Paper in Fire: Material Intensity in Paper Use

When cardboard and paperboard are included, packaging and shipping constitute around half of paper use[93], which packaging reductions discussed in the section immediately prior to this one can reduce by 75%-80%.

Another 12.5% is used for newsprint[93]- mostly to be read once, and then thrown away. The major potential for reducing newsprint size lies in reading daily newspapers on screens rather than on printed pages. This does not refer to current fuzzy monitors, not even LCD types. Comparatively new technology exists that allows electronic printing onto extremely thin laminates at resolutions better than that of newsprint. This is no longer experimental. Sony now sells the 160 dpi Librie EBR-1000EP e-reader - whose six inch screen has (as promised) a better resolution than a newspaper[94]. I don't expect the Librie to prove a great success. On initial release, it accepted documents only in a proprietary format[i]. The controls are unresponsive. And, as befits a bleeding edge product, it is expensive - over $400 for a machine with computing power exceeded by some calculators.

But none of this is inherent in the technology. According to Reuters, the cost of the screen itself is in the "tens of dollars"[95]. So there is no reason a decent e-ink reader about the size and weight of a thick trade paperback could not sell for $120 dollars or under, probably less than the cost of printing a typical U.S. daily newspaper for two years[96]. It would have no keyboard, only the minimum controls for navigating documents; the screen would be easier to read than most paper pages.

What about the manufacturing and operating impacts of such readers? E-book readers normally use much smaller screens than desktop LCD monitors. Smaller sizes are more convenient, and higher resolution screens don't need to be as big. And even for a given size, e-ink type screens have about a third less impact than LCD monitors[97]. Similarly, in operation e-ink readers use drastically less energy even than a typical PDA. Energy to download and read is probably around a tenth that required to make and deliver the paper to the printer, print the paper, then distribute and deliver it to the reader. And you don't need the fastest chips or memory for this purpose[ii]. While reading on a full size desktop with a CRT has a similar impact to a paper periodical, an e-ink style reader has between a tenth and quarter of the impact of real paper – even allowing for the "clipping" of articles, ads and coupons by printing. There is no reason e-ink could not eventually completely replace printed newspapers. It is absurd to use enormous amounts of material to produce newspapers which are almost never completely read, mostly read only once, and then discarded the next day. And with a properly designed newsreader, there is no reason there should be any loss of convenience.

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[i] Remember Sony is the same company whose marketing geniuses chose to keep the superior Betamax format proprietary - which is why the technically inferior VHS was the standard video format until DVD replaced it

[ii] Because screen refreshes really are done by printing to the screen, they take a noticeable fraction of a second. So fast chips and memory would not be useful in any case; they would still run into a screen refresh bottleneck. That is also why this technology is only useful in niche applications such as e-readers. The screen refresh rate is too low for normal computing.

There are plenty of other publications the same reasoning applies to. Many popular periodicals are read a limited number of times and then discarded. So is a great deal of popular fiction. And even a lot of periodicals or papers that are kept over the long run and intensively studied don't need to be written in. E-ink, at its current stage of development, can be used to created inexpensive readers, suitable for any publication or document that does not need significant markup. There is no reason this should not apply to at least 80% of books and periodicals. So a three quarters intensity reduction in 80% of published work is a 60% reduction.

Office paper (including home offices) is another major portion of use. (Remember that along with magazines and books it constitutes about 30% of the total.) There are fairly low tech means that can cut paper use in offices by 60%-90%. These include:

1) Replace all non-duplex printers as they wear out with duplex ones - then instituting a policy of using both sides of all paper when practical.
2) Keep a reuse bin, and use the back side of paper printed on only one side for in-house work.
3) Making minor correction on in-house work and preliminary drafts in pen without reprinting the document.
4) Don't print e-mail and other electronic documents unnecessarily.
5) Make a practice of reducing margins for in-house work,

For example British Petroleum's Melbourne office reduced paper use 61% by these methods[98]. One office of Innovative Management Solutions, a Canadian environmental company operating out of Ottawa managed to reduce paper consumption by 84% in a seven month pilot program[99].

