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Contents

Abstract

This paper analyzes the current wood supply estimates for North America. The result of the analysis casts doubts whether the North American supplies are sustainable. It is obvious that current estimates do not consider many of the aspects of sustainable forest management but are based on a concept of the availability of timber. It can be concluded that there is a lack of consistent national projections in both the USA and Canada. The North American analyses do not take into account that the wood supply issue is driven by the political economy and not only by the market economy. North America has a lot to gain if future analyses of the supply would be carried out based on a political economic concept.

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How Sustainable Are North American Wood Supplies?

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1. Background

The issue of a sustainable supply of industrial wood has been investigated on several occasions (e.g., Nilsson 1996, WRI 1997, 1998, Duinker *et al*. 1998). In these previous studies, there were difficulties matching North American estimates. We think that some estimates of the United States of America (USA) and Canadian industrial roundwood supply are overestimated based on the lack of considering the impact of sustainable forest management and by the use of different assumptions. Perhaps the major concern is that the current analyses of future wood supplies are driven by either price (Haynes *et al*. 1995) or issues (Cubbage *et al*. 1996a, Apsey and Reed 1995). This difference in assumptions causes problems when comparing potential outcomes and when trying to get a complete and consistent picture of the future wood supply. In addition, most analyses do not take into account the fact that wood supply during the 1990s has not been driven by the *market economy* but by the *political economy*. With political economy we mean "the ways in which various sorts of government affect the allocation of scarce resources in society through their laws and politics as well as the ways in which the nature of the economic system and the behavior of people acting on their economic interests affects the form of government and the kinds of laws and politics that get made" (Johnson 1996). There is probably no shortage of wood from a market economic point of view, but the *political economy* puts serious constraints on the availability of the identified supply based on a pure market economic approach (Nilsson 1996). The objective of this paper is to illustrate our concerns and draw some conclusions leading to more realistic forecasts.

2. Official Industrial Wood Supply Estimates

In order to discuss wood supply estimates, there is a need to define what we mean with wood supply. One basic approach is the "sustainable wood supply". In this case the supply is defined as the sustainable yield (net annual growth or annual allowable cut) on productive, closed non-reserved forests (e.g., WRI 1997). But to sort out a more realistic future, the impact of government policies on forest utilization, developing utilization technologies, landowner attitudes, land use, environmental constraints, etc.

on sustainable wood supply has to be considered. This measure is what can be realistically expected to happen, given the multiple policy constraints in vogue and technical constraints (Apsey and Reed 1995). This supply is called “cut potential” (e.g., Jaakko Pöyry 1994), “timber availability” (e.g., Apsey and Reed 1995) or “probable wood supply” (e.g., WRI, 1997). The probable supply is substantially lower than the sustainable wood supply. In the following text we use the term “probable wood supply”. The third level of supply is the “economic wood supply” taking the market economy into account and “economic supply” is defined as supply equals the demand. Normally the “economic supply” is lower than the “probable supply” because the element of cost has been explicitly introduced and compared with prices. In some regions significant amounts of probable supply are not affordable given the assumptions on price trends and real increase in marginal logging costs.

2.1 Official Industrial Wood Supply Estimates — USA

Haynes *et al*. (1995), published by the USDA Forest Service, throughout this paper is considered the official wood supply estimate for the USA. The most recently published information on official projected roundwood harvests (total harvests including industrial wood and fuel wood) for the USA is an “economic supply” and estimates that the level of harvesting will increase from 509.4 million m^3 in 1990 to 716 million m^3 by the year 2040 (*Table 1*). This represents an increase of 41 percent over the 50 year time span, reflecting that a substantial increase in harvest levels in the USA is expected. The volumes presented in *Table 1* are based on estimates for timberland only. Timberland is forest land with at least 10 percent stocking of trees that is considered available for harvest.

In addition to these timberland estimates, harvesting occurs on nonforest lands with trees. Nonforest lands with trees are lands that have trees present but with non-forest dominant land uses (rangelands with trees and urban lands are some examples). In 1992, harvesting from nonforest lands with trees constituted 43 million m^3. The estimated harvest levels presented in *Table 1* do not differentiate between harvests for industrial wood and those for fuelwood. We adjusted the estimate so that it is valid for industrial wood only by deducting the estimated fuelwood harvest (Haynes *et al*. 1995) for each projected period. The estimate on industrial roundwood harvests after this calculation is presented in *Table 2*.

Table 1. Projections of total roundwood harvests on timberland in the United States between 2000 and 2040 (Haynes *et al*., 1995).

	Year of Harvest				
Species Group	2000	2010	2020	2030	2040
	(Million m^3 per year)				
Coniferous	314.1	322.6	353.8	384.9	413.2
Deciduous	237.7	263.2	280.2	288.7	302.8
Total	551.8	585.8	634.0	673.6	716.0

Conversion factor used: 1 cubic foot = 0.0283 cubic meter.

Table 2. Estimate of industrial roundwood harvests on timberland in the United States between 2000 and 2040 (Haynes *et al*. 1995).

Species Group	Year of Harvest				
	2000	2010	2020	2030	2040
	(Million m^3 per year)				
Coniferous	294.3	297.2	328.4	362.3	387.8
Deciduous	155.6	175.4	189.6	189.6	192.4
Total	449.9	472.6	518.0	551.9	580.2

Within the USA, there is a shift in estimated supply over time predicted on a regional basis to the South (Table 3). Some 90 percent of increased coniferous harvest and 70 percent of the increased deciduous harvest is predicted to take place in the South. It is expected that, in the future, the majority of the wood supply from the USA will be from southern and western regions.

Table 3. Estimates on economic supply of total timber harvests on timberland and regions (Haynes *et al*. 1995).

Region	Year of Harvest									
	2000		2010		2020		2030		2040	
	Con.[1]	Dec.[2]	Con.[1]	Dec.[2]	Con.[1]	Dec.[2]	Con.[1]	Dec.[2]	Con.[1]	Dec.[2]
	(Million m^3 per year)									
Northeast	23.2	56.3	26.9	61.7	28.3	66.8	28.6	72.2	29.2	79.8
North central	11.0	64.0	13.6	67.4	14.4	69.9	14.7	73.0	14.4	77.8
Southeast	83.5	45.6	88.9	50.1	91.1	51.2	86.0	50.4	92.3	50.4
South central	94.0	61.7	92.0	72.5	109.2	77.5	137.3	77.0	147.7	79.0
West	102.5	11.6	101.6	13.0	110.6	14.4	118.6	15.6	131.0	15.9
Total[3]	314.2	239.2	323.0	264.7	353.6	279.8	385.2	288.2	414.6	302.9

[1]Con. = Conifer.
[2]Dec. = Deciduous.
[3]Totals do not match totals in *Table 1* due to rounding.

The USA analyses (Haynes *et al*. 1995) are carried out by employing rather sophisticated models that include price as a consideration for availability of supply. The USA analytical system provides for a balancing of supply and demand including export and import flows into and outside North America.

2.2 Official Industrial Wood Supply Estimates — Canada

Estimates of Canadian industrial roundwood production stem from UNFAO (1998) and are based on official Canadian figures presented by EDF (1995), UNFAO (1996), and CCFM (1997). The forecast on future industrial roundwood production encompasses assumptions about future demand, prices, and changes in technology over time but it is not an economic supply estimate but rather a "probable supply" estimate. It also assumes some expansion of the economically accessible forest-land base in Canada (*Table 4*).

Table 4. Canadian industrial roundwood production and annual allowable cut levels and projections (UNFAO 1998).

	1970	1980	1990	1995	2000	2005	2010	2015
				(Million m^3 per year)				
Industrial Roundwood Production ("probable wood supply")	117	151	156	183	194	202	213	227
Annual Allowable Cut (AAC)	228	228	253	233	n.a.	n.a.	n.a.	n.a.

The industrial roundwood production estimate includes both coniferous and deciduous species. Since 1970, the majority of production increase has been in coniferous, although deciduous removals have grown at a faster rate. In 1970, coniferous production constituted 91 percent of total removals compared to 85 percent in 1994 (EDF 1995, Natural Resources Canada 1997). In 1993, AAC totaled 230.4 million m^3 with the deciduous component representing 25 percent of the total (EDF 1995). This deciduous harvesting level indicates a relation of 75 percent coniferous and 25 percent deciduous in the roundwood estimate presented in *Table 4*.

The level of sophistication is substantially lower in Canadian analyses compared with the USA analytical system. The official timber supply analyses rely on provincial analyses as reflected in allowable cut calculations, which are not always completely transparent (UNFAO 1996) and lack consistent standards and definitions. It seems that the official Canadian estimates are closely tied to potential net growth estimates.

3. Concerns about Official Estimates — USA

3.1 Growth/Drain Ratio

Cubbage *et al*. (1994) presented a study on the growth to drain ratio for the Southern United States. They found that twenty of the south's fifty-one forest survey units had coniferous removals that exceeded growth as of the most recent inventories. The average growth to drain ratio for these twenty units was 0.74. The authors also carried out timber inventory projections for the six southeastern states and predicted a decrease in the coniferous inventory in five of the six states. Of special concern was the predicted dramatic drop in inventories for Georgia and Mississippi of some 34 to 40 percent between 1990 and 2010. Cubbage *et al.* (1995a and b, 1996a) and Cubbage and Abt (1996) presented additional analyses on the Southern situation. In these documents, they estimated growth/drain ratios for the entire South of 1.51 for deciduous and 0.88 for coniferous species groups. They concluded that:

> "The national RPA (Haynes *et al*. 1995) indicate that the South is projected to increase its total magnitude and national share of timber harvest for decades. Our capability to achieve and maintain these projected increases in timber supply, however is moot."

