TREE-FREE PAPER – WHEN IS IT GOOD FOR THE ENVIRONMENT?

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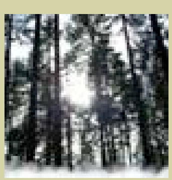

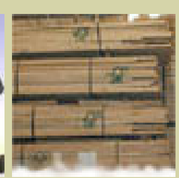
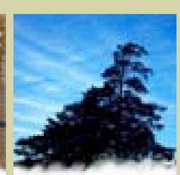

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Summary

From the earliest colonial times to the early part of the twentieth century, 2.1 acres of American forest were converted to agriculture for every person added to the population. Globally, conversion to agricultural uses is still the number one cause of deforestation today. Currently, both hemp and kenaf are being offered as alternatives to wood fiber in the manufacture of paper and similar products. Both of these materials are produced in mono-cultural, annual rotation, agricultural systems referred to as "dedicated crops." This paper explores the environmental issues surrounding the use of dedicated crops, in comparison to wood, as an industrial raw material. There are two key issues to consider with these materials: net productivity of the land and the direct environmental impacts associated with fiber production. Evidence suggests that the negative environmental impacts of commercial production of hemp and kenaf fiber can be greater than those attributed to the production of wood fiber. In addition, commercial production of these alternate materials potentially increases the land area required for agriculture, a need that is generally met by the conversion of forestland and other natural environments.

Introduction

It is technically possible to make high quality paper out of almost any kind of fiber. Although virtually all paper in the U.S., as well as most paper worldwide, is made of wood fiber, that has not always been the case. For example paper was invented in China in A.D. 105, but it was not until about 1850 that wood began to be used as a principal raw material for papermaking. Today, about 12 percent of paper worldwide is made of non-wood fiber, primarily wheat straw, bagasse (sugar cane residue) and bamboo.

In some circles, paper made of non-wood fiber is viewed as environmentally preferable to paper made of wood, largely because production of such paper does not require the harvesting of trees. This view is the basis for the emergence of "tree-free paper" in printing and writing paper markets.

But is tree-free paper really better from an environmental point of view than paper made of wood? It turns out that there are environmental impacts associated with the production of all papermaking raw materials and their subsequent conversion to paper. Systematic analyses of these impacts reveal that environmental impacts associated with production of non-wood fiber vary considerably depending upon the fiber source involved. In some cases, and especially where fiber can be obtained from food crop residues, the use of non-wood fiber is quite attractive from an environmental perspective. In other instances, and particularly those in which fiber is obtained from dedicated fiber crops, the environmental impacts can be quite substantial, and often greater than impacts linked to the periodic harvest of trees.

Agricultural Residues

Agricultural residues of interest as papermaking raw materials in North America today include the stalks (straw) of wheat, barley, oats and flax. In some regions that consistently produce high crop yields, straw is produced in quantities above that required for maintenance of soil productivity. In these regions, dealing with excess straw can represent a disposal problem, and development of alternative uses for straw is both economically and environmentally attractive. Several initiatives are underway in the U.S. and Canada to move toward paper production from straw. It appears that the most likely use of straw is as a supplement to wood pulp. *An in-depth examination of agricultural residues is the subject of the next report in this series.*

Dedicated Fiber Crops

- **Perceptions –** A current focus of the tree-free paper movement is on paper made of fiber from dedicated fiber crops – namely kenaf and hemp.[1] Such paper is sometimes aggressively promoted in environmental terms, with one current website proclaiming paper made of hemp to be "a hundred times better for the environment" than paper made of trees. Despite these claims, the production and harvest of dedicated crops tend to have the greatest environmental impact of all fiber production options.

- **Background –** During World War II the U.S. was cut off from jute fiber suppliers in Asia, triggering a massive effort to develop fast-growing alternative crops, including hemp, and kenaf as jute substitutes. The United States government supported the growing and use of hemp over a period of many decades primarily in Illinois, Iowa, Indiana, Wisconsin, Kentucky, and Minnesota. Kentucky and Wisconsin together accounted for approximately 60 to 70 percent of total U.S. hemp production by the late 1940s.

  In the mid-1950s, the U.S. Department of Agriculture set about to identify new, commercially viable crops to help expand and diversify markets for American farmers. The idea was to find new fiber crop species that contained major plant constituents different from those then available and to promote their potential for industrial use. After screening over 1200 fiber crops and subjecting 61 to extensive pulping tests, project scientists concluded that kenaf was the top candidate for further development. Over 15 years of intensive research on kenaf followed, with a focus on its use as a papermaking raw material. Despite this concerted effort that was largely terminated in 1978, commercial development did not occur.

