In developed countries, wood is mainly used for other commodities such as packaging, biochar, biochemicals, textiles, and lumber (Durbak et al., 1998). It is likely that in a catastrophe described above, fuel sources such as oil, gas, and electricity, may not be easily accessible, making wood a much more valuable resource (Denkenberger & Pearce, 2015; Sreevani, 1992). About 3% of the world's forests are disturbed every year due to human activity such as logging (Pan et al., 2019). This is arguably a high number in a non-catastrophe scenario and should be lowered for many reasons, however it does show the abundance of wood available on Earth.

Additionally, food is widely harvested from almost all forests, both for commercial and subsistence use (Ingram & Schure, 2010). In some cases, these foods have been domesticated and grown in plantations and/or intentionally cultivated in natural forests (e.g., cacao, coffee, rubber, and plantain) (Armengot et al., 2016). Importantly, forests provide 'wild' edible plants (WEPs) which currently act as famine foods for many populations when agriculture fails (Cruz García, 2006; Ocho et al., 2012) and provide regular sustenance to many forest-dwelling peoples around the world (Claude Marcel Hladik et al., 1993). This indicates that WEPs may be a critical source of foraging stockpiles and potential cool-, drought-, and shade-tolerant crops during a time of global food insecurity and a sun-blocked climate (Winstead & Jacobson, 2022). Even though forests provide many food resources, most are seasonal and not abundant enough to feed the world's populations. Alternatively, converting wood itself into a food resource may be possible.

A large amount of energy exists within the hemicellulose and cellulose of all the woody plants. In fact, about three fourths of the world's plant carbon resides in forests which equates to about 2×10^{18} kcal of available energy in carbohydrates (Bar-On et al., 2018; Pan et al., 2019; Pettersen, 1984). If those indigestible carbohydrates of wood were broken down to digestible simple starches and sugars with 5% efficiency, the woody mass in forests would be enough to feed the earth's population for 16 - 18 years given a 2,000-kcal day^{-1} diet. Unfortunately, most of this biomass is inedible by humans in its natural state. However, there are processes to make this energy bioaccessible that will be discussed later in the paper.

By reviewing literature on past catastrophes and disasters (e.g., Cretaceous-Paleogene (K-Pg) extinction event, wildfires, and volcanic eruptions) and current forestry literature, we aim to give an overview of how a sun-blocking event would affect forest health and wood resource accessibility. Additionally, we will look at the accessibility of calories held in forest-based woody material. It is wishful thinking that a largescale, coordinated effort to gather and process forest resources would be feasible given the widespread infrastructural damage likely to occur worldwide after such a large catastrophic event (Graham, 2009). For this reason, our main focus of this review will be on community and household level wood resource use instead of industrial, coordinated responses as written about by others (Denkenberger & Pearce, 2014a). We will be focusing our attention on post-nuclear war climate models in this paper as it is one of the most likely sun-blocking catastrophe scenarios and also the most preventable (Ord, 2020).

2 Effects of a sun-blocking catastrophe

2.1 Hypothesized direct effects on forest health

Atmospheric conditions after a nuclear war pose many problems for the world's forests. Climate models from Coupe et al. (2019) show that the effect of nuclear war on the world's climate would not be uniform, particularly between temperate and tropical areas. Large temperature decreases (5-12 °C) are predicted globally, but would result in multi-year deep freezes in northern latitudes (90-25°N), while tropical areas would mostly remain above freezing (Coupe et al., 2019).

Therefore, nuclear winter would affect life differently depending on location. Recent studies have shown that tropical plants have wide temperature tolerance ranges similar to temperate plants and that most tropical plants currently reside in the higher portion of that temperature range (Sentinella et al., 2020). This suggests that tropical plants may adapt to moderate cooling better than temperate plants. Although, it was thought that tropical plants were more sensitive to large temperature increases than temperate plants in the past (Wright et al., 2009), many plants may be able to survive the shift in decreased temperature in the tropics from a nuclear disaster. However, tropical plants are extremely sensitive to frost and any freezes would result in plant death (Greene et al., 1985).