Colberg (1996) investigated the growth to drain ratio in 14 southern states and found that the ratio averaged between 0.6 and 0.8 for coniferous species groups. In this study it is pointed out that for most of the South's "pine producing region" the growth to drain ratios average 0.68. The author points out that these ratios are significantly lower than US Forest Service estimates, which he felt were outdated. Colberg (1996) concluded that:

> "There is firm evidence that coniferous inventories are declining in most of the South's major timber-growing regions and for the next 15 to 20 years there will not be enough coniferous volume to meet current mill requirements."

Colberg (1998) illustrates that the US Forest Service drain estimates in the South represent "average" annual removals for the previous inventory cycle. The difference with the "current" mill consumption is significant. The latter figure is more than 20 percent higher than the US Forest Service estimates for the South. Smith (1998) shares the opinion that the collected official drain data is not consistent. Cubbage and Abt (1998b) state that the official deciduous harvest data probably underestimate removals significantly.

Lindberg (1997) projects a similar growth to drain ratio for southern pine as Colberg (1996), namely 0.7. Random Lengths (1997) states that Virginia, Tennessee, Oklahoma, Florida and North Carolina are the only states in the South currently growing more coniferous timber than they harvest. South Carolina and the Georgia North-Central Unit are growing only about 75 percent of what they are harvesting. The Alabama North-Central and East-Central Units, Louisiana Southwest and Northwest Units, Mississippi Southwest and North Southeast Units, and Georgia Southwest and Central Units are growing 80 percent or less of what they are harvesting.

Cubbage and Abt (1997, 1998b) have aggregated the latest Forest Inventory and Analysis (FIA) data to determine the current inventory, growth and removal situation for all regions of the South. Based on this data the coniferous growth and removals are currently about equal in the South (a growth/drain ratio of 0.98) and with a ratio of 1.37 for deciduous. But the surplus timber inventories are far away from mill locations (Cubbage *et al.* 1995b) and it can be concluded that coniferous harvest still exceeds growth in most regions with large mill locations. If the most recent data is correct, this indicates that growth to removal imbalances have improved recently.

The anxiety regarding over-harvesting is not only concentrated in the South, but is also a frequent concern in other regions. Irland and Maass (1989) and Irland (1996) report that much of the harvest in the 12 states constituting the so-called "frostbelt" in the North is concentrated in removing sawlogs and veneer logs and leaves behind poorly-stocked stands of firewood and pulpwood. They felt that the only way to sustain and increase the harvest in the frostbelt region was by an increased harvest of low quality wood from now through the foreseeable future.

Growth to drain ratios according to Haynes *et al.* (1995) are presented in *Table 5* for the years 1991 through 2040. The ratio for the owner group "Other private lands" shows a very low value for the dominating part of the projection period for both coniferous and deciduous species groups. This is the owner group that is estimated to take care of most of the increased wood supply that is expected to be needed to meet the future demand between 1991 and 2040. A ratio of less than 1.0 is no problem if there is sufficient unused forest inventory to tap from, and if efficient reforestation is carried out after harvesting. But as will be illustrated later in the text, this does not seem to be the case for the “Other private lands” ownership group.

Table 5. National level growth to drain ratio (Calculated from Haynes *et al*. 1995).

	1991	2040
Conifers		
National Forests	1.54	2.87
Other public forests	1.47	1.38
Forest industry	0.78	0.99
Other private lands	1.19	0.86
Deciduous		
National Forests	1.82	1.55
Other public forests	2.70	2.44
Forest industry	1.00	0.77
Other private lands	1.37	0.68

3.2 Reforestation

Colberg (1996, 1998) has followed the development of coniferous volumes harvested and the reforestation rate in the South since 1960. Thus, the comparison is made between planted areas and volumes harvested which, to some extent, is a mixing of apples and oranges. But harvested volumes can be used as a substitute for harvested areas. For example, in 1997 the coniferous consumption by all of the mills in the USA South totaled 189.6 million m^3. This represents current mill consumption levels rather than the historical averages developed by the US Forest Service in their periodic surveys, and is substantially higher than US Forest Service estimates. Of the total wood consumption, only 36.8 million m^3 stemmed in 1997 from thinnings or partial cuts. The remaining 152.8 million came from clearcuts. The average industrial harvest volume for southern yellow pine is 56 to 84 m^3 per ha. If the higher number is used, 1.82 million ha must be clearcut in order to provide the 152.8 million m^3 required to satisfy 1997 demand levels. The US Forest Service reports 0.69 million ha seeded or planted in 1997. While some of the remaining 1.13 million ha was reseeded to pine, most reverted to a lower quality stand with a sizable hardwood component. Based on these calculations, Colberg (1996) found that harvested coniferous areas have doubled during the time period studied but at the same time seeded or planted areas only increased by 13 percent. Rooks (1998) made the conclusion that reforestation of coniferous forests has been practiced by a large number of industrial forest owners in the South. But, in the case of deciduous forests in the South, he also concluded that limited reforestation has taken place. White (1998) points out that most of the deciduous forest management in the South is coppice with standards of low quality.

However, WRI (1998) expects an increase in pine plantations in the South in the future. It is expected that the new plantation area will come from continued conversion of natural pine stands to plantations on the remainder of industry land, and a strong timberland investment industry, which will act as a driver and consolidator for a portion of the "Other Private Lands." WRI (1998) estimates that pine plantations in the South will increase from the current 12.9 million ha to some 17 million ha by the year 2030, an increase of some 33 percent. This can be compared with the Moffat *et al.* (1998) estimate (based on an opinion survey) that planted pine area will increase by 7 percent in the South by the year 2020. Colberg (1998) concludes that in study after study, from Texas to the Carolinas, there is not a single instance where "near term" softwood inventories have increased.

3.3 Demographic Impacts

De Forest *et al.* (1991) and Rooks (1998) conclude that the economic growth in the southern USA has led to a major population growth. It is stated that about 25 percent of the total timberland area and growing stock are in counties with major metropolitan areas in the South (De Forest *et al.* 1991). It is identified in the article that the increase in urban population may become a major drawback on forest utilization. One estimate in the latter article is that:

> "over the next 10 to 15 years, hundreds of square miles of rural forest land will essentially become off-limits to the forest products industry."

Decisions Support Inc. has carried out similar analysis and found also that 25 percent of the South's softwood volumes were located in metro counties. It could also be seen in this study that these same counties were providing a disproportionate share of the harvest volumes. Industry is buying a sizable amount of inexpensive wood cut from metro areas that are being cleared for construction. While this may be beneficial now, these same sites will no longer be available for future timber growth. Wear (1998) estimates that in 2020 additional 2–2.5 million ha of forest land in the US South have been lost for urban development.

In addition to losses due to development, it has been projected that cropland needs nationwide may rise by 20 million ha by 2020 (Joint Council of Food and Agriculture Sciences, 1984). The southern USA will be one of the primary sources of this new cropland area and the only land-use that easily lends itself to cropland production in the south is forest land. A 1988 study (USDA, 1988) estimated that 10 million ha of timberland in the South had high or medium potential for conversion to cropland over the next 35 years. If these projected land conversions occur, the potential for the South to meet the growing wood fiber supply will be limited.

3.4 Stocking and Productivity Estimates

Most forest stands are not maintained at full stocking (generally more stands will be either under- or over-stocked than will be fully stocked), yet potential stand productivity estimates in the USA are based on full stocking. As a result, assessments of realized productivity are often overestimated if based on potential productivity since stands that are under- or over-stocked will not reach their productivity potentials. The difference between potential productivity and realized growth needs to be assessed.

In addition, more than 1.6 million hectares of timberland in the southern USA was classified as being nonstocked in 1992 (Smith *et al*. 1994). These nonstocked timberlands represented 70 percent of the total nonstocked forest land in the Eastern USA in 1992. However, the area of nonstocked timberland in the Southern USA represents only 2 percent of the total timberland base of the USA. Estimates of future sustainable wood supply based on area of forest land must discount these nonstocked areas.

3.5 Increment Estimates

There are uncertainties in USA increment estimates. Haynes *et al*. (1995) show an increase in the net conifer growth in the South Central USA of 35 percent (with a declining land base of timberlands) between 1990 and 2040. It is difficult to agree with such increases in the rate of increment given the conditions for reforestation that since 1960 there has been a 13 percent increase in reforestation but a two-fold increase in clearcuts (Colberg, 1996, 1998). It is reasonable to assume that the net annual growth in well-managed pine plantations can be increased by as much as 35 percent by the year 2040. The problem arises when these increases are applied to all of the South’s timberland. Only industry lands are being managed to provide maximum wood and fiber yields, and represent less than a quarter of the South’s commercial timberland. Few believe that public lands will provide any appreciable harvest volumes in future years, and history has taught us that without “up-front” incentives, few non-industrial private land owners will plant their cut-over timberlands after harvesting. Adams (1998) points out that there are no sufficient incentives for private non-industrial landowners to manage their forest lands for their future wealth and productivity.

3.6 Topographical Restrictions

Forest inventory data for the USA on a regional level do not consider the potential limitations regarding topography when determining area of timberland and associated volumes. Topography can limit not only harvesting but other management activities such as regeneration and/or thinning as well. Topographical restrictions on implementing management will limit the production potential, however, this may be moot if the wood fiber produced cannot be harvested.