  In the early 1990s interest in alternative crops re-emerged in the form of a new alternative crops initiative of USDA, as well as research on industrial hemp funded by at least four state governments. Although the new federal

[1] Both kenaf and hemp are fast growing annual herbaceous plants that produce stems characterized by a relatively thin outer layers (referred to as bark or bast), and wood-like cores. Kenaf, a native of east-central Africa, is not suited to cold climates, and can be grown only as far north as southern Illinois in the U.S. Midwest. Hemp, in contrast, thrives in colder climates and could be grown throughout the upper Midwest (if it were legal) and is grown in southern Canada.

effort is focused on potential energy and chemical crops, much of the state-funded research has been directed toward further investigation of the commercial potential of kenaf and of industrial hemp, the latter having been excluded from the earlier USDA alternative crops research. The primary impetus for all of these efforts appears to be the depressed farm economy throughout most of the U.S.

Investigation of industrial hemp has proceeded more slowly than of kenaf, in part because of the legal hazards and social stigma associated with marijuana, a different but closely related plant; in this case, most research and pilot studies are occurring in countries other than the United States, including Canada, France, and the Netherlands.

- **Growth rates –** When comparing the annual growth of kenaf and hemp crops to average growth rates of trees in natural forests the differences can be quite striking. The growth of both crops can be shown to be much faster than wood production, meaning that less land is required to produce a given amount of fiber. However, when the growth rates of kenaf and hemp are compared to annual growth rates in the best natural forest stands or in tree plantations the differences narrow considerably (Table 1). In comparison to tree plantations, hemp yields range from 30 percent lower to 50 percent higher, and kenaf yields are approximately 2.5 times higher.

Table 1
Yield of Dry Stalk (tons)/Acre/Year for Hemp, Kenaf, and Hardwood and Softwood Tree Plantations[1]

	U.S. Hemp[2]	Non-U.S. Hemp[3]	U.S. Kenaf[4]	U.S. Hardwoods[5]	U.S. Softwoods[5]	Non-U.S. Hardwoods[6]	Non-U.S. Softwoods[6]
Range	1.0-3.6	1.2-7.7	2.6-12.8	0.9-4.8	1.3-3.8	1.2-15.6	2.7-6.0
Average	2.2	3.8	6.3	2.6	2.5	6.8	4.8

[1] Total stalk yield for hemp and kenaf. For wood, yield includes only wood (xylem) contained in the bark-free main stem.
[2] U.S. hemp data based on 10 research reports published between 1935 and 1948.
[3] Non-U.S. hemp data based on 17 research reports from 10 countries, published between 1995 and 1999.
[4] U.S. kenaf data based on 8 research reports, focused on kenaf production in 11 states, published between 1969 and 1990.
[5] U.S. hardwood and softwood data based on 12 research reports focused on wood production in 10 states, published between 1983 and 1996.
[6] Non-U.S. hardwood and softwood data based on 5 research reports focused on wood production in 10 countries, published between 1976 and 1994.

Aside from growth rates, current promotion of both kenaf and hemp suggest that the growing of kenaf and hemp require few synthetic chemicals, if any, and no pesticides or herbicides. The fiber itself is said to be longer, to have a higher useful fiber content, and to make superior paper to that made from trees.

- **Production inputs –** Research results from around the world indicate that the kinds of kenaf and hemp yields as seen in Table 1 are not attainable without attention to a number of production factors, including soil moisture and fertility, competition from weeds, and problems posed by insects and disease. It appears that regardless of claims to the contrary, production of both kenaf and hemp require regular application of fertilizer and various chemicals, and sometimes irrigation, similar to other forms of high yield agriculture.