This temperature stress would be exacerbated by large decreases in precipitation (Coupe et al., 2019). One to two years of drought alone are enough for acute tree death(Poulos, 2014), and frost events during drought have been shown to be detrimental to tree health and often result in tree mortality due to the inability of the plant to transport water because of xylem freezing and embolisms (Poulos, 2014). Decreased precipitation would also mean an increase in dry, dead wood which would make wildfires more likely (Denkenberger et al., 2017). Although wildfires are sometimes healthy and a natural part of ecosystem function in dry temperate areas, tropical rainforests rarely experience natural wildfires, and those rare events are not well understood (Cochrane, 2009).

The causes of ignition for wildfires are a complex issue that differs across the world (Syphard & Keeley, 2015). Although lightning is the leading cause of fire in some areas, several studies in Europe, Asia, and North America have shown that more than 95% of wildfires with known origin are human caused and are therefore largely preventable (Depicker et al., 2020; Hering et al., 2009; Rorig & Ferguson, 1999; Syphard et al., 2007; Ying et al., 2021). For instance, one study on wildfires in California showed that depending on the municipal region, most land burned in wildfire is due to fires ignited by powerlines, machinery, campfires, and arson (Syphard & Keeley, 2015). All but the last are preventable through education and awareness.

The ash and soot from a catastrophic event and resulting wildfires would disrupt forest and plant health. In addition to windblown soot abrasions, fine soot particles are known to attach themselves to leaves easily, which may further block photosynthesis (Pierson et al., 2013). Previous volcanic eruptions have demonstrated the destructive power of soot fallout over many years. For instance, soot from the 1991 Hudson eruption in Patagonia continued to be mobile for years afterwards and many farmers could not successfully grow crops for several years after the eruption because of ash storms (Wilson et al., 2011).

In order for plants to survive, light levels must remain above the light compensation point (LCP), which is the point where a plant “breaks even” between photosynthesis and cellular respiration, and is the threshold of both survival and growth (Bravo et al., 2007; Harwell, 1984). This point is different depending on a plants stage of growth and the natural conditions the plant is adapted to (Sendall et al., 2015; Timm et al., 2002). Trees' LCP ranges roughly between 5-40 µmol photons m^{-2} s^{-1} depending on if they are early successional (pioneers) or late successional (mature forest) (Bravo et al., 2007; Eschenbach et al., 1998; Kitao et al., 2016). In models of nuclear winter, sunlight would be decreased to at most 40% of pre-catastrophe direct sunlight in the tropics and 5% of pre-catastrophe light intensity (60 µmol photons m^{-2} s^{-1}) at higher latitudes (Coupe et al., 2019). Although this is higher than the normal LCP for most plants, colder temperatures also increase light needed to survive (i.e. increase LCP) in some plants (Bravo et al., 2007). Therefore, these model outcomes suggest that plants in northern latitudes would be most likely to suffer from insufficient light for growth and survival. Similarly, evidence from the K-Pg boundary shows that there would likely not be enough light to reach LCP after a large meteor impact like the K-Pg bolide impact discussed later (Bardeen et al., 2017). Additionally, the Community Earth System Model-Whole Atmosphere Community Climate Model version 4 (WACCM4), predicts a decrease of global net primary production (NPP) to near 0% after a 150 Tg atmospheric soot injection (Toon et al., 2019). In lieu of nuclear winter, NPP is predicted to slowly rise over the next 10 years (Toon et al., 2019).

UV-B/C radiation poses unique and less predictable threats (Greene et al., 1985). Soot injections from either a small or large nuclear war would cause a depletion of ozone in the atmosphere, and in turn an increase in UV-B/C radiation at the earth's surface after the soot dissipates (Denkenberger et al., 2017; Jagermeyr et al., 2020; Mills et al., 2008). Unfiltered UV-B radiation has many detrimental effects on plant growth and reproduction, including but not limited to: stunted growth, decreased photosynthesis, sterility, genetic mutation, and abnormal development (Greene et al., 1985). Effects of UV-B/C radiation on seed germination differs greatly depending on species, killing some species while others are not severely affected (Tepfer & Leach, 2017).