The western USA will perhaps have the most easily recognized and severe topographical restrictions but this type of restriction occurs throughout the USA. Steep, dry, rocky slopes in the south to bogs and swamps in the Lake States are some examples of topography that will limit harvesting the existing timber on these sites. There is a dramatic reduction in the operability in the US South when the average soil moisture in the surface of 12 inches reaches 40 percent (Carrath and Brown, 1996). Operability is a data element for forest inventories in the southern USA, for example 12 million ha of wetlands, but is not incorporated into national estimates of timberland available for harvest. Decisions Support Inc. has carried out resource studies for the USA South and found that as much as 40 percent of the deciduous inventories are not available for industrial use. Pacheco *et al.* (1997), Cubbage *et al.* (1997), Cubbage and Abt (1998a) estimate the deciduous area reduction to 30–50 percent. These inventories are growing on slopes too steep to log, wetland sites, or in-stream or roadside reserves. There is a similar situation for pine but the deduction is 10 to 15 percent (Decisions Support Inc.). Cubbage *et al.* (1997) and Cubbage and Abt (1997) also estimate the deduction for coniferous forests to 10–15 percent. UNFAO (1998) shows that of a total area of 298.1 million ha of forests in the US, 122.7 million ha are inaccessible for wood supply and 19.2 million ha are legally protected areas, which results in an area available for wood supply of 156.2 million ha. This latter figure is 30 to 35 ha million less than the timberland area used in the projections by Haynes *et al.* (1995).

3.7 Inventory Data

USDA Forest Service, Forest Inventory and Analysis (FIA) data have been collected using different methodologies in different areas of the country. While on a local scale this creates some comparison problems, it has been possible to accurately gather and collate this data on an aggregated national scale. FIA data based on field plots and their analyses are recognized internationally for their scientific quality (and in fact form the basis for many of the comparisons provided in this paper), the problem arises when this data is used for projections into the future (Colberg 1996, Flowers *et al*. 1993, Kaiser 1994, Martin and Darr 1997). Colberg (1998) states that using a timber-supply forecasting system similar to the ATLAS model used by the Forest Service in the Haynes *et al.* (1995) forecasts, but with supply and demand assumptions that are based on observed data rather than theoretical abstractions, a sizable supply gap is foreseen for the US South with softwood inventories declining as much as 40 percent by the year 2015.

3.8 Ownership

Haynes *et al*. (1995) expect the relative contribution of non-industrial lands to total timber harvests to grow in all regions, while the share from industry and public lands is expected to decline (*Table 6*). Almost 60 percent of private forest owners have less than 10 acres and less than 1 percent of the owners have 45 percent of the total timberland in the USA (*Table 7*). The majority of the timberland in the larger land ownership category is associated with forest industry. A much wider proportion of private lands in the South and in the North are in smaller ownerships in comparison to the remainder of the country. Birch (1996a and b) stresses that management goals vary widely among different ownerships. Studies show that the degree of active forest management increases with the size of the forest holding (RTI, 1992). A study by Birch (1994) identified that only about 3 percent of private owners identified timber production as their primary objective and only 5 percent of private owners identified income from timber as a goal. However, about 70 percent of the responding landowners expressed that timber production was an ownership goal but not necessarily their primary objective for owning timberland. Owen (1998) argues that the increasing fragmentation of the forests due to changed ownership and ownership objectives are the real threat to the southern US forests. Another example is from North Carolina (Hunt, 1996); only some 35 percent of the owners intended for sure to harvest during a coming 10 year period and only 28 percent of owned forest land had timber production as a primary objective of the ownership. Fleury and Blinn (1996) conclude that the implication of the ownership fragmentation makes it difficult to produce any definitive timber supply projections from non-industrial private forest owners. Sampson (1996) stresses that a deep-seated historical trend of the American dream is the private ownership of forest land and production of timber and economic values are seldom the owners' primary motivator. This is in strong contrast with the basic assumption by Haynes *et al.* (1995) and Martin and Darr (1997) that assume a strong impact on the harvest behavior by increased prices for the non-industrial private ownership group. Mills *et al.* (1996) conclude from a quantitative study of the non-industrial private forest owners' management objectives that the objectives are very complex and doubt that traditional models based on technology adoption processes are appropriate for a decision involving many complex personal values. As stated earlier, in general non-industrial private landowners will not plant their cut over timberland unless there is an "up-front" cash incentive. Colberg (1998) has illustrated sharp upward spikes in seeding and planting in the USA South, during the period 1956 to 1997, namely in 1960 and 1988. Both years were at the height of a government sponsored incentive program to encourage tree growth. But when the funds were depleted, there was a sharp decline in planting rates. There is, however, some evidence suggesting a recent increase in planting activity in response to stumpage prices that are not at or near an historical high. Adams (1998), Owen (1998) and Smith (1998) require increased financial incentives for private non-industrial forest owners in order to manage their land on a long-term sustainable basis. Cubbage *et al.* (1996a) point out that the ownership situation will especially negatively influence the future deciduous wood supply in the southern USA.

Table 6. Timber harvests by ownership class and region, 1991; and projected for 2000. (Haynes *et al.* 1995).

	Public	Private	
		Industry	Other
	Percentage	Percentage	Percentage
Actual 1991 Levels			
South	6.5	28.9	64.6
North	9.5	20.5	70.1
West	44.9	35.6	19.5
TOTAL USA	**17.9**	**28.5**	**53.6**
Projected 2000 Levels			
South	4.9	26.1	69.0
North	8.6	18.0	73.4
West	38.2	34.3	27.5
TOTAL USA	**12.8**	**25.5**	**61.7**

Table 7. Distribution of private forest ownership (EDF, 1995).

Size class	Percent of private timberland	Percent of all private owners
> 500 acres	45	< 1
100 to 499 acres	23	6
50 to 99 acres	12	7
10 to 49 acres	15	28
1 to 9 acres	4	59

In 1985, it was estimated that 43 percent of the Southeastern and 46 percent of the South Central USA timberlands needed treatment to reach their production potential (USDA, 1988). Recommended treatments related primarily to concerns about stocking, i.e., improve regeneration, thin overstocked young stands, control stocking of undesirable trees. At the same time, about two-thirds of the southern USA's timberlands were owned by non-industrial private landowners (USDA, 1988). We believe that this ownership group is the least likely to implement forest management/treatment without incentives. As a result, it is projected that a significant portion of the southern USA's timberlands will not receive adequate management and as a result will not reach their potential productivity regarding wood fiber supply.

3.9 Sustainable Forest Management

Martin and Darr (1997) point out that generally accepted indicators of sustainable forest management have yet to be defined for the United States and currently there is no knowledge whether harvested lands on non-industrial private ownerships are being managed in a sustainable fashion. IIED (1995) point out a similar opinion and state that the harvests are unregulated on private forests in the southern USA and that the harvest cannot be carried out in a sustainable manner. Especially for the South, discussions are on-going related to a reduction of the harvest. Concerns about the elimination of harvests on national and state forests, elimination of harvests on wetlands, extension of pine rotations in order to protect late-successional species, elimination of clear-cutting, and introduction of increased use of unevenaged management schemes (IIED, 1995) are being expressed. Hayes (1998) demonstrates that from the mid 1970s to the mid 1980s there was a loss of some 1.5 million ha of forested palustrine wetlands in the USA (89 percent in the US Southeast) due to mainly forestry and agriculture operations. Similar concerns are expressed by Barrett (1995) at the national level. Random Lengths (1997) points out that so far, much of the sustainability discussion has concerned the West Coast, but environmental issues will also become an issue in the southern USA. In addition, the topic of endangered species is a hot issue in the South and is expected to negatively impact the future wood supply. Hayes (1998) illustrates that there are 86 threatened and endangered species in the US South, which can be compared with 12 in the Pacific NW; the region where a lot of environmental restrictions on wood utilization have been implemented. Campbell (1998) points out that the red-cockaded wood pecker is listed as a federally endangered species due to short-term rotation forestry in the US South. Flynn (1998) illustrates that environmentalists in the South have become increasingly critical of the rapid increase in clearcutting of hardwood stands for chip production. Hughes and Radar (1998) demonstrate in a case study for the US South that implementation of sustainable forest management will reduce the gross timberland by some 20 percent. Sales of eastern timber is also under public scrutiny (Barrett 1993). Baumgras (1996) illustrates how environmental concerns affect the forest operations and wood supply in the central Appalachians and Virginia.

Cubbage *et al*. (1996a), Cubbage *et al.* (1997), Pacheco *et al*. (1997), and Cubbage and Abt (1998a) point out that the ownership issue, environmental factors, and demographic factors may reduce the actual deciduous hardwood inventory available for harvest in the US South by 30 to 50 percent and the coniferous inventory by 10 to 15 percent. They estimate the economic wood supply to be even less.

There have been many discussions on the reduction of harvests in the Pacific Northwest in response to concerns about threatened species and a desire to manage the public timberlands for a broader objective than solely timber production. Perez-Garcia (1993) and Brooks (1995) estimate that the future supply from public timberlands will be only 20 percent of the average harvest during the period 1980 to 1989. The reduced harvest is forecasted to correspond to some 18 million m^3 per year in public forests (Brooks 1995). Rooks (1998) confirms such a development, showing that the harvest from public lands on the West Coast has declined from 54.4 million m^3 in 1986 to 16.3 million m^3 in 1997. This corresponds to a decline in the harvest of 70 percent during this 10-year period, which can be compared with a 25 percent decline in the official estimate for this region during the period 1990 to 2040.

Some of the environmental concerns on the West Coast are reflected in the official estimates, however, the concerns considered are far from complete. The complete issue of sustainable forest management is not taken into account in the official estimates, which are based on a balancing of the economic supply and demand. This is one of the primary differences between the various estimates, results are based on the inclusion of sustainability and other related issues or on the inclusion of price considerations.

3.10 Best Management Practice Guidelines

In some 48 US States the Best Management Practice Guidelines now exist. These guidelines apply to most timberland; they affect harvesting in riparian areas and have a significant impact on the accessibility of hardwood inventories. In addition, Blinn and Dahlman (1996) show that the harvesting costs increase substantially due to the Best Management Practice Guidelines. Woodman and Cubbage (1994) found that the implementation of Best Management Practice increased the average harvesting costs from $19 to $46 per acre in 1992 in the South. Henry (1998) demonstrates that some 40 percent of the US inland waters still do not meet designated uses and non-point sources (land use) are the major cause. Hayes (1998) points out that there is a need to protect some 325 watersheds (most of them in forestland and the US South) — 15 percent of the total — to conserve populations of all at-risk freshwater fish and mussel species in the United States.

