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The wood from the trees: The use of timber in construction

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ABSTRACT

Trees, and their derivative products, have been used by societies around the world for thousands of years. Contemporary construction of tall buildings from timber, in whole or in part, suggests a growing interest in the potential for building with wood at a scale not previously attainable. As wood is the only significant building material that is grown, we have a natural inclination that building in wood is good for the environment. But under what conditions is this really the case? The environmental benefits of using timber are not straightforward; although it is a natural product, a large amount of energy is used to dry and process it. Much of this can come from the biomass of the tree itself, but that requires investment in plant, which is not always possible in an industry that is widely distributed among many small producers. And what should we build with wood? Are skyscrapers in timber a good use of this natural resource, or are there other aspects of civil and structural engineering, or large-scale infrastructure, that would be a better use of wood? Here, we consider a holistic picture ranging in scale from the science of the cell wall to the engineering and global policies that could maximise forestry and timber construction as a boon to both people and the planet.

1. Introduction

Timber for construction is one of the many forest products used around the world. It is used in buildings both large and small; here we consider timber for the construction of buildings of six or more storeys, and the biochemistry and chemistry of wood modification that could enable much larger buildings. There is ample global supply for the foreseeable future, and although there is a worldwide trend towards deforestation, it is generally due to clearing land for agriculture rather than logging for timber. Nevertheless illegal logging remains a concern.

How should one use timber? While there are limitless possible designs, and construction is based in both engineering and cultural practice, timber has a high strength to weight ratio, and is used most efficiently in structures where it is carrying a lot of its own self-weight. In many areas of the world building codes trump engineering, so heights are limited well below what is possible in timber. We also address important questions relating to the service life of timber structures, affected predominantly by their fire performance and moisture sensitivity, and how this can be extended through the modification of the natural material, and using effective design details. While such modifications may increase the carbon sequestration period due to prolonged life, there may be however detrimental implications to end-of-life scenarios.

Why should one use timber? Construction-grade timber and

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engineered forest products are some of the highest value products from trees. This suggests that structural use is important for economies that rely on forestry. Furthermore, following primary use as structure, there are many secondary or tertiary uses for timber construction waste that retain its value.

When should one use timber? Timber can have economic benefits for construction, as modern timber is largely factory prepared and brought to site for rapid assembly. Both local and global markets exist for timber, so each could be important in assessing the value of using timber at a large scale. The environmental benefits have been demonstrated on some projects, but are not always easy to quantify or generalise.

This review article aims to provide a big-picture view of the environmental impacts of using timber in construction, and the choices that influence this. The novelty of this article is that it succinctly covers current knowledge and provides important insights at multiple scales across a range of disciplines, all of which contribute to the environmental impact of timber use: trees as a resource, wood cell biology and molecular structure, forestry and management practices, processing into products, modification for durability, design and engineering for full-scale applications, end-of-life considerations, and global use, trade and policies. Following this assessment, we also highlight directions for future research that will shape environmental outcomes for constructing with such natural materials.

2. Trees

2.1. Tree variation

The ability to become a "tree" has been acquired many times during the evolution of plants, and so there can be great variability between tree species. In our era, the most abundant tree forming groups are within the angiosperms (group of plants producing flowers and enclosed seeds), but almost all gymnosperms (plants producing uncovered seeds such as spruce, pine, fir) are also trees. Industrially, wood obtained from angiosperms (dicots, often deciduous broad-leaved, including oak, birch, beech, ash) is called hardwood, and that from gymnosperms, softwood (Fig. 1). Notably, this nomenclature does not necessarily reflect the actual wood properties; balsa (a hardwood) is much softer than average softwood.