There are also some high tech ways to reduce paper use. An old idea from decades ago has justifiably fallen into disrepute – the hypothesis that computers and electronics would eliminate the need for paper. In point of fact, by making more documents accessible for easy printing, information technology has increased paper use. Abigail J. Sellen and Richard Harper's wrote an entire book about this - "The Myth of the Paperless Office" [100].

There are several ways in which electronic documents are inferior to paper - print resolution, readability, and multi-document interfaces. Paper has higher resolution than normal screens, better portability, and is easier to position. Multiple paper documents on a desktop handle more simply than multiple electronic documents on a screen. Paper is easier to mark than electronic documents of any sort. Compare the use of a red pen to using Microsoft's Word's "Track Changes" feature.

But this does not mean electronic storage does not have strengths too. If you don't already know exactly where your information is, it is a whole lot faster and easier to search properly indexed electronic files than thumb through paper archives. Similarly, electronics can store large amounts of information more easily than paper. A red pen may be convenient for one person to make simple changes - but electronic change tracking systems make collaborations among many people easier than paper. This is especially true if some are in remote locations.

By working with the strengths of electronic storage, while not trying to make it replace paper for the things paper does well, you can create an office that is not paper-less, but uses less paper.

O'Driscoll O'Neill , a Dublin a major Irish insurance brokerage operating out of Dublin, switched from a paper to an electronic document management and paper handling system in January of 2003[101]. I can't find information on the exact amount of paper reduction, but paper files have been reduced in number by at least 90%, and file clerks eliminated, along with 1,200 square feet of file rooms. Mail is processed faster than in the old system, and all documents are available electronically from any desk with appropriate security authorization. Because of this, people are spending 60% more time at their desks. "Lost documents" have been almost eliminated. As is normal in such system the gains in productivity and customer service are the main point, paper savings being a minor secondary effect.

KAF financial group, an accounting and consulting company reduced paper by 75% - again as a side effect of productivity increases[102]. The same article discusses even larger gains Nevada County in California made by automating its system, and essentially putting all public documents on line.

It seems like a combination of "less paper" technology, common sense paper saving techniques, ought to easily save 75% - 90% of paper used in offices. The cost for common sense techniques is low enough to more than pay for itself in paper saved. Electronic document interfaces are normally installed to produce productivity gains; paper saved is a side effect. The cost is better than free – a side effect of something that is already producing a net gain.

Another "business use" of paper is junk mail - unsolicited advertisements. It is often argued that these "subsidize" the U.S. postal service - paying for first class mail. Even if true, such subsides are not really free. Obviously these, like all advertising and public relation costs, are incorporated into the price of products sold. If junk mail was eliminated or reduced the U.S. postal service could be subsidized in some other way. But the claim that this is a subsidy depends upon how post office accounting procedures match costs and revenues. It is at least possible that first class customers are paying a bit more than their fair share, and influential large mailers a bit less.

We won't discuss the 6.5% of paper used for tissues - paper towels, Kleenex, napkins and such, assuming no substantial saving there.

So, adding it all up in the table below we end up reducing intensity by over 68% and paper tonnage by a bit under 75%.

Paper Use Category	**% Use**	**Reduction in Intensity**	**Net Reduction**	**Reduction in Paper**	**Net Reduction in Paper**
Paperboard and cardboard	45.3%	75.0%	34.0%	75.0%	34.0%
Packaging	5.4%	75.0%	4.1%	75.0%	4.1%
Printing,home+office paper,books, magazines -30.3%					
Home + Office printing - copiers, laser, inkjet etc.	15.2%	80.0%	12.1%	80.0%	12.1%
Books + magazines	15.2%	60.0%	9.1%	80.0%	12.1%
Newsprint for Newspapers	12.5%	75.0%	9.4%	100.0%	12.5%
Tissues etc.	6.5%	0.0%	0.0%	0.0%	0.0%
Total			**68.6%**		**74.8%**

What about the 25% of paper we would continue to use (while still producing 32% of the environmental damage due to impact of additional electronics)? The first step would be to reduce the intensity of fiber grown for raw material.

Making paper from dead trees is comparatively recent in history. The ancient world produced it by boiling and hand pulping harvested fibers. Only in the 19th century was industrial technology strong enough to be able to make pulp from wood fibers. Only in the 20th century did wood become paper's main ingredient.