3.11 Quality Decline and Changed Assortment Distribution

Wood supply estimates by Haynes *et al*. (1995) do not deal with the qualitative or assortment aspects. Luppold *et al*. (1998) investigated and compared the relative quality of sawtimber on National Forest lands with adjacent lands for 41 eastern Forest Survey units and conclude that we could expect a decline in higher value sawtimber in Eastern National Forests over the next 20 to 50 years. Similar concerns are expressed by Flowers *et al.* (1993) for Montana.

3.12 Governmental Regulations

The current government regulations increase forest management costs making it more difficult to manage the forests sustainable by private non-industrial forest owners (Rodgers, 1998 and McEvoy, 1998). Rodgers (1998) claims that current estate and inheritance taxes force increased fragmentation of the forest land. The taxes force families to sell the properties for land use other than forestry instead of handing them over to the next generation. Smith (1998) advocates for a reduction of existing tax disincentives. Sampson (1996) is pointing out that existing tax policies are the most significant economic disincentive for private forest owners and that they are ill-suited to millions of people who want to do a good job with their forests. Hanson (1996) demonstrates from a study in Washington State that the government's incentive programs for sustainable forest management were being overwhelmed by the government's disincentive programs. Some government agencies offer cost-sharing incentives for non-industrial forest landowners to stay in forestry but other agencies create more compelling incentives to get out of forestry. Hanson (1996) also illustrates that the forest management practices for this group of landowners to a large extent was driven by uncertainty about future regulations.

3.13 Regional Supply Analyses

A number of regional supply analyses have been carried out in the USA attempting to reflect some of the aspects dealt with above. In the following, we present some of these regional estimates and put them in relation to Haynes *et al*.'s estimate (*Table 8*).

Cubbage *et al*. (1996b) speak of a substantial decline in the Southern USA coniferous wood supply by the year 2010 and a dramatic decline by the year 2015. As discussed earlier, WRI (1998) has a somewhat more optimistic view on future plantation rates for the South. The coniferous plantation rate is estimated to be 12.9 million ha in 1997 and some 17 million ha in the year 2030. This can be compared with the official estimate (Haynes *et al.* 1995) of 14.6 million ha in the year 2000 and 18.3 million ha in the year 2030. Thus, the WRI (1998) estimate on new coniferous plantations is some 60 million ha less than the official base estimate for the studied period. But in spite of this, WRI (1998) is coming up with a "probable supply" estimate, which is very similar to the official "economic supply"of coniferous in the South. If we use Cubbage *et al*. (1996a), Pacheco *et al.* (1997), Cubbage *et al.* (1997) and Cubbage and Abt (1998a) low estimates on reductions of deciduous harvests in the official estimate by 30 percent we get a result according to *Table 9* for USA South.

Table 8. Comparison between regional coniferous wood supply estimates.

Coniferous Southern USA	2000	2010	2015	2020
	(Million m3 per year)			
Haynes et al. (1995) “Economic supply”	177.5	180.9	n.a.	200.3
Colberg (1997a, 1998) “Probable supply”	161.4	117.8	95.3	n.a.
Apsey and Reed (1995) “Probable supply”	n.a.	152.0	n.a.	160.0
Reed (1998) “Probable supply”	n.a.	125.0	n.a.	n.a.

Table 9. Comparison between regional deciduous supply estimates.

Deciduous Southern USA	2000	2010	2020
		(Million m^3 per year)	
Haynes *et al*. (1995) “Economic supply”	107.3	122.6	128.7
Cubbage *et al*. (1996a) “Probable supply”	75.0	86.0	90.0
Apsey and Reed (1995) “Probable supply”	n.a.	88.0	90.0
Reed (1998) “Probable supply”	n.a.	75.0	n.a.

Cubbage (1997) and Cubbage and Abt (1998b) have carried out an interesting exercise. They have applied the Haynes *et al*. (1995) harvest and area projections for the US South to the gross latest available (1997) Forest Inventory and Analyses (FIA) data and their developed Southern Regional Timber Supply (SERTS) model. This model is based on price relations and a simple age class component shifting the supply over time. The supply is a function of stumpage price and beginning period inventory (Cubbage *et al*. 1998). They find that it is possible to take out (along with the Haynes *et al*. 1995 estimate) increased coniferous harvest of 24 percent and an increased deciduous harvest of 39 percent between 1990 to 2020. But the growing stocks decreased during the same period by 33 percent for coniferous and by 5 percent deciduous. In this case no deductions are made for any of the other factors discussed earlier influencing the wood supply. This clearly concludes that the Haynes *et al*. (1995) estimates are hardly sustainable.

Cubbage *et al*. (1998) have on the other hand carried out analyses on the impact of intensified forest management in pine plantations and conclude that the productivity potentials are tremendous, and if implemented, they could prevent any timber shortages in the US South from about 2020. It would have been of importance if Cubbage *et al*. had carried out these analyses in combination with a full sustainable forest management concept.

Flowers *et al*. (1993) state that most projections of harvests in Montana show a 41 percent decline in annual Forest Service harvest and a 30 percent decline in Forest Industries annual harvest by the year 2010. None of these declines can be detected in Haynes *et al*. (1995) estimates. Irland and Whaley (1993) and Irland and Maass (1994) point out that the Haynes *et al.* (1995) estimates for Northeastern USA project increases in aggregate inventories. However, land ownership changes are likely to cause the commercially available growing-stock inventory to peak in the short term and then decline starting in the succeeding decade. Irland and Whaley (1993) and Irland and Maass (1994) conclude that in general, the forests are overstocked in the region, but looking at marketable species and quality aspects understocking is much more common. Thus, the growing-stock statistics are not reliable indictors of potential commercial volume when making long-term projections.

Box 1: The Case of North Carolina

Most of the arguments we have tried to make for the US situation can be illustrated by the conditions in North Carolina. We use data from Hunt (1996) for the illustration. In this case the availability of forest land for industrial use was screened at three levels:

Maximum Availability	*Medium Availability*	*Minimum Availability*
No Constraints	*Minus*	*Medium Availability Minus*
(The gross Forest inventory and Analysis (FIA) data used in official analyses, e.g., by Haynes et al. (1995))	• *Non-stocked land* • *Roads impractical* • *Year-round water* • *Slope >50 percent* • *Protection zones around streams* • *Vol./ha < 42m* ^{3}	• *Metro development counties* • *Deep swamps* • *Slope >40 percent* • *Wider protection zones around streams*

This screening resulted in the following results:

	Maximum Availability	*Medium Availability*	*Minimum Availability*
Timberland area	*7.57 million ha*	*4.69*	*2.91*
Growing Stock:			
• *Coniferous*	*354 million m*^{3}	*317*	*224*
• *Deciduous*	*572 million m*^{3}	*422*	*226*
Annual Growth (Net growth)	*32.8 million m*^{3}	*20.4*	*13.2*
Annual Growth Minus Current Harvest	*+6.3 million m*^{3}	*–6.2*	*–14.0*

Hunt (1996) points out that the screening did not take into account that the harvest is carried out on some steep slopes, that considerable amounts are harvested in metro regions, and did not account for the effect of rising stumpage prices upon availability. But on the other hand the screening did not take into account many of the sustainable forest management issues stressed in this article either.

Hunt (1996) concludes that there is an unknown, but potentially large, gap between gross timberland areas and available timberland areas. The gap is somewhere between 35 to 60 percent. Virginia has completed a sophisticated study of a similar nature. The results are strikingly similar to the data presented for North Carolina.

4. Canada

4.1 Increment/Sustainable Yield

Net mean annual increment is a key component to estimate sustainable yield (sustainable harvest). There is no continuous measurement of the increment in Canada. Officially (UNFAO, 1996), Canada makes reference to an old study by Honer and Bickerstaff (1985) for estimates on growth. Based on this study the official estimates on Annual Gross Growth on productive and available forest land in Canada is 262.6 million m^3 per year for coniferous and 75.4 million m^3 per year for deciduous. In a later official estimate (UNFAO, 1998) the total gross annual increment is increased by about 10 million m^3 per year. But many natural losses occur — the estimate is 100.9 million m^3 per year for coniferous and 43.0 million m^3 for deciduous. It leaves us with a net growth of 161.7 million m^3 per year for coniferous and 32.4 for deciduous for total Canada (UNFAO, 1996). Hagler (1995) questions these estimates and suggests lower ones.

Thus, there are great uncertainties with the estimated Canadian growth figures because there is no efficient monitoring system of the forest growth in place in Canada. How desperate the situation really is can be illustrated by the fact that the federal forest administration has carried out a Delphi study in order to get better Canadian growth estimates (Phillips *et al.*, 1995).

As stated above, the net mean annual increment is one of the cornerstones for analyses of sustainable yield and harvests and there are concerns that growth estimates are overestimations in Canada. If we use the official increment estimate (UNFAO, 1996) and compare it with the AAC for 1993 (UNFAO, 1996) it can be seen that the AAC for all species for 1993 and 1995 exceeds the net annual increment by some 15 percent. The discrepancy is largest for deciduous species where the AAC exceeds the net annual increment by 40–45 percent. Already at this stage we can start to doubt the official wood supply estimates for Canada, because they are mainly based on regional AAC calculations.

4.2 AAC Calculations

Smith (1994) points out that there is no commonly accepted methodology for calculations of allowable cuts in Canada, and there is wide concern that the calculations are not transparent (e.g., Booth, 1995) and in the end they are a political exercise. Williams and Tanz (1994) have produced an excellent paper describing the procedure for AAC calculations in Canada.