2.2. Trees – the biggest organisms on earth

Different species grow at different rates. Examples of the fast growing trees are Trema micrantha, which is used for site amelioration of deforested land and can reach 20 m after seven years [1], Royal Empress Trees, eucalyptus (three m per year), and willow and poplar. The studies on the possible maximum height of trees consider various issues like hydraulic requirements [2,3] or limited leaf expansion and photosynthesis on the top of the tree [4]. Despite such constraints, the tallest living trees on Earth, Sequoia sempervirens, found in California Redwood National Park (Fig. 2), can reach well over 100 m, with the tallest measuring 115.7 m. The tallest tree ever reported was Eucalyptus regans in Australia, reaching at least 143 m. The biggest trees (by volume) are Sequoiadendron giganteum, with estimated trunk volume of nearly 1500 m^3. Trees of the same species grown in diverse conditions may grow very differently. The increase in girth of a tree grown in the open is twice as much as one grown in woodland. An average free-standing tree would add 2.5 cm per year to its girth, with fast trees (like giant sequoia, coastal redwood, Sitka spruce and Douglas fir) reaching 5–7.5 cm. Some trees, for example Scots pine, grow more slowly [5,6]. Matching optimised growth and usefulness of trees for construction is not an easy task. For example, the main tree grown for construction in the UK is Sitka spruce, an imported conifer from the Pacific Northwest of North America. It can reach 40–70 m height, but in the UK, where conditions are milder than its native

A B

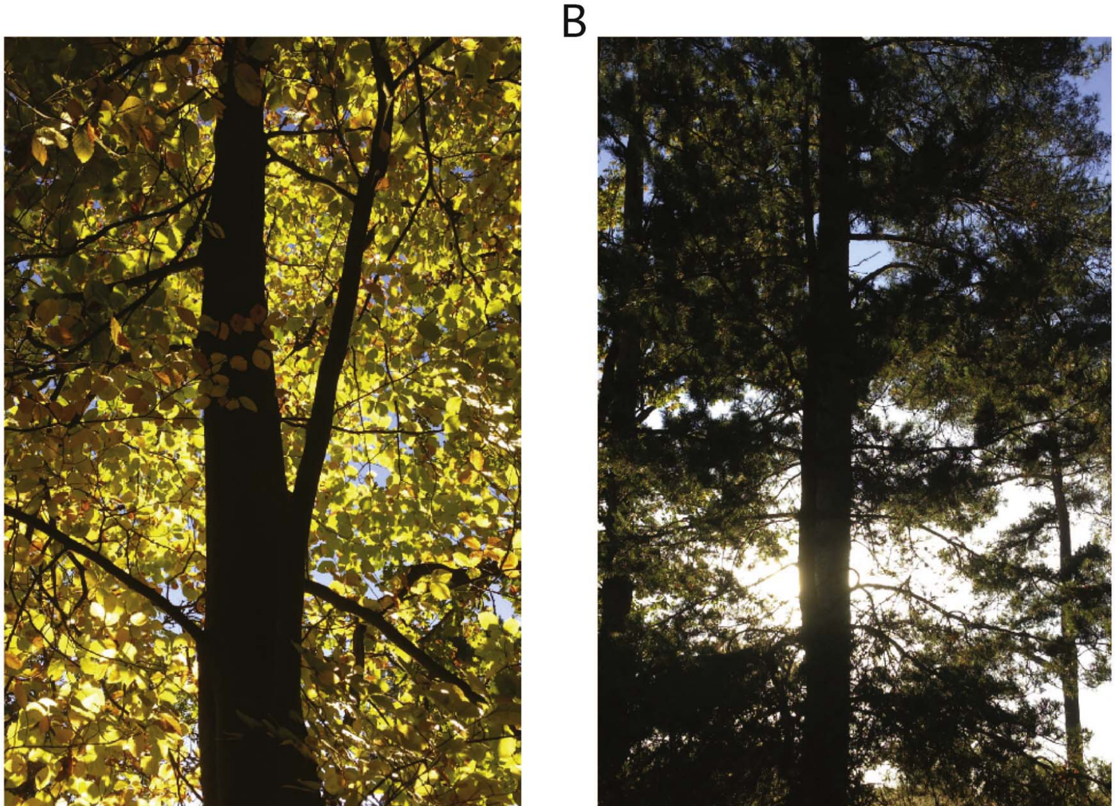

Fig. 1. Trees. (A) Beech, a hardwood. (B) Pine, a softwood.