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# Forest Level Effects of Stand Density Treatments



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## **Forest-Level Effects of Stand Density Treatments<sup>1</sup>**

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### **Key ideas**

1. Timber supply is driven and controlled by much more than stand growth.
2. Stand treatments affect timber supply through specific, understandable mechanisms.
3. For stand treatments to have a recognized effect on forest-level values, they must be incorporated into a forest-level analysis.
4. Planning silviculture activities should not be based on stand-level objectives alone.

### **Outline**

I will start by explaining some fundamental concepts and terms so that we are all speaking the same language. These include timber supply and related ideas and terms. Then we'll examine timber supply analysis, and the data used in timber supply analysis, particularly the data relevant to discussions about stand density management. Finally, we'll examine the mechanisms by which stand density management activities can affect estimates of timber supply – the link between forest-level and stand-level planning. At the end, I will touch on the framework for silviculture strategy planning that my business partners and I have developed over the last few years.

### **Concepts**

#### **What is timber supply?**

Let's start with a simple definition of timber supply: *Timber supply is the rate at which timber becomes available for harvesting.* Timber supply is not the same as timber inventory. Inventory is a stock, measured in cubic metres. Supply is a flow or rate, measured in cubic metres per year. The rate of harvest draws on the standing timber volume, which is replenished by growth.

This definition could be extended to: *Timber supply is the rate at which timber is made available for harvesting in response to social, economic, and environmental considerations.* Timber supply is the portion of the inventory that we make available for harvesting.

We make timber available according to social, economic, and environmental considerations. Social considerations include management objectives for non-timber values and issues such as community stability. Economic considerations, such as prices for wood products, affect utilization standards and the amount of available timber that can be profitably harvested. Environmental considerations include such things as riparian buffers and seral stage structure.

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<sup>1</sup> Paper presented at the Stand Density Management Conference, Edmonton, Alberta, Nov. 23-24, 1998. Most of the slides used in the presentation are available on Cortex's web site. <http://www.cortex.org>

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<sup>3</sup> Some of the concepts and graphics presented here have been drawn from earlier papers and presentations developed by Cortex staff, mainly Cortex (1997), Tanz (1995), Williams (1994), and Williams (1998).



## Elements of a timber supply forecast

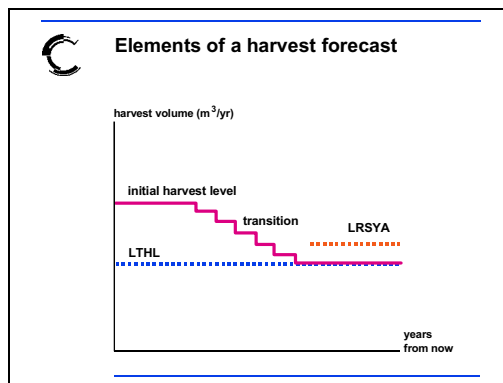
Timber supply forecasts project the evolution of the forest over the planning horizon of interest, often two to three rotations. They typically show three phases: an initial harvest level (often the current allowable annual cut, or AAC), a long-term harvest level (LTHL), and a transition from the initial harvest level to the LTHL (Fig. 1).

The long-run sustained yield average (LRSYA), is defined in the Alberta Land and Forest Service (ALFS) planning manual as, "the hypothetical timber harvest that can be maintained indefinitely... once all stands have been converted to a managed state under a specific set of management activities."

We can calculate LRSYA by multiplying the area of each component of our forest (e.g., yield class or analysis unit) by the mean annual increment (MAI) associated with the expected harvest age (e.g., culmination age) for managed stands. LRSYA is the theoretical maximum biological production capacity of the forest landbase, assuming that every stand is cut exactly at the specified rotation age and no constraints affect harvest levels. I say theoretical, because in practice we do not cut stands exactly at the prescribed rotation age, and we do have constraints. But LRSYA does serve as a useful benchmark.

The long-term harvest level, or LTHL as I refer to it, is the level of sustainable harvest found through modelling the evolution of the forest. It is the harvest level that can be sustained indefinitely given a particular forest management strategy, stand management regimes, and estimates of timber growth and yield. It is less than the LRSYA because of management constraints and sub-optimal scheduling.

Figure 1. Elements of a typical forecast.



## Timber supply forecasts

The long term is the period that begins when the harvest reaches its sustainable LTHL, usually when most harvesting is mainly from managed stands. This does not mean that no old growth remains in the forest, just that the harvest comes almost entirely from managed stands. The short term is the period beginning now, and during which the scheduled harvest levels (AAC) are significantly different than the LTHL. The mid term begins with the end of the short term (often the second decade) and ends when old growth is no longer a significant part of the harvest (Fig. 2).

The situation shown here, where current harvest levels are higher than the LTHL, is possible only if there is a large stock of mature standing timber available for harvesting.

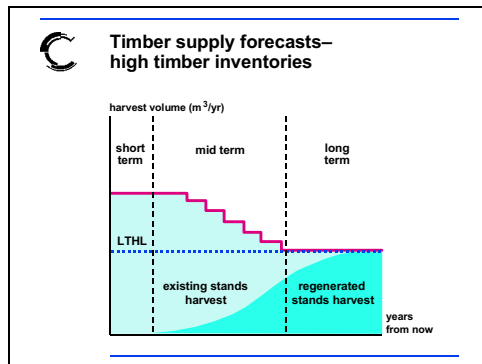
A different, but complementary view of the planning horizon is that the long term is when supply is determined by forest growth and management objectives, medium term is when supply is determined by



interaction of available inventory and timing of availability of second growth, and short term is determined by the available inventory and decisions about transition strategy.