> “The allowable annual cut (AAC) is a short-term measure of timber supply that reflects the quantity of timber that the regulating agency (generally the province or territory) is willing to make available for harvest, under current conditions, for a specific geographic area for a defined period of time. These conditions will include the state of the forest and the prevailing policy and economic environment. The AAC may be determined through a calculation, or be selected through a

> process that includes knowledge of long-term sustained yield, the results of timber-supply analyses and other studies.”

There are different views in Canada on what’s included in the AAC. One view is that the AAC is assumed to be the economic volume available for harvest. The other view is that the AAC is an upper limit on the harvest that is physically and biologically feasible. Williams and Tanz (1994) illustrate a number of problems with the AAC calculations accessed from Canada. One problem is that different definitions are used for the land base for which AAC’s are determined. A second problem is that the rate of timber utilization must be specified when estimating timber supply and different standards are used across Canada (merchantable or gross utilization). Anderson and Bonsor (1981) and Baskerville (1986) show that the use of acceleration factors in the allowable depletion in Ontario has resulted in short-term overharvesting that, coupled with poor regeneration success, contributes to long-term wood supply decline. Williams and Tanz (1994) show that the relationship between AAC estimates and long-term sustainable yield varies significantly across Canada. They also illustrate that the level of management to support the AAC varies through the provinces in Canada. Extensive management is used for Northwest territories and Labrador, basic management for Ontario, Manitoba, Saskatchewan and Alberta, intensive management (meaning planting and spacing) in Nova Scotia and New Brunswick. British Columbia uses something between basic and intensive (silviculture treatments required to ensure the establishment of a free-growing tree crop within a specified period of time after harvest). After this description it can be clearly stated that the AAC calculations do not take into account the requirements on sustainable forest management (SFM) discussed below in the text.

As stated earlier, the official Canadian wood supply estimates are based on the provincial AAC calculations (UNFAO, 1996). From this we conclude that the official estimates are not built on sustainable forest management. In addition, we have the problem of non-transparent AAC calculations and questionable inventory data for the calculations (e.g., Booth, 1995; Williams and Tanz, 1994).

4.3 Reforestation

Anderson and Bonsor (1981) and Baskerville (1986) point out that poor regeneration after harvesting in Ontario leads to long-term wood supply decline. Levy (1994) illustrates that the spruce cover type in Ontario has been reduced from 18 percent in the original forest harvested to 4 percent in the regenerating second forests. These secondary forests are being dominated by poplar. Only 35 percent of the cut-over forests have been treated by artificial regeneration and the survival rate on was only 9 percent during the period 1970–1975 and 18 percent during the period 1980–1985 (OIFA, 1992). Parent (1997) illustrates that the plantation rates have dropped by 35 percent during 1989–1995 in Eastern Canada. The major concern with the current reforestation rate is the change of species groups and the forthcoming quality and distribution of species in the new forests. Between 1975 and 1992 the yearly area harvested increased from 680,000 ha to some 800,000–1,000,000 million ha in the early and mid-1990s. But still only 417,000 ha were either planted, seeded or scarified in 1992 (CCFM, 1996) and 438,000 in 1996 (NRC, 1998). Even if we deduct for the development of increased selection and shelter wood harvests it means that about 50 percent of the clear cut areas were not treated for renewed regeneration. NRC (1998) illustrates that the commercial forest area not growing commercial species 10 years after harvesting has increased from 1.65 million ha in 1981 to 2.99 million ha in 1995.

4.4 Inventory Data

Williams and Tanz (1994) conclude after analyses of the AAC calculations in Canada that existing inventory data, growth, and yield information is questioned throughout Canada. Baskerville (1986) illustrates that the Forest Resource Inventory of Ontario overestimates the growing stock substantially and concludes that the area supporting the AAC calculation is accurate, but there is much ambiguity with respect to the volume that will be available for harvesting. Cooperman (1994) stresses that the Timber Supply Review is not really a review of the inventory because of the low accuracy of forest inventories that were done mostly by aerial surveys 10 to 30 years ago.

The inventory situation in Canada is frustrating. The government recently dissolved the start of a Canadian National Inventory that was established. The basic inventory information in Canada comes from the provinces. But the information is not transparent, having inconsistent definitions, and to a large extent obsolete, which results in overestimates of the harvesting possibilities.

The governmental agencies seem to be well aware of the problem. NRC (1998) states "Commercial Forest Account to date has been estimated from a variety of data sources. Future State of Forests reports will not include a Commercial Forest Account until such time as improved and more comprehensive information and estimation techniques are developed."

4.5 Native Forestry

The native people of Canada have recently been successful in their land claims and this is probably just the beginning of a structural process in Canada. The role that natives will play with increased land claims and the corresponding responsibilities by the federal government for native forestry are not dealt with at all in current official wood supply estimates (e.g., Reed, 1998).

4.6 Sustainable Forest Management

In the discussion on current AAC calculations for Canada it was concluded that sustainable forest management is not currently taken into account in the calculations. Kimmins (1994) points out that:

> "there are more extensive stream protection reserves, more wildlife reserves, more parks, wilderness areas and ecological reserves, green-up restrictions that limit the harvest of adjacent areas until the new forest has re-established environmental control of the harvested areas, and new rules about the landscape pattern of logging. Collectively these result in

significant reductions in one or more of: area of commercial forest, harvestable volume, and operable volume."

Kimmins (1994) concludes that the rate of timber harvest under these new management objectives will drop significantly. Wedeles *et al*. (1995) and Williams *et al*. (1997) have studied the impact of the wood supply through the implementation of sustainable forest management compared to current practices. The conclusions from the case studies reported that the decrease would be between 10–25 percent of the harvesting volume in the boreal zone of Canada and 30–40 percent on the coast in British Columbia. The selection harvest is currently about 10 percent in Canada but the trend to use silvicultural systems other than clear-cutting increases. With an increased selection harvest the wood supply is expected to decline (CCFM, 1996). Some companies in British Columbia have just announced a ban on clear-cutting, which will impact the harvest level too.

4.7 Regional Supply Analyses

A number of regional supply analyses exist for Canada. Callaghan (1994) presents long-term harvesting potentials for Ontario. In *Table 10* we present the average for the upper and lower bounds in the estimate. Apsey and Reed (1995) show an even stronger decline (*Table 11*). Messmer and Booth (1993) support a development of this kind in their analyses. Aspey and Reed (1995) also illustrate a strong decline in the future wood availability in Quebec (*Table 12*). Miller (1994) shows a similar development for the AAC in British Columbia (*Table 13*).

Table 10. Future "sustainable wood supply" (AAC) in Ontario (Callaghan, 1994).

	1995	2015	2035	2055	2075
			(Million m^3 per year)		
Coniferous	22.5	19.8	18.3	16.7	17.9
Deciduous	13.6	12.1	12.7	12.8	13.2

Table 11. Future "probable supply" in Ontario (Apsey and Reed, 1995).

	1995	2010	2020
		(Million m^3 per year)	
Coniferous	22.5	17.0	18.0
Deciduous	10.0	7.5	8.5

Table 12. Future “probable supply” in Quebec, in million m^3 per year. Source: Apsey and Reed (1995).

	1995	2010	2020
		(Million m^3 per year)	
Coniferous	33.5	27.0	28.0
Deciduous	19.2	12.0	13.0

Table 13. Future “sustainable wood supply” AAC in British Columbia (Miller, 1994).

	1994	2000	2010	Beyond 2010
		(Million m^3 per year)		
Total AAC	71.6	66.9	63.7	53.1
Reed (1998) “Probable supply”		n.a.	47.0	n.a.

Flynn (1998) points out that most experts agree that there will not be adequate fiber to run all existing mills in the future in British Columbia. Innes (1994) states that there is an age-class gap developing in Eastern Canada and the reality is that the long-term wood supply is decreasing as well as a decline in quality. OMNR (1990) concludes that the long-term effects will downsize the central Ontario industry as it adjusts to the available volume of sawlogs. OMNR (1992) concludes that Ontario’s softwood sawtimber harvest has been held above sustainable levels in the past, and will have to be reduced in the coming decades as sawlog inventories are depleted.

The above examples cover 75 percent of the Canadian wood supply and, by having an unchanged development over time in other provinces (Williams and Tanz, 1994), there is no possibility to achieve a development as stated in the official estimate in *Table 4*. A second conclusion from these examples is that there is a strong need to carry out wood supply analyses in Canada broken down by species and assortments.

Box 2: Forest Sustainability -- Walking the Walk in Ontario

The first and dominant policy theme of Ontario's Crown Forest Sustainability Act (CFSA) is that there will be forest sustainability. Placing sustainability first is a bold move for Ontario for it proposes that biological sustainability is paramount to economic well being. This is evident in how sustainability is determined by the following principles:

1. *Large, healthy and productive Crown forests and their associated ecological processes and biological diversity should be conserved.*
2. *The long term health and vigor of Crown forests should be provided for by using forest practices that, within the limits of silvicultural requirements, emulate natural disturbances and landscape patterns, while minimizing adverse effects on plant life, animal life, water, soil, air and social and economic values, including recreational value and heritage values.*

This creates what might be one of the most progressive forest management frameworks in the world — Ontario is not only "talking the talk" but also leading a change in the way we think about forest management. But how close is reality to this framework? How well is Ontario "walking the walk"?

The management framework requires extensive analyses of biological diversity, ecological processes and current forest practices prior to decisions about where and when the next tree will be cut. These analyses mean investment in practitioners, technology and time. Unfortunately, this requirement, with its substantial increase in human and capital investment, is being called for at the same time as increased pressure to maximize short-term profits. The result is a perceived conflict between short-term economics and biological sustainability. In practice this means dropping long-term forest sustainability stewardship for crisis-style brinkmanship (e.g., we don't know enough information to make a decision to change so we will continue with business as usual). Alternatively, many have suggested using adaptive management (developing management strategies as hypotheses that are to be tested, evaluated and modified by learning) to addresses the conflict that comes from the uncertainty in strategic direction.