2.2 Prehistoric catastrophes as examples

Prehistoric catastrophic events give insight into the potential conditions of a nuclear winter or post-asteroid strike winter. The bolide impact, which marks the Cretaceous-Paleogene (K-Pg) transition and is evidenced by the K-Pg geologic boundary layer, is a good case study for the potential effects of nuclear winter driven global wildfires and sun-blocked conditions on plants. The K-Pg boundary layer is characterized by the presence of soot particles, the sudden absence of flowering plants (angiosperms), and a spike in fern populations, which indicates mass deforestation in the presence of fire (Vajda et al., 2001). There is a debate whether ejecta from the impact itself, or the subsequent drought caused the widespread wildfires (Harvey et al., 2008; Morgan et al., 2013). A geological study using scanning electron microscopy, suggests that more than half of the charred wood present at the K-Pg boundary layer was partially decomposed before its ignition (Jones & Lim, 2000). This supports the hypothesis that wildfires came later in dry conditions, only after mass plant death due to the sun-blockage and decreased temperatures (Vajda et al., 2001).

Contrarily, recent models seem to suggest that the soot needed to reduce light below the photosynthetic threshold to cause plant death could only have occurred if there were widespread firestorms immediately after impact. These would have been caused by ejecta and a bolide heat wave (Bardeen et al., 2017; Tabor et al., 2020). One of these recent models published by Tabor et al. in 2020 estimated critical soot levels for widescale plant death based solely on the sun-blocking effect of soot and not the potential coincident changes in environmental conditions (drought, cold, increased UV-B/C radiation) and their cumulative effects on LCD and thus plant health as we have discussed in the previous section. Although it is apparent that widespread firestorms influenced the post-impact environment, and that dark conditions did play a role in plant extinction, other effects such as cold temperatures and drought may have been even more influential in plant death. Taking these factors into consideration decreases the initial amount of soot needed to cause plant death from that predicted in the Tabor et al. (2020) model and may suggest earlier forest death and a later onset of forest fires as an indirect effect due to drought. Besides the timing of wildfires, both Bardeen et al. (2017) and Tabor et al. (2020) further support our predictions about forest health with very robust climate models.

The estimated range of the amount of soot injected into the atmosphere from the K-Pg bolide impact is very broad (750-35,000 Tg of fine soot) (Bardeen et al., 2017). This is anywhere from 5 - 467 times larger than the current day estimates of soot from a large nuclear war (150 Tg)(Bardeen et al., 2017). The effects on climate from the bolide impact modeled by Bardeen et al. in 2017, also show that UV-B radiation increased above normal levels 5-9 years after the impact. This suggests that UV-B radiation would not be a problem for the first several years after a similar catastrophe.

Separately, geologic evidence across multiple continents from around 74,000 years ago shows severe cooling and ash deposition that coincide with the Toba super-volcano eruption in Sumatra (Rampino & Self, 1992). Other geologic and archeological events that coincide with the eruption include: replacement of forests by grassland, an ice age, and animal extinctions (Williams et al., 2009). Additionally, this eruption caused drought in the tropics and subsequent wildfires (Rampino & Ambrose, 2000). Although the sulfate aerosols produced from this volcanic eruption had different atmospheric and optical properties than black carbon from a nuclear explosion would have, the sulfate aerosols still caused regional cooling effects similar to black carbon soot making this a good proxy for a regional "nuclear winter" (Rampino & Self, 1992). Direct ashfall also seemed to alter plant diversity for thousands of years (Williams et al., 2009). Cumulatively, these geological data and historical catastrophes suggest that there would be worldwide tree death before subsequent wildfires after a similar modern-day, sun-blocking catastrophe.

2.3 Wood resource loss and decomposition

Considering these detrimental effects on the world's forests, begs the question; how long and in what condition would wood resources be available after trees die? It is likely that wood decomposition rates across the world would be altered in a post-catastrophe climate.

Firstly, decomposition would slow in cooler temperatures as does most biological metabolisms (Anderson, 1991). The majority of wood decomposition is led by microbial and fungal enzymatic digestion, but invertebrates also play an important role in wood decomposition as they also digest wood and provide openings for more decomposers (Ulyshen, 2016). The decomposition process typically takes many years for large pieces of wood to fully decompose into humus and yet it is an essential part of the carbon cycle (Harmon et al., 2004).