There are, however, crops that can provide fiber every bit as good or better. In the U.S., it looks like the best for this purpose is kenaf.

Kenaf is part of the hibiscus family, related to cotton and okra. As you would guess from that family tree, it needs plenty of moisture, and grows best with plenty of light - in short is best suited to the Southern parts of the U.S. It can be grown in dry sunny climates like New Mexico as well - with plenty of irrigation, which I think is a bad idea for the same reason as growing cotton in Arizona.

Before proceeding with this analysis let's deal with an objection emphasized by the timber industry, but raised by many environmentalists as well. Granted that timber farming is not particularly ecologically sound, isn't replacing timberland with cropland a further degradation? If that was what we would be doing, they might have a point. But it does not particularly make sense to grown kenaf and fiber crops on land currently devoted to forestry. Kenaf requires only four to five months from planting to harvest[103]; devoting any parcel of land entirely to it would cost farmers money. Both ecologically, and economically it makes the most sense to include it as part of a rotation with other crops on existing farmland.

Now this doesn't mean we don't lower the yield of other cultivars; adding a fiber crop to a rotation does reduce total food produced on average per acre per year. Not every piece of land used to grow food will convert to a kenaf rotation, of course. Still we are going to have to increase the total acreage of land under cultivation to accommodate the kenaf[i].

A significant amount of cropland held out of production is in economic reserve or as a part of a soil erosion program – without being used for wildlife preservation or converted to non-farm uses.

Converting some of this to no-till rotational agriculture could increase total acres under cultivation - while (as we have already shown) building the soil[ii]; cropping this acreage by such means would help rather than harm the environment.

Further, shifting some production from timber to agriculture could help provide more income to farmers – contributing toward reducing the single greatest threat to long term food production - loss of agricultural land.

Intensive industrially farmed kenaf production uses about one half the water that intensive production short rotation timber does[104], erodes soil at about half the rate, uses about a third less fertilizer, and slightly few pesticides and herbicides, and produces about three times the fiber per acre once credit is given for soybean production in rotation on the same land.

Kenaf could also be produced more sustainably via a system similar to "the old rotation", the longest running experiment in rotational agriculture in U.S. (run by Auburn University College of Agriculture), which began in the late 19th century[105]. The old rotation grows cotton (no nitrogen), crimson clover or hairy vetch as green manure (no nitrogen), corn (no nitrogen), rye as cover crop (60 pound nitrogen), soybeans (no nitrogen) in a three year rotation. Given that Kenaf can mature from planting to harvest in two months shorter time than cotton, you could probably get the same effect with a two year rotation, alternating between soybean/corn, and kenaf/corn and putting in clover or vetch every year. The annual use of a leguminous green manure would eliminate the need for nitrogen fertilizer. The variety of crops and crop types would allow farmer to use true no-till farming, as the old rotation does for cotton[106].

[i] Just a reminder - this is a long run problem. In the short run we grow more food than the world needs. World hunger is entirely due to injustice and stupidity. There is no food shortage.

[ii] Other conservation tillage alternatives can do this to some extent too. But any level of plowing disrupts glomalin completely; soil without glomalin will never hold together as well, or be as fertile, or as good a carbon sink as untilled land.

Kenaf farmed in a modified "old rotation" system would consume about one fifth the water, fertilizer, and land area of long rotation tree farms (where trees grow 45-75 years before being clear cut), and build soil instead of eroding it, and need fewer herbicides and pesticides as well. Because we are doing no-till with green manure we are building soil at the fastest rate possible - and offering the greatest carbon sink harvested plants are capable of. We are going beyond carbon neutrality to do a very small amount of greenhouse gas mitigation.

The superiority of kenaf to timber is even greater than a comparison to timber farms alone would suggest. More than half of new (as opposed to recycled source) pulp comes from clear cut natural second growth timber[107]; an additional ~15% is logged from natural old growth forest.