Some challenges to the principles of sustainability in Ontario that need to be addressed by adaptive management include:

Challenges for maintaining biological diversity:

A study of regeneration of Ontario's forests (Hearnden et al. 1992) found that harvested areas are sufficiently regenerating although to different species compositions than originally occurred and, in cases of artificial regeneration, not the (conifer) species planted. Many forests are nearing structural and compositional conditions for which habitat for specific wildlife species (e.g., Caribou or Marten) may become temporarily unavailable. Suppression of forest fires in Ontario to protect future wood supply has resulted in forests that are probably older and have a different diversity than would occur under natural fire regimes.

No clear goals for biodiversity have been stated in forest management guidance. Indeed, current forest management struggles to incorporate strategies to maintain biodiversity without knowing a biodiversity-based desired future forest condition. The CFSA points to emulating natural disturbance to guide forest managers in conserving biodiversity yet this paradigm has caveats which will require extensive testing and monitoring (Duinker 1995). Lack of biological direction allows economic direction to primarily determine management strategies with biological sustainability as an afterthought. The present challenge is to use scientific rigor in constructing management strategies in ways that integrate the best current biodiversity knowledge with forest management activities and future monitoring.

Challenges for maintaining long-term health and vigor:

Ontario uses a strategic forest management model to determine an allowable harvest area based on biological and economic factors. Manipulating the model, however, through introducing intensive silviculture work (e.g., commercial thinning, etc.) can increase the amount of your current annual available harvest suggested by the model. This makes sense if the silviculture work is realistic, practical and will ever really happen the way the model predicts. Case in point, one could declare that 30 to 40 year-old jack pine stands could be commercially thinned and then they will grow more volume afterwards. Although good in theory, it is telling the model is that you will remove 30% of the volume from a stand and immediately get back more volume than you started with! This will cause the model to estimate higher allowable harvests than are really practical.

Ontario's challenge to achieving forest sustainability lies in carrying the theory of its Crown Forest Sustainability Act to the reality of the forest. This challenge must be met using the combined knowledge and experience of forest science and practitioners — in the form of adaptive management.

5. Overall Alternative Estimates

A number of alternative estimates exist. These scenarios are based on the authors' detailed knowledge of the forest resources and restrictions on availability.

5.1 USA

In *Table 14* we use two major studies for a comparison with the official estimates for the USA, namely Apsey and Reed (1995) and WRI (1998).

Table 14. Comparison between estimates on total wood supply for the USA.

Forest type	2000	2010	2020	2030
		(Million m^3 per year)		
Coniferous				
Haynes *et al*. (1995) "economic supply"	314	323	354	385
Apsey and Reed (1995) "probable supply"	–	245	265	–
WRI. (1998) "probable supply"	–	275	308	351
Deciduous				
Haynes *et al*. (1995) "economic supply"	238	263	280	289
Apsey and Reed (1995) "probable supply"	–	190	198	–
WRI (1998) "probable supply"	–	186	185	185

Thus, there are substantial differences between the estimates. EDF (1995) also suggests a much more constrained coniferous supply in the future due to a continuing decline in annual growth due to age-class structure and lack of management on non-industrial private lands.

5.2 Canada

We use four major studies to make a comparison with the official estimates for Canada. This comparison is presented in *Table 15.*

Table 15. Comparison between estimates of industrial wood supply for Canada, selected years.

	1990	*1995*	*2000*	*2005*	*2010*	*2015*
	(Million m^3 per year)					
Official estimate on industrial roundwood production ("probable supply")	156	183	194	202	213	227
Hagler (1997) WRI (1998) ("probable supply")	*1995*	*2010*	*2020*	*2030*		
Coniferous	146	131	129	129		
Deciduous	36	32	32	32		
Total	182	163	161	161		
Apsey and Reed (1995) ("probable supply")	*1995 (AAC)*	*2010*	*2020*			
Coniferous	160.3	127.4	134.5			
Deciduous	52.2	37.8	41.6			
Total	212.5	165.2	176.1			
Colberg (1997b) ("probable supply")	*2000*	*2020*	*2030*			
Coniferous	149.5	142.0	133.0			
Reed (1998) ("probable supply")	*1995*	*2010*				
Coniferous	160.3	115				
Deciduous	5.2	32				

Thus, there seems to be differences in the estimates on the long-term supply between the different estimates of some 50–60 million m^3 per year.

6. Discussion

We have identified that the current official North American wood supply estimates do not consider issues such as sustainability. Since UNCED in Rio de Janeiro, the perception has been growing that sustainable forestry must be based on the three supports of environmental conservation, economic development and the needs of people (ECE 1998). The current "official" estimates are mainly based on a concept of the availability of timber volume. Sampson (1992) points out that "moving from a more narrow concept of sustainability of timber to a much broader one of sustainability of all forest values is going to affect how much timber we can harvest." In the case of the US, Adams (1998) points out that the national planning process do not articulate or integrate a national policy goal, such as sustainable forest management, which can provide coherent direction for stewardship of the forest lands. He is stressing that the concept of sustainable forestry should be used as one over-arching national policy and the Montreal Process criteria should be used for measuring and assessing the progress.

In addition it can be concluded that there is a lack of consistent national projections in both the USA and Canada. Sampson (1996) discusses three principles for governments to reach sustainable forest management and one of the principles is that governments must effectively develop and communicate the forest resource data. Lastly, and as seen, the current analytical approaches are based on a pure *market economic* approach. But the major forces influencing the wood supply during the 1990s have been stemming from the *political economy* (composed of collective consumption units, Ostrom, 1997). Reed (1998) illustrates how the political economy through the introduction of Protected Area Strategy, Forest Practices Code, and changed Forest Tenure has dramatically changed the wood supply possibilities in British Columbia during the mid 1990s. Among the policy areas (political economy) having important impacts on the forest sector are economic growth, energy, environment, agriculture, trade and the role of the public sector, demography and social affairs, land use, rural and regional development, and industry and construction. These policies reflect the society's interest in the forest sector. This societal interest is in turn reflecting the multiple individual and collective interactions between the forest sector and people, which constitute a complex and dynamic process that changes according to society's economic, cultural, technological and political development (ECE 1998). Binkley (1997), Christensen (1998) and Popovich (1998) stress that public understanding of acceptable methods for sustainable forest management is a major difficulty and that the resolution of conflicts on the meaning of sustainable forest management is a major challenge. Hayes (1998) concludes that a variety of new analytical tools are needed in order to deal with these conflicts. Thus, the current modeling efforts with respect to future wood supply are based on an unsatisfactory platform.

In order to come up with relevant analyses of sustainable national wood supply in North America, the following steps have to be taken:

- There is a strong need to establish and implement improved projection techniques for both the USA and Canada forest inventories and a relevant forest inventory in Canada. These new techniques should jointly consider market issues and political aspects of the wood supply.
- There is a strong need to implement generally accepted indicators of sustainable forest management in the wood supply analyses in North America.
- A new generation of analytical tools and analyses, based on a *political economic concept* (Nilsson, 1996), has to be developed and implemented for North American wood supply analyses. The current tools and analyses do not take into account the development of the political economy. Without thorough analyses of the sociopolitical concerns, the use of North American wood-supply analyses are limited.

By taking these steps, a lot of the current distortions in the North American policy debate with respect to the future of the forest sector could be avoided and a constructive platform for sustainable development of the North American forests could be established. In addition, these steps could result in North American leadership in the international debate on the development of global forest resources. Lastly, these steps would give the North American forest industry a relevant platform for setting long-term strategies.

7. References

Adams, S. (1998): *Individual Perspectives on South Forest Sustainability: State* Forestry Agencies. Paper presented at the Forum “Perspectives on Sustainable Forestry for the South”, The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Anderson, F. and Bonsor, N. (1981): *The Economic Future of the Forest Products Industry in Northern Ontario*, Report prepared for the Royal Commission on the Northern Environment by Lakehead University, Thunder Bay, Ontario.

Apsey, M. and Reed, L. (1995): *World Timber Resources Outlook, Current Perceptions. A Discussion Paper*, December 1995, Council of Forest Industries, Vancouver, Canada.

Barrett, G. (1993): The Ancient Forests of the East. *Weekly Hardwood Review* 8(52). September 10, 1993.

Barrett, J.W. (1995): *Regional Silviculture of the United States.* Toronto: John Wiley and Sons.

Baskerville, G. (1986): *An Audit of the Crown Forests of Ontario*, Ontario Ministry of Natural Resources, Queen’s Printer for Ontario, Toronto.

Baumgras, J.E. (1996): Environmental Concerns Affecting Forest Operations on Public Lands in the Central Appalachians. In: Blinn, C. and Thompson, MA. (Eds.) *Planning and Implementing Forest Operations to Achieve Sustainable Forests.* Gen. Tech. Rept. NC-186. USDA Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota, USA.

Binkley, C.S. (1997): *Preserving Nature Through Intensive Plantation Forestry: The Case for Forest Land Allocation with Illustrations from British Columbia*. Forest Chronicle, 73, pp. 553–559.

Birch, T.W. (1994): *The Private Forest-land Owners of the United States*, USDA Forest Service, Northeastern Forest Experimental Station, Radnor, P.A.; Preliminary findings.

Birch, T.W. (1996a): *Private Forest Landowners of the United States, 1994*. USDA Forest Service Resource Bulletin NE-134, USA.

Birch, T.W. (1996b): *Private Forest Landowners of the United States, 1994*. Paper presented at the Symposium on Non-industrial Private Forests: Learning from the Past, Prospects for the Future, Washington, DC, 18–20 February 1996.