Additionally, climate models show a global precipitation reduction average of 50% but also a slight increase in global troposphere relative humidity (10%) up to 10 years after a large nuclear war (Coupe et al., 2019). Although decreased precipitation would reduce standing free water, very high relative humidity (>90%) could provide the moisture needed to decompose smaller diameter lignocellulosic matter and labile litter (Dirks et al., 2010; Jacobson et al., 2015). It is less likely that increased humidity would be sufficient to provide enough moisture to decompose large diameter logs, as fungi on larger lignocellulosic matter require free water to saturate logs (Jacobson et al., 2015). More importantly, lower temperatures would still slow decomposition rates in most areas because although water is essential for decomposition, change in temperature is generally more influential in determining decomposition rate than moisture content (Anderson, 1991; Seibold et al., 2021; Sierra et al., 2017). Mainly, for wood to decay, it must have enough water to transport extracellular enzymes created by decomposers (Kirk & Cowling, 1984). This happens when the wood reaches its fiber-saturation point, i.e., when about 27% of the wood's dry-weight of water is absorbed (Kirk & Cowling, 1984). A 90% reduction in precipitation in the tropics would likely not allow for large diameter dead wood to reach this fiber-saturation point.

We postulate that after a nuclear winter scenario, decomposition rates of wood would be lower in temperate areas when only considering temperature. Although wood in tropical areas would still decompose, the decomposition rate of the tropics may also slow marginally because of decreased precipitation. Tropical areas may see substantial amounts of wood lost to decomposition after the climate begins to warm up again 7-10 years after the sun-blocking catastrophe.

As stated previously, wildfires would be common for years after the catastrophe, adding more soot into the atmosphere and burning remaining wood resources. If moisture would be returned to an area that has been burned, the remaining burned material would likely have a faster decomposition rate than unburned material (Throop et al., 2017). Additionally ozone depletion would cause an increase in unfiltered UV-B/C radiation after a sun-blocking catastrophe (Coupe et al., 2019; Jagermeyr et al., 2020; Mills et al., 2008). Increased UV-B/C has also been shown to speed the rate of litter decomposition via photodegradation (Dirks et al., 2010; Pieristè et al., 2019). These variables add yet more uncertainty to wood decomposition rates after such a catastrophe.

2.4 Cumulative effects of post nuclear climate on wood resources

Based on the above discussion, places that normally have exceptionally high decomposition rates (e.g., tropical rainforests), would have decomposition rates similar to other temperate zones after a catastrophe. Not everywhere would be affected equally, as some areas see less temperature and precipitation anomalies than others (Coupe et al., 2019). Most wood decomposition rates would likely start to increase after year 7 as this is when both precipitation and temperature would begin to increase.

This wood decomposition timeline would be an important consideration to a community after a global catastrophe as resource availability would be influenced heavily by decomposition rates and wildfire. The importance of these factors would undoubtedly differ between communities given their proximity and access to forests. Decomposition would not be an important factor influencing resource loss in higher latitudes but may be a severe problem in areas closer to the equator if precipitation is not limiting. Mainly, the greater temperature in the tropics would continue to support decomposition if dead trees reached their fiber-saturation point.

High altitude montane forests (e.g., Eastern slopes of the Andes Mountains) may serve as short-term wood repositories in tropical areas as they may cool and freeze, preserving the woody material for a moderately longer period than submontane tropical forests. Temperate forest wood resources would largely be threatened by wildfires and not decomposition given low and even freezing temperatures. However, slow decomposition in temperate areas would allow the preservation of fresh logs to use for lumber or conversion to fuel.

As the climate stabilizes 10-15 years after the event and temperatures return to normal, decomposition rates would increase back to normal decomposition rates. This means although fresh wood may be plentiful directly after a catastrophic event, wood in the tropics may become a scarce resource after a few years. If the conditions after previous catastrophes (K-PG bolide impact and Toba supervolcanic eruption) are any indication, there would be fires and lack of substantial new wood production after the catastrophe for many years.