408 Million acres are classified as timberlands, not including any lands removed from production, in the U.S[108]. Around 29% of this is used to produce paper[109], so 118 million acres are currently devoted to paper. If we institute a 74.75% paper reduction, then around 30 million acres will still be needed for that purpose with conventional timber harvesting. Population growth will increase that to ~44 million acres by 2050. Kenaf tends to range from 3 times more production per acre (comparing most intense to most intense) to 7 times more production per acre (comparing longest pulp-farm rotations to lowest impact form of kenaf rotation). Halfway between those two would be five, to be conservative, let us model kenaf as producing 4 times as much per acre. (Remember this gives credit for the fact that kenaf rotates with food, and thus does not use 100% of the capacity of the land.) We would need 7.5 million acres of kenaf to replace wood pulp for paper with today's U.S. population, and a bit over 11 million to replace timber needed to serve reduced paper needs by the projected U.S. population of 2050. In 2002 57 million acres of cropland was idled according to the 2002 U.S. Department of Agriculture's Natural Resource Inventory[110]. Even given that much of this would be wildlife reserve land, or otherwise not suited for cropping, there should still be a lot more than 11 million acres we can use. Most of it would probably not be good land for kenaf. But more than 11 million acres would be suitable for some type of food, to replace the food production kenaf would displace when put into rotation with existing food crops.

Obviously, not one acre of timber farm has to be converted to kenaf farm to grow kenaf for paper. But let's confront for a moment the worst nightmare the timber industry uses to scare us from considering kenaf - that timber land would be directly converted to kenaf production. Currently 118 million acres of land is used to grow timber for paper. Suppose we gradually replaced 11 million acres of that with kenaf farms, as it was harvested for pulpwood anyway, then moved the rest out of production into wildlife preserves. That is still many times better than what we are doing now. As will be seen in later sections, we probably will have to do something on these lines – not to produce paper, but for energy farms.

Why not used waste straw, and other fiber waste - rather than cultivating crops on purpose for paper production? There are two reasons. One is that straw is a great building material. As previously pointed out it makes a board superior to particle board, and it can be directly used in home construction. Paper is rather a waste for it - especially since kenaf makes a much higher quality paper than straw. Most fiber waste is high in silica - making it more difficult to recycle than paper pulp. Kenaf in contrast is low silica, but has sturdier fiber that can be recycled more often. Kenaf is actually more recyclable than wood pulp as a paper ingredient. And the silica in straw is a plus for building applications - strawboard and such. Incidentally there are similar reasons for not using hemp for paper. The extremely high quality fiber in hemp is more difficult to process than kenaf into paper, and has more important uses. Hemp bast can replace a great deal of cotton; hemp hurd can produce a plaster substitute for building facings.

Now obviously we should not be wedded to agricultural fibers for paper. If the timber industry wants to propose a wood pulp source that has even less environmental impact than kenaf - more power to their elbows. But that certainly does not include anything they are doing now.

Kenaf based paper currently costs about double that of wood pulp based. Even if that remains the price, with a 75% reduction in use at a cost of "better than free" we would end up spending a lower portion of our GDP on paper than we do now. Thomas A. Rymsza, the founder and President of Vision Paper (a kenaf based paper manufacturer) claims that if can get the capital to open a pulp mill suitable to processing kenaf, the cost will be 20% lower than conventional paper[111]. Of course Rymsza is a successful entrepreneur, and therefore an optimist by definition. The case he makes is plausible, but that is part of the definition too.

Raising and harvesting fiber is only one part of the impact paper has. Just as, or probably far more, important is the conversion of fiber to pulp and pulp to paper.

Probably the single most significant part of the process in terms of environmental impact is manufacturing. A dedicated kenaf mill would provide a bit of a head start in this respect. It would use 15% less water, 25% less energy, and be totally chlorine and sulfur free. But the best of breed commercially successful pulping mills can do much better. According to the World Watch institute, the most efficient technology produces 80% less effluent than the least efficient[112]. In the same report, one mill using 100% recycled input managed to produce zero effluent of any type, and use 98% of the fiber input. They also noted that mills using the environmentally soundest technology tend to be the most profitable - since they make more efficient use of labor, and also depreciate their equipment more slowly. Not exposing your equipment to highly volatile toxins lengthens its lifespan - something it also does for the plant's workers, and the local community.

The European Commission's Integrated Pollution Prevention and Control produced an extremely detailed report on this in December of 2002[113].