Blinn, C.R. and Dahlman, R. (1996): Timber Harvester Perceived Costs and Benefits of Applying Water Quality Best Management Practices in Minnesota. In: Blinn, C. and Thompson, MA. (Eds.) *Planning and Implementing Forest Operations to Achieve Sustainable Forests*. Gen. Tech. Rept. NC-186. USDA Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota, USA.

Booth, D. (ed.) (1995): *Timber Supply in Canada: Challenges and Choices*. Summary of the results from the conference participants follow-up survey. Policy, Economics and International Affairs Directorate, Canadian Forest Service, Natural Resources Canada, Ottawa, Canada.

Brooks, D.J. (1995): Federal Timber Supply Reductions in the Pacific Northwest. International Environmental Effects. *Journal of Forestry* 93(7): 29–33.

Callaghan, B. (1994): Ontario Status Report. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Campbell, P. (1998): *Habitat Restoration and Management/Safe Harbor Program*. Paper presented at the Forum “Perspectives on Sustainable Forestry for the South”, The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Carrath, S.J. and Brown, J.C. (1996): Predicting the Operability of South Carolina Coastal Plain Soils for Alternative Harvesting Systems. In: Blinn, C. and Thompson, MA. (Eds.) *Planning and Implementing Forest Operations to Achieve Sustainable Forests*. Gen. Tech. Rept. NC-186. USDA Forest Service, North Central Forest Experimental Station, St. Paul, Minnesota, USA.

CCFM (1996): *Forest Regeneration in Canada 1975–1992.* Canadian Council on Forest Ministers, Ottawa, Canada.

CCFM (1997): *Compendium of Canadian Forestry Statistics.* Canadian Council on Forest Ministers, Ottawa, Canada.

Christensen, N.L. (1998): *Sustainable Forest Management: A Southeastern Perspective.* Paper presented at the Forum “Perspectives on Sustainable Forestry for the South”, The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Colberg, R. (1996): *Emerging Trends in Southern Timber Supply and Demand Relationships*, Paper presented at the International Wood fibre Conference, Atlanta, Georgia, 13–14 May 1996.

Colberg, R. (1997a): *Future wood supply from US South*, Presentation at the FAO Forest Sector Outlook Studies, Working Group, 24–25 February 1997, Rome, Italy.

Colberg, R. (1997b): *A Critical Review of Canadian Timber Supplies*, Paper presented at the FAO Forest Sector Outlook Studies Working Group, 24–25 February 1997, Rome, Italy.

Colberg, R. (1998): *Supply/Demand Balance for Pine Saw Timber in the US South. A 20 Year DSI Forecast.* Decisions Support Inc., Columbus, Georgia, USA.

Cooperman, J. (1994): Perspective on Western Canada's Timber Supply. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Cubbage, F.W. (1997): *A Look at Southern Timber Supply*. S.C. Forestry, November Issue.

Cubbage, F.; Harris Jr., T.; Abt, R.; Armster, R.; Anderlon, D.; and Pacheco, G. (1994): *Timber Supply in the South: Where Is All the Wood?*, Paper prepared for the 1994 Southern Forest Economic Workers (SOFEW) Meeting, 29–30 March 1994, Savannah, Georgia, USA.

Cubbage, F.; Harris Jr., T.; Abt, R.; Pacheco, G.; Armster, R.; and Anderlon, D. (1995a): Timber supply in the South: Surplus or Scarcity? *Forest Farmer* 54(3): 28–39.

Cubbage, F.; Harris Jr., T.; Wear, D.N.; Abt, R.C.; and Pacheco, G. (1995b): Timber Supply in the South: Where is all the wood? *Journal of Forestry 93*(7): 16–20.

Cubbage, F.W. and Abt, R.C. (1996): *Timber Supply in the South: Where is all the Wood? A Review of National RPA Projections and Implications for the South.* Testimony presented before the United States House of Representatives Subcommittee on National Parks, Forests, and Lands Committee.

Cubbage, F.W.; Abt, R.C.; and Pacheco, G. (1996a): *Timber Supply and Prospects in the South*, Paper presented at the International Wood Fibre Conference, Atlanta, Georgia, USA, 14–15 May 1996.

Cubbage, F.W.; Dvorak, W.S.; Abt, R.C.; Pacheco, G. (1996b): *World Timber Supply and Prospects: Models, Projections, Plantations, and Implications*, Paper presented at Central America and Mexico Coniferous Resource (CAMCORE) Annual Meeting, Bali, Indonesia, 15–24 October 1996.

Cubbage, F.W. and Abt, R.C. (1997): *Southern Timber Supply*. Southern Forest Resource Assessment Consortium Report No. 8. The Southern Forest Resource Assessment Consortium, Research Triangle Park, South Carolina, USA.

Cubbage, F.W., Pacheco, G. and Abt, R.C. (1997): *Overview of the Hardwood Resource Situation*. In: Wiedenbeck, J. (Ed.) **Eastern Hardwoods. Resources, Technologies, and Markets**. Forest Products Society, USA.

Cubbage, F.W. and Abt, R.C. (1998a): *Trends in Hardwood Timber Availability*. In: Meyer, D.A. (Ed.) **Technology and Market Information for the Next Millenium**. National Hardwood Lumber Association, USA.

Cubbage, F.W. and Abt, R.C. (1998b): *Southern Timber Supply: Implications for the Pulp and Paper Sector*. Paper Age, Volume 114, No. 2.

Cubbage, F.W., Siry, J., Moffat, S., Wear, D. and Abt, R. (1998): *Southern Forest Resource Assessment and Linkages to the National RPA.* Proceedings of the 1998 Society of American Foresters National Convention. SAF, Bethesda, MD, USA.

De Forest, C.E., Harris, T.G. Jr., Cubbage, F.W. and Nelson, A.C. (1991): *Timberland Downtown: Southern Forest Resources Along the Urban-Rural Continuum.* Paper presented at the Ecological Land Classification: Applications to Identify the Productive Potential of Southern Forests Symposium, 7–9 January, Charlotte, North Carolina, USA.

Duinker, P.N. (1995): *Managing Ontario's Forests as Natural Landscapes: Opportunities and Challenges.* Paper presented at OMNR Workshops on Emulating Natural Disturbances in Forested Landscapes. Chair in Forest Management and Policy, Faculty of Forestry, Lakehead University, Thunder Bay, Ontario, Canada.

Duinker, P.N.; Nilsson, S.; and Chipeta, M.E. (1998): Forestry for sustainable development and global fibre supply, *Unasylva* 49(193): 3–10.

ECE (1998): *People, Forests and Sustainability.* Timber Committee, Economic Commission for Europe, Geneva, Switzerland, http://www.unece.org/trade/timber/.

EDF (1995): *Economic Considerations in Forest Management*, White Paper no. 11, Paper Task Force, Environmental Defense Fund, Washington, USA.

Fleury, T. and Blinn, C.R. (1996): *Ownership Fragmentation in the Non-industrial Private Forest Lands of Northern Minnesota Between 1965 and 1990.* Paper presented at the Symposium on Non-industrial Private Forests: Learning from the Past, Prospects for the Future, Washington, DC, 18–20 February 1996.

Flowers, P.J.; Conner, R.G.; Jackson, D.H.; Keegan III, C.E.; Long, B.; Schuster, E.G.; and Wood, W.L. (1993): *An Assessment of Montana's Timber Situation 1991–2010*, Miscellaneous Publication no. 53, September 1993, Montana Forest and Conservation Experiment Station, School of Forestry, The University of Montana, Missoula, Montana, USA.

Flynn, B. (1998): International pulpwood trade still growing. *European Papermaker* 5(4): 27–31.

Hagler, R.W. (1995): *The Global Wood Fiber Balance: What it is; What it means?* Proceedings TAPPI Global Fiber Supply Symposium, Chicago, 5–6 October 1995.

Hagler, R.W. (1997): The Outlook for Global Timber Supply 1995–2030. In WRI: *Monitoring the Gobal Fiber Equation*. Wood Resources International, Virginia, USA.

Hanson, N. (1996): *Family-Owned Forests in an Era of Regulatory Uncertainty*. Paper presented at the Symposium on Non-industrial Private Forests: Learning from the Past, Prospects for the Future. Washington, DC, 18–20 February 1996.

Hayes, L. (1998): *Individual Perspectives on Southern Forest Sustainability: Conservation/Management Organizations.* Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Haynes, R.W., Adams, D.M. and Mills, J.R. (1995): The 1993 RPA Timber Assessment Update, General Technical Report RM–GTA–259, Rocky Mountain Forest and Range Experiment Station, United States Department of Agriculture, Fort Collins, Colorado.

Hearnden, K.W., S.V. Millson and W.C. Wilson. (1992): A Report on the Status of Forest Regeneration. The Ontario Independent Forest Audit Committee, October 1992. Ontario Ministry of Natural Resources.

Henry, T. (1998): *Watershed Protection Approach. Overview of the US Concept and Practice*. Paper presented at the Great Lakes/Baltic Sea Partnership Workshop, 4–6 November 1998 in Riga, Latvia.

Honer, T.G. and Bickerstaff, A. (1985): *Canada's forest area and wood volume balance*, 1977–81: An appraisal of change under present levels of management, Canadian Forestry Service Pacific Forestry Center, BC-X-272, Victoria British Columbia, Canada.

Hughes, J. and Radar, D. (1998): *A Case Study: The Weyerhaeuser–Environmental Defense Fund Conservation Partnership*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Hunt, J.B., Jr. (1996): *Report of the Governor's Task Force on Forest Sustainability*. The Governor's Office of the State of North Carolina, USA.

IIED (1995): *Forest Resources and Forestry Practices of Selected World Regions*, Substudy 1b produced by Wood Resources International Ltd. For the Study Towards a Sustainable Paper Cycle, International Institute for Environment and Development, London, UK.