2.5 Indirect effects and forest succession after catastrophe

As conditions begin to return to near-normal levels, some amount of succession and regrowth would likely take place in previously productive forest. Although some seeds are transient and lose their viability very quickly (within a year), both woody and non-woody plants can produce seeds that remain viable for several years under the soil in natural seedbanks (Dalling & Brown, 2009). Increased UV-B/C may also damage seeds near the surface of soil after exposures longer than a couple years; however, seeds with extra seed coatings would be able to resist some UV-B/C damage (Tepfer & Leach, 2017). Overall, seeds designed for long-term viability with seed coatings would be the most likely to survive after a sun-blocking catastrophe.

Many species would likely go extinct, however there may be some species that rise "out of the ashes" as pioneer species filling newly created ecological niches. Although this would happen naturally over many years, this process could be expedited through reforestation efforts by planting key local species (Hooper et al., 2002; Ma et al., 2020).

It has been observed that indirect effects due to wildfires are less influential than the direct effects of fire, and change depending on how many fire events occur (Bowd et al., 2021). Similarly, many indirect effects due to shifts in the ecological community after a sun-blocking catastrophe would occur but given the already unpredictable direct effects these are even less predictable and would be more localized than direct effects. Some drivers of the unpredictability of indirect effects on any given ecological community include the timing and local intensity of UV-B/C radiation; pre-catastrophe climate and forest structure, dynamics, and health; cultivation of emergency non-native food plants; unregulated gathering and transport of wood resources post-catastrophe; radioactive fallout; declining and overharvesting of herbivore populations; etc.

3 Using wood resources

As we have discussed, wood resource availability after a nuclear catastrophe would be variable and potentially quite different than wood resource availability during current conditions. However, the usability of remaining wood resources after the catastrophe for fuel and NTFPs is a similarly important issue. This section will discuss how wood may be used and in what form.

3.1 Wood as an energy source

Wood, for both heat and cooking, would likely be the most accessible and important resource after heavy damage to energy infrastructures (gas, electric, oil, etc.)(Sreevani, 1992). By simply using small, efficient wood stoves with more controlled air intake like the Envirofit Rocket Stove (http://envirofit.org) and those put forward by the Clean Cooking Alliance (https://www.cleancookingalliance.org), households can efficiently cook while using a smaller amount of fuelwood and preventing illness due to poor indoor air quality due to excess smoke (Ochieng et al., 2013; Peck, 1942; Rosa et al., 2014). Likewise, rocket mass heaters (RMHs) are efficient, low-tech woodstove designs made of barrels, tubes, and cob masonry that can heat the home up to 24 hours after the wood fuel has been burned, and can double as a cooking surface (Peck, 1942; Schumack, 2016). Similar makeshift woodstoves and wood-fueled heating systems would be the ideal, if not only, technologies available in a sun-blocked catastrophe.

Likewise, wood chips and pellets can be used to produce combustible biogases including hydrogen through pyrolysis and gasification (Arief et al., 2021). At its core, this is a simple process of heating wood until those flammable gases are released. A simple wood gasifier can be constructed with a welder and spare metal scraps. Biogas from wood gasification as well as methane production from anaerobic digestion of other biomasses can be used to power simple electric generators, cook food, and heat homes (Aita et al., 2016).

Similarly, charcoal burns hotter and has more energy than wood by weight; however, about two thirds of the original energy in wood is lost in the charcoal making process (Wood & Baldwin, 1985). Therefore, in a disaster scenario, charcoal production may not be the most efficient form of fuel. However, charcoal could be useful in blacksmithing, smelting, and other high temperature crafts. There is much to learn from efforts in developing countries that use stoves that are more efficient in wood use than the traditional three-stone woodstove (Wood & Baldwin, 1985).

3.2 Wood as a food source

Wood reduced to smaller particle sizes can be used for composting, and plant growing media. Particularly, sawdust made in mills as described below can be used as substrate for growing mushrooms, providing many of the required nutrients for mushroom growth especially when supplemented with agricultural/food waste (Girmay et al., 2016). Lignin and cellulose digesting mushrooms such as oyster mushrooms (*Pleurotus* spp.) would be best for both producing food and partially breaking down woody material (Bonatti et al., 2004). If chipping or sawing wood would not be feasible, small-scale mushroom farmers could resort to using whole logs (Frey et al., 2020).