Techniques recommended in this document include:

1) better training of workers, and better maintenance of equipment,
2) large enough equipment and buffer areas to minimize spills, and to capture them when they occur,
3) mills that use trees as input should debark them by dry methods to avoid wet processing of bark
4) Where bleach process are used, delignification before bleaching by extended or modified cooking and additional oxygenation, followed by chlorine free bleaching or elemental chlorine free bleaching
5) Highly efficient closed cycle brown stock for Kraft and Sulphite mills.
6) Effective spill monitoring and containment.
7) Closed water cycles where possible, water reuse, and recycling where not.
8) Counter current washing (water from cleanest process used as wash water for the next cleanest, and so on).
9) Separation of various water cycles to avoid contaminating one another.
10) Primary and biological treatment of wastewater, sometimes followed by flocculation or chemical treatment, and sometimes followed by recycling of treated wastewater.
11) Efficient processes for mechanical mills that spot potential rejects before processing
12) Avoidance of production of excessive emissions to air through precise monitoring, temperature oxygen and chemical controls,
13) Filtering, scrubbing, recovery, and in some cases incineration of noxious gases.

The next major impact is end of life. Currently around half of all paper in the U.S. is collected for recovery[114]. The Germans manage to collect around 70%[115] of their consumption for the same purpose. There is no reason the U.S. should not match that. Given reduced paper use, and thus easier management of paper burdens, we should be able to exceed it and reach an 80% or better collection rate. Also, with the use of kenaf, the longer fibers may be recycled more times than wood. So we get a higher percent of usable fiber from recycling kenaf than we do with recycling paper based pulp. The two combined mean we can reduce end of life impact by around three times. And, of course, increased recycling reduces the amount of kenaf we have to grow, and makes it slightly easier to run lower impact mills. But note that of all the steps we as a society can take to reduce paper impact, recycling (though significant) is the **least** important.

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So what are we looking at in total impact? We can reduce paper consumption by around 75%, lowering impact by about 68%. We can reduce the impact of growing the remainder by about 80%, and manufacturing it by a similar amount. Growing and harvesting fiber for paper, and manufacturing it are overwhelmingly where paper impact lies. At the end of life, through increased recycling, and the ability to recycle fibers more times, we can reduce end-of-life impact by around another two to three times. This totals better than 80% - a factor five reduction+[i] - at rough estimate leading to a 60% or better reduction in energy use for paper manufacturing.

[i] Let us underestimate growing, harvesting fiber and manufacturing paper as jointly accounting for half of paper's impact. Use reduction saves ~75% of paper use (though only ~69% of impact). So if we were able

End Notes

[93]Figures for 1999, but without packaging, and with a total for 1998(not 1999) that excludes building paper: Peter J. Ince and Irene Durbak, "Pulpwood Supply and Demand: Development in the South, Little Growth Elsewhere,". *Journal of Forestry* 100, no. 2 1/Mar 2002, Society of American Foresters, 18/Sep/2005 <http://www.fpl.fs.fed.us/documnts/pdf2002/ince02b.pdf>.pp20-21.

Totals for 1998 and 1999 paperboard – which is the bulk of paper products not including building paper. James L. Howard, U.S. Timber Production, Trade, Consumption, and Price Statistics 1965-1999, FPL-RP-595. April 2001. United States Department of Agriculture Forest Service Forest Products Laboratory, 18/Sep/2005 <http://www.fpl.fs.fed.us/documnts/fplrp/fplrp595.pdf>.p71.
Table 45—Paperboard production, imports, exports, and consumption, 1965–1999

Using the growth consumption between 1998 and 1999 from the above I was able to take the 1998 total from the first source and estimate the 1999 total consumption. Given 1999 total consumption and every other category, 1999 packaging may then be calculated by subtraction.

[94]Mark J Lytle, "Library Without Books,". *The Guardian (Guardian Unlimited)* 22/Apr 2004, 11/Jun/2004 < http://www.guardian.co.uk/online/story/0,3605,1197495,00.html>.

[95]Reuters, *Let's Make Reading Better!* 9/Feb 2004, IT supplement of The Tribune, The Tribune of India, 20/Sep/2005 <http://www.tribuneindia.com/2004/20040209/login/main3.htm>.