Innes, M.R. (1994): Perspective on Eastern Canada's Timber Supply. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Irland, L.C. (1996): Forest and Fiber Supply Trends in the Frostbelt, Paper presented at the International Wood Fiber Conference, Atlanta, Georgia, 13–14 May 1996.

Irland, L.C. and Maass, D.I. (1989): Characterizing the north's hardwood resource, In Jones, S.B. and Stanturf, J.A. (eds.) *Hardwood Forest Product Opportunities: Creating and Expanding Businesses*. College Station, Pennsylvania State College on Agriculture, School of Forestry, pp. 73–81.

Irland, L.C. and Maass, D.I. (1994): Regional perspective: Forest conditions and silvicultural trends in the Northeastern USA, *The Forestry Chronicle* 70(3): 273–278.

Irland, L.C. and Whaley, R. (1993): Northern forest outlook: a working sketch of regional forest conditions in 2040. In: Lepisto T.A. (ed.) *Sustaining ecosystems, economics, and a way of life in the northern forest*. The Wilderness Society, Washington, D.C., USA, pp. 77–82.

Jaakko Pöyry (1994): *Fast-growing Plantations: Increasing Role in Wood Trade and Securing Wood Supply*. Jaako Pöyry Oy, Helsinki, Finland.

Johnson, P.M. (1996): *Political Economy Terms.* Dept. of Political Science, Auburn University, Auburn, AL. USA. http://www.duc.auburn.edu/~johnspm/gloss-p.htm.

Joint Council of Food and Agriculture Sciences. (1984): Reference document: needs assessment for the food and agriculture sciences, Washington, D.C. Joint Council of Food and Agriculture Sciences. 328 p.

Kaiser, F. (1994)*: Working Toward Ecosystem and Landscape Management: The US Experience*, In: Timber Supply in Canada. Challenges and Choices. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Kimmins, J.P. (1994): Sustainable Development in Canadian Forestry in the Face of Changing Paradigms. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Levy, M. (1994): Timber Supply in Ontario: Environmentally Sensitive??? and Transparent. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Lindberg, K.W. (1997): *Southern Pine Resources and Marketing.* Paper presented at Pacific Rim — World Wood Products Marketing Conference. 27–29 April, 1997, Vancouver, British Columbia, Canada.

Luppold, W.G, Baumgras, J.E. and Sheffield, R.M. (1998): A Comparative Analysis of Hardwood Saw Timber Quality on National Forests versus Adjacent Lands. *Forest Products Journal,* No. 5, Vol. 48.

Martin, M.R. and Darr, D.R. (1997): Market Responses to the US Timber Demand–Supply Situation in the 1990s: Implications for Sustainable Forest Management, *Forest Products Journa*l 47(11/12): 27–32.

McEvoy, T.J. (1998): *Legal Aspects of Owning and Managing Woodlands*. Island Press, Washington, DC and Covelo, CA, USA.

Messmer, M. and Booth, D. (1993): *An Economic Timber Supply Analysis for Ontario*, Working Paper, Policy and Economics Directorate, Forestry Canada, Ottawa, Canada.

Miller, I. (1994): British Columbia Status Report. In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Mills, W.L. Jr., Hoover, W.L., Vasan, S., McNamara, K.T. and Nagmbadi, V. (1996): *Factors Influencing Participation in Public Management Assistance Programs.* Paper presented at the Symposium on Non-industrial Private Forests: Learning from the Past, Prospects for the Future, Washington, DC, 18–20 February 1996.

Moffat, S.O., Cubbage, F.W., Cascio, A.J. and Sheffield, R.M. (1998): *The Future of Forest Management on NIPF Lands in the South: Results of an Expert Opinion Survey*. Proceedings of the 1998 Southern Forest Economics Workers (SOFEW) Annual Meeting. To be published by USDA Forest Service, Southern Research Station, USA.

Natural Resources Canada (1997): *Selected Forestry Statistics*, Natural Resources Canada, Ottawa, Canada.

Nilsson, S. (1996): *Do We Have Enough Forests?*, Occasional Paper no. 5, IUFRO, Vienna, Austria.

NRC (1998): *The State of Canada's Forests. The People's Forests 1997–1998*. Canadian Forest Service, Natural Resources Canada, Ottawa, Canada.

OMNR (1990): *Central Ontario Wood Supply*. Ontario Ministry for Natural Resources, Toronto, Canada.

OMNR (1992): *Ontario Forest Products and Timber Resource Analysis, Volumes I and II*. Ontario Ministry for Natural Resources, Toronto, Canada.

OIFA (Ontario Independent Forest Audit Committee) (1992): *A Report on the Status of the Forest Regeneration*, Ontario Ministry of Natural Resources, Forest Audit Secretariat, Sault Ste. Marie.

Ostrom, E. (1997): *The Comparative Study of Public Economics*. Acceptance Paper for the Frank E. Seidman Distinguished Award in Political Economy. September 26, 1997, Rhodes College Memphis. The P.K. Seidman Foundation Memphis, Tennessee, USA.

Owen, C. (1998): *Individual Perspectives on Southern Forest Sustainability: Forest Industry*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Pacheco, G., Abt, R.C. and Cubbage, F.W. (1997): *South-wide Timber Supply Projections and Assessment*. In: Proceedings of the Southern Forest Economics Workers Meeting. University of Tennessee and USDA Forest Service, Southern Research Station, USA.

Parent, S. (1997): Monitoring the global wood fibre equation. Eastern Canada, In WRI: *Monitoring the Global Fiber Equation*. Wood Resources International, Virginia, USA.

Perez-Garcia, J.M. (1993): *Global Forestry Impacts of Reducing Softwood Supplies from North America*, CINTRAFOR Working Paper 43, University of Washington, Seattle, Washington, USA.

Phillips, W.; Beck, J.; Boulter, D.; Booth, D.; and Clark, K. (1995): *A Delphi Study of Growth and Yield in Canada's Forests. Report of a scientific survey*. Working Paper. Policy, Economics and International Affairs Directorate, Canadian Forest Service, Ottawa, Canada.

Popovich, L. (1998): *Unifying Partial Solutions to Further Sustainable Forestry*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Random Lengths (1997): *South's timber basket under strain*, Random Lengths, December 1997 issue, Random Lengths Publications Inc.

Reed, L. (1998*): North American Timber Supply Trends in a Global Context*. Paper presented at the Widman Seminar, "North American and Overseas Wood Products Markets: Outlook 1999". Vancouver, 23–24 November 1998.

Rodgers, K. (1998): *Individual Perspectives on Southern Forest Sustainability: Non-industrial Private Forest Landowners*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Rooks, A. (1998): The U.S. South: Steaming Ahead. *PIMA's International Papermaker* 80(5) 46–52.

RTI (1992): *Economic Analyses of Coastal Nonpoint Source Pollution Control: Forestry*. Research Triangle Institute, Research Triangle Park, NC, 15 December 1992.

Sampson, N. (1992): Pivot Point for Public Forests. *American Forest.* (9–10) 98.

Sampson, N.R. (1996): Keynote Address: *Non-industrial Private Forests — Learning from the Past, Prospects for the Future.* Paper presented at the Symposium on Non-industrial Private Forests: Learning from the Past, Prospects for the Future, Washington, DC, 18–20 February 1996.

Smith, G. (1998): *Policy Options to Advance Sustainable Forestry: Conservation/Environmental*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Smith, S. (1994): Perspective on Western Canada's Timber Supply, In: *Timber Supply in Canada. Challenges and Choices.* Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Smith, W.B.; Faulkner, J.L.; and Powell, D.S. (1994): Forest statistics of the United States, 1992 metric units. Gen. Tech. Rep. NC-168. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 147 p.

UNFAO (1996): *North American Timber Trends Study*, Geneva Timber and Forest Study Papers ECE/TIM/SP/9, United Nations, New York and Geneva.

UNFAO (1998): *Global Fibre Supply Study*, Forest Products Division, Forestry Department, Food and Agriculture Organization of the United Nations, Rome, Italy.

USDA (1988): The south's fourth forest: Alternatives for the future. Forest Resource Report 24. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 512 p.

Wear, D. (1998): *Forest Land Use Changes: Fragmentation, Urbanization and Population.* Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Wedeles, C.L.; Van Damme, D.C.; and Sully, L. (1995): *Alternative silvicultural systems for Ontario's boreal mixed woods*, Canadian Forest Service, Sault Ste. Marie, Ontario, Canada.

White, F. (1998): *Extensive Forestry*. Paper presented at the Forum "Perspectives on Sustainable Forestry for the South", The Southern Center for Sustainable Forests, 12–13 November 1998, Charlotte, North Carolina, USA.

Williams, D.H. and Tanz, J.S. (1994): Summary and Analysis of Provincial and Territorial timber Supply Status Reports, In: *Timber Supply in Canada. Challenges and Choices*. Conference Proceedings, 16–18 November 1994, Natural Resources Canada, Ottawa, Canada.

Williams, J.; Duinker, P.; and Bull, G. (1997): *Implications of Sustainable Forest Management for Global Fibre Supply,* Working Paper GFSS/WP/03, August 1997, Food and Agriculture Organization of the United Nations, Rome, Italy.

Woodman, J.N. and Cubbage, F.W. (1994): *Potential Costs of Mandatory Best Management Practices in Georgia*. In Proceedings, 1994 Southern Forest Economics Workers (SOFEW) Annual Meeting. Warnell School of Forest Resources, University of Georgia, Athens, Georgia, USA.

WRI (1997): *Global Wood Fiber Study*. Final Report to European Commission. October 1997. Wood Resources International Ltd., Reston, Virginia, USA.

WRI (1998): *The Global Timber Supply/Demand Balance to 2030 – Has the Equation Changed*. Wood Resources International Ltd., Reston, Virginia, USA.