    - **Irrigation -** Both kenaf and hemp are prone to damage from dry soil conditions, suggesting the need for irrigation, or at least the capacity to irrigate, on kenaf and hemp producing fields.
    - **Use of fertilizer -** Both hemp and kenaf appear to require application of fertilizer to obtain optimum yields, with fertilizer needs at the time of planting generally at a rate consistent with wheat production.
    - **The use of insecticides and pesticides -** At least 88 species of fungi cause disease problems in hemp, the most damaging of which is gray mold that at high humidity levels and moderate temperatures can completely destroy a crop of hemp within one week. Root-infecting nematodes are also identified as a serious problem, and specifically in Canadian hemp; nematodes are also known to cause serious damage to crops of kenaf. In both cases, aggressive use of pesticides is recommended. Dr. John MacPartland of the University of Vermont recently summarized disease and insect problems in hemp with the observation that "Many current authors claim hemp is problem-free. None of these authors has ever cultivated a fiber crop. In reality, hemp is not pest-free, it is pest <u>tolerant</u>; many problems arise in *Cannabis*, but these problems rarely cause catastrophic damage. However, diseases and pests cause small losses that may accumulate over time to significant numbers." Referring to several studies documenting losses in hemp production, Dr. MacPartland points out that crop losses can reach 40 percent or more. He also notes "As long as *Cannabis* continues to be grown in artificial monoculture, we will continue to need pesticides." It is clear that MacPartland uses the term "pesticide" to refer to both fungicides and insecticides.

    - **The need for herbicides -** Several documented attempts to grow hemp without applying herbicides resulted in crop yields that were 25 to 40 percent lower than yields obtained in subsequent years in which herbicides were applied. One study of kenaf showed losses of 85 percent in the absence of weed control. A general consensus among scientists who have studied kenaf and hemp production is that use of herbicides is needed, especially early in the growing season.

- **Landscape impacts and energy use -** In addition to the need for regular application of fertilizer and other chemicals, a significant environmental disadvantage of any annual fiber crop as compared to tree plantations is the frequency of activity on the landscape. Consider, for example, a pine plantation that is grown to an age of 20 years before harvest. Site intervention would occur three to six times over the 20-year rotation (once or twice to prepare the site, once to plant, zero to two times to suppress competition, and once to harvest). Compare this with kenaf production as outlined by Scott and Taylor (1990): annual activities including chisel, disc, disc/herbicides/disc (2X), application of pre-plant fertilizer, bedding, seeding and planting, application of side-dressing, cultivation, and harvesting. Assuming this sequence of production steps, direct site impacts would occur several hundred times over a 20-year time span; this number could easily be as high as 300. This reality not only dramatically increases fuel requirements, but also greatly increases the risk of such things as soil erosion and impacts on water quality.

- **Other environmental factors -** Concerns often expressed about the use of wood from tree plantations for papermaking are that the trees are sometimes exotics, are often planted in monocultures, that such plantations support limited diversity of other flora and fauna, and that they are harvested by clear cutting. All of these concerns apply to production of kenaf and hemp.

- **Raw Material Characteristics –** Reports indicating that hemp has longer and higher yielding fibers than wood are based on characteristics of the outer or bast fibers of the stem. These fibers are 4 to 10 times longer than those of wood and have substantially higher cellulose and lower lignin contents. Outer fibers of kenaf are much longer than core fibers, but about the same length as wood fiber, and again have a higher cellulose and lower lignin content. That’s the good news. The bad news is that the bast fibers of both kenaf and hemp comprise only about 30 percent of the stalk. The other 70 percent is made up of fibers that are about one-fifth the length of wood fiber and that have similar lignin and lower cellulose content. Thus, glowing reports of kenaf and hemp properties ignore the properties of two-thirds of the raw material produced.

  Fiber length and chemical content issues aside, it is possible to make high quality papers out of both hemp and kenaf and out of both the outer and core fractions of the stems. The superior properties of the outer fibers make them useful for a wider variety of products. While there are processes that allow separation of stalks into the outer and inner regions, many feel that the viability of kenaf and hemp as papermaking materials depends, in part, on the technical feasibility of using both bast and core fibers, rather than simply one or the other. Presently there is little use of core fiber, even in countries aggressively pursuing production of non-wood paper. In France, for example, both the government and a large commercial producer of hemp paper are seeking alternative markets for core hemp core fiber, selling such material for such uses as pet litter and particleboard manufacture. The fact that hemp core is being sold into relatively low value markets suggests lack of success in attaining commercial adoption of higher value applications such as papermaking fiber.

The Bottom Line

High quality paper can be made from agricultural fiber crops such as hemp and kenaf, and from crop residues of wheat or other cereal grains. In some cases, and particularly those involving crop residues, there are environmental advantages of non-wood paper. However, there are substantial environmental costs of producing dedicated fiber crops that must be considered when comparing paper made from these vs. traditionally used wood fibers. When all environmental impacts are considered, it is debatable whether tree-free paper made of dedicated crops such as kenaf and hemp is environmentally better than paper made of wood.

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