[96]Advertising accounts for around 65% of daily revenues, circulation for 35%, while newsprint accounts for about one third of total costs. Allowing for profit (so that one third of revenues does not equal one third of costs), this means printing a typical daily U.S. newspaper costs well over half, and perhaps as much as 90% of the subscription price.

"Newspaper," *Microsoft® Encarta® Online Encyclopedia.* 2004, 11/Jun/2004 < http://encarta.msn.com/text_761564853___62/Newspaper.html>.

[97]Lyad Atuan et al., *Life-Cycle Assessment of Desktop Computer Display*. Mar 2004. *None - Term Project in Masters Level Class*, 6/Jun/2004 <http://s93889521.onlinehome.us/docs/mie415.pdf>.

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to eliminate 100% of remaining paper consumption at zero cost or environmental impact that would still leave ~6% of intensity that could not be eliminated. That leaves ~25% of paper whose manufacturing we can impact, with maximum arithmetically possible savings of 19%.

We can eliminate 80% growing, harvesting and manufacturing impacts of production of this remaining ~25%, and reduce end-of-life impact by 2/3rds. Since end-of-life is where the least savings are possible, we will be conservative and assume it represents half of total environmental costs. So, by these conservative and in fact extremely pessimistic assumptions:

Net Paper Reduction	74.8%
Net Reduction in Intensity	68.6%
Intensity that cannot be eliminate, due to environmental costs of use reduction	6.2%
Maximum Arithmetically possible remaining reduction	19.1%
Allocate 50/50 between growth/harvest/manufacture and end-of-life	50.0%
savings in growth, harvest and manufacturing	80.0%
savings in end of life	66.7%
net savings growth, harvest and manufacturing	7.6%
net savings end of life	6.4%
net savings in paper cycle (as opposed to use reduction)	14.0%
Intensity reduction from use reduction and savings in paper cycle combined	82.6%

(Please note that this is only student project in a masters program. However it tracks quite closely to the EPA result for CRT and LED monitors, using differing sources. So it is not an unreasonable source for the saving for e-ink – especially since we are not talking about a big difference in any case.)

[98] 2002 paper consumption was 21.4 kg per person
Clare Walker, *Melbourne Central Green Office 2002 Performance Report.* Jul 2003. *BP Australia,* 11/Jun/2004 <http://www.bp.com.au/environmental_social/green_office_2002_report.pdf>.p6.

According to the 2001 report, the 1997 bench was 55 kg per person. So that was indeed a 61% reduction. Also there were layoffs and hours per person increased - so this may understate the saving.
Kerryn Schrank, *Melbourne Central Green Office 2001 Performance Report*. Aug 2002. *BP Australia*, 11/Jun/2004 <http://www.bp.com.au/environmental_social/green_office_2001_report.pdf>.p4.

[99]Brad Wallace, "Paper Reduction Program Saves Money And The Environment," *Knowledge Bank Articles*, 28/Sep 2004, Innovative Management Systems, 20/Sep/2004 <http://www.solutions.ca/Knowledge_Bank/Articles/article.asp?doc_id=158>.

[100]Abigail J. Sellen and Richard Harper, *The Myth of the Paperless Office* (Cambridge MA USA: MIT Press, 2001).

[101]David Stewart, "Ensuring Effective Insurance Thanks to Paperless Office,". *SiliconRepublic.Com - Ireland's Technology News Service* 19/Apr 2004*Case Studies*, Silcon Republic - Dublin, 11/Jun/2004 <http://www.siliconrepublic.com/news/news.nv?uid=lipowg&sid=C5mmenoD&storyid=single3087>.

[102] Mike Martin, "Paperless Office: Case Studies Show How and Why,". *Computer Bits* 14, no. 1 Jan 2004, Bitwise Productions Portland Oregon, 14/Jun/2004 < http://www.computerbits.com/archive/2004/0100/paperless.html (if no longer good cache at: http://66.102.7.104/search?q=cache:IrULwCmYYXYJ:www.computerbits.com/archive/2004/0100/paperless.html)>.

[103] KP Products, *About The Kenaf Plant*. 14/Jan 2005, KP Products, 20/Sep/2005 < http://www.visionpaper.com/kenaf2.html>.