Humans do not have the ability to digest lignocellulose on our own. However, this biomass can be broken down through the process of saccharification into digestible, simple sugars which, conventionally, is done as a precursor for biofuel production (Anu et al., 2020). This can be accomplished by using both thermochemical and enzymatic pretreatment methods to separate the components of lignocellulose (cellulose, hemicellulose, and lignin), and then using enzyme baths to break apart the cellulose and hemicellulose at the molecular level into hexose and pentose sugars (Bhatia et al., 2020). Although these treatments work well, they are not straight forward tasks requiring specific tools, materials, and energy inputs not widely available in addition to the possibility of bacterial contamination (Barba et al., 2021; Beig et al., 2020). Pretreatments are usually quite expensive, and it would be costly to create a universally available pretreatment method (Beig et al., 2020).

There would be two main challenges for household level saccharification after a catastrophe: the absence of a "one size fits all" enzyme to break down all lignocellulose types, and that those different types of lignocellulose need different pretreatments (Østby et al., 2020). Simpler pretreatment methods such as hydrothermal and acid bath pretreatments still require expensive equipment and chemicals, in addition to energy (Anu et al., 2020; Seguí & Fito Maupoey, 2018). Some less effective methods may be possible such as freeze-thaw, ball milling, and microwaving (if some device was created with household microwave ovens) (Haldar & Purkait, 2021; Rooni et al., 2017). Even if pretreatments work, the creation of specific enzyme cocktails to break down the lignocellulosic polymers would likely need to be done onsite using local fungi strains (Østby et al., 2020).

Saccharification would also make it easier for other organisms to use and digest wood. For instance, partially processed wood could also be fed to cellulose digesting livestock like cows and sheep as a feed alternative (Denkenberger et al., 2017). Because ruminants cannot digest lignin, sawdust and wood chips need to be pretreated to remove lignin to below 10% using enzymatic hydrolysis in order for them to digest the lignocellulosic material (Anthony et al., 1969). Likewise spent mushroom substrate made from hardwood sawdust has also been shown to be a plausible feed source for ruminants (Anthony et al., 1969).

3.3 Post-catastrophe wood processing challenges

To use wood for lumber or fuel most efficiently it must be dried, or "seasoned," to remove moisture. Under normal circumstances this can take 6 months to a year of air drying; however, just a month of drying allows for more efficient burning in emergencies (Peck, 1942). Although, partially seasoned wood can be burned, a significant amount of energy is lost turning the remaining moisture content into steam (Peck, 1942). For this reason, it would be important to start harvesting green firewood as soon as possible after a catastrophe to increase drying time. Additionally, the smaller the surface area to volume ratio of the wood, the shorter the drying time will be. For this reason, wood used for biogas production could be chipped while green to shorten drying time.

To use wood more effectively for biogas production and saccharification methods, there would need to be ways of processing large woody material into usable, smaller fragments like woodchips and sawdust. Although our understanding of how infrastructure may be affected by such a large catastrophe is very limited, it is reasonable to suggest that the effects to infrastructure of a catastrophe would be worse than localized disasters. With the absence of electricity and potentially the absence of large-scale industries and infrastructure after catastrophe (Graham, 2009), appropriate technologies and hand tools for processing wood would be needed at the community and family level (Peck, 1942).

For example, traditional technologies like watermills have been used for centuries to power lumber mills and grain mills across the world (Archer et al., 2017; Pujol et al., 2010; Sharma et al., 2008). The watermill design can be used today with much more efficiency using upgraded metal parts if they can be made with resources available (Agarwal, 2006). Likewise, windmills have been used for similar purposes across the globe (Rossi et al., 2017; Vowles, 1932), although they may not have the reliable constant power needed to process wood. Although gasoline powered chippers and chainsaws would still be available, gasoline may become a rare commodity. Electric powered chainsaws and chippers are becoming more efficient and may be a worthy use of the little electrical energy available to communities. Steam powered mills, though certainly not a quick build, would also be efficient and not lack fuel (wood/sawdust).