[104]Jame A. Rydelius, *Growing Eucalyptus for Pulp and Energy. Mechanization in Short Rotation, Intensive Culture Forestry Conference, Mobile, AL, March 1-3, 1994*. Mar 1994, Short Rotation Woody Crops Operations Working Group (Established by DOE ORNL, USDA and EPRI), 14/Jun/2004 < http://www.woodycrops.org/mechconf/rydeliu.html>.

[105] Gene Stevenson, *90 Years' Results Say Yes to Winter Legumes, Crop Rotations*. 9/Feb 1989, College of Agriculture: Auburn University Alabama Agricultural Experiment Station, 15/Jun/2004 < http://www.ag.auburn.edu/aaes/webpress/1989/rotations.htm>.

[106]Charles Mitchell, Wayne Reeves, and Dennis Delany, "Breaking Records: Sensible Management Helps Alabama's Long Term Experiments Net Record Yields,". *Online Highlights: A Magazine of Research from the Alabama Agricultural Research Station at Auburn University* 48, no. 3 Fall 2001, College of Agriculture: Auburn University Alabama Agricultural Experiment Station, 15/Jun/2004 < http://www.ag.auburn.edu/aaes/communications/highlightsonline/fall01/fall-mitchell.html>.

[107] Jane N. Abramovitz and Ashley T. Mattoon, *Paper Cuts:: Recovering the Paper Landscape*, ed. Jane A. Peterson, WorldWatch Paper 149. Dec 1999. *Worldwatch Institute*, 16/Jun/2004 <http://www.worldwatch.org/pubs/download/EWP149/>.p21.
Figure 5

[108]David R. Darr, *U.S. Forest Resources*. 28/Sep 2000, U.S. Forest Service, 15/Jun/2004 <http://biology.usgs.gov/s+t/noframe/m1103.htm>.

[109] Jim Motavalli, "Beyond Wood | Tree-Free and Chlorine-Free Papers Offer Sound Alternatives to Forest Destruction,". *E, The Environmental Magazine* IX, no. 1 Jan-Feb 1998, Earth Action Network, Inc., 1/Oct/2005 <http://www.emagazine.com/view/?41>.

[110]U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS);Iowa State University's Center for Survey Statistics and Methodology, *2002 Annual Natural Resources Inventory: Land Use.* April 2004. *U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS);Iowa State University's Center for Survey Statistics and Methodology*, 15/Jun/2004 <http://www.nrcs.usda.gov/technical/land/nri02/landuse.pdf>.p2.

[111]Thomas A. Rymsza, "Firm Profile: Vision Paper,". *Journal of Industrial Ecology* 7, no. 3-4 May 2004, Massachusetts Institute of Technology and Yale University, 16/Jun/2004 <http://www.visionpaper.com/speeches_papers/jiec_7_3-4_215_0.pdf>.p217.

[112] Ibid 107 p49.

[113]European Commission, *Integrated Pollution Prevention and Control (IPPC) Reference Document on Best Available Techniques in the Pulp and Paper Industry.* Dec 2001. *European Commission*, 20/Sep/2005 <ftp://ftp.jrc.es/pub/eippcb/doc/ppm_bref_1201.pdf>.

[114]"In 2003 the U.S. paper recovery rate achieved an all-time high of 50.3%. Paper recovery has increased steadily from 33.5% in 1990, to its present level of 50.3%." (Note that not all of the 50.3% recovered can be used. So, the actual recycling rate is less than 50%.)

American Forest and Paper Association, "Recycling," *Environment and Recycling*, 2005, American Forest and Paper Association, 21/Jun/2005 <http://www.afandpa.org/Content/NavigationMenu/Environment_and_Recycling/Recycling/Recycling.htm>.

[115]European Recovered Paper Council;Confederation of European Paper Industries, *The European Declaration on Paper Recovery Annual Report 2000.* 14/Sep 2001, European Recovered Paper Council;Confederation of European Paper Industries, 21/Jun/2005 <http://www.paperrecovery.org/files/ERPC%20AR%202000_2.pdf>.p17.

Table 2-2 - CEPI – European Paper and Board and Recovered Statistic by Country in 2000 – 1000 tonnes