Although the natural process of wood decomposition breaks down lignin, cellulose, and hemicellulose, the organisms catalyzing such processes are ultimately fully oxidizing the material and releasing CO_2 (Kirk & Cowling, 1984). In the case of food, unless the decomposers are themselves edible, they pose serious bio-contamination issues for both mycoculture (mushroom farming) and saccharification techniques. As for direct energy through burning, decomposing wood collects and stores moisture and is constantly losing mass and energy through decomposition (Kirk & Cowling, 1984). For these reasons, using fresh wood sources would likely be the best option for most uses. There would be the possibility of capturing heat from aerobically decomposing wood and using the decomposed wood as compost, although these uses would likely not take priority over uses of nondegraded wood.

4 Conclusion

A sun-blocking catastrophe would disrupt agriculture, food security, and forest health across the globe. Wood resources would be extremely valuable after a catastrophe, perhaps more so than at the present. Wood would not only be a source of fuel, but also could be converted into food directly. Current literature seems to suggest that global forest health after such a sun-blocking catastrophe would be grim, and possibly result in mass extinctions and loss of the planet's forests for many years. The wood resources left behind would stay intact for several years until they decomposed, were burned by wildfire, or used. Using current literature, we posit that wood decomposition in tropical areas would accelerate as temperatures increase steadily to normal conditions. Especially in the tropics, human populations should focus on wood collection soon after the catastrophe as decomposition may destroy wood resources quicker than in temperate areas. Wood resources in temperate areas would be preserved in ice until thawed, in which case wildfire would be the likely mode of resource destruction. To use these wood resources, appropriate technologies and low-tech solutions such as watermills, windmills, and woodchippers are needed to convert logs into more usable material such as sawdust or chips. In lieu of a catastrophe, these methods and technologies have the potential to be immediately useful in developing countries and areas with less reliable energy sources.

Studies show that although there is a positive correlation between disaster preparedness and perceived disaster risk, the effect of this correlation is quite small (Akbar et al., 2020; Howe, 2018). Although many may feel that they are prepared for unforeseen disasters, surveys have shown that very few people are actually as prepared as they think they are (Kapucu, 2008). It can be difficult to convince people to correctly prepare for unforeseen disasters, even if that disaster is likely. For this reason, it may be more prudent to encourage actions that benefit people in their current lives rather than enticing people to be prepared for the future. As applies to this study, it is likely that education programs geared towards teaching people how to process wood and find food when all infrastructure fails would not get much attention, interest, or funding. However, framing the use of wood resources as a potential source of food and as a renewable resource to improve livelihoods in the present, will likely be more effective. This, in turn, will also build a knowledge base for communities to be better suited to react to possible local disasters, famines, and even global catastrophes. Similarly, another actionable step would be to change the culture of disaster preparedness itself to be more popular (Kapucu, 2008). Although, this may prove more difficult than advocating for the immediate benefits of disaster preparedness strategies for households and communities.

For instance, educating people to be more aware of common causes of wildfires and areas most at risk could significantly reduce wildfires currently and after a catastrophe. Prioritizing areas with high wildfire risks such as sloped areas and areas close to roads for logging and wood gathering after a catastrophe event could be a good strategy for efficient resource use and conservation of wood resources (Syphard & Keeley, 2015). Education programs on wood resource management would be a prudent way of both increasing yield and efficiency of local communities that currently use wood as fuel, and for preparing communities for possible disasters and catastrophe.

The information gathered for this review suggests that many of the aftereffects of a global sun-blocking catastrophe would be out of human control even if humans caused such an event. The results of a catastrophe event would likely be disastrous and irreversible to the plant and animal communities as well as human populations. Including this sort of information and guidance in a catastrophe response kit could be beneficial in providing needed information for human survival at a community and household level if such an event occurred. Additionally, more research into how to make saccharification accessible to regular homeowners with generic enzymes and pretreatments could prove useful during times of famine and disaster in countries today in addition to global catastrophe.

This article further illustrates the destructive power a nuclear war would have on the entire planet and not just the actors directly involved. Although humans have little influence on the probability of most sun-blocking catastrophes, nuclear war is easily avoidable and should be avoided at all costs for the security and future of humanity and our planet as we know it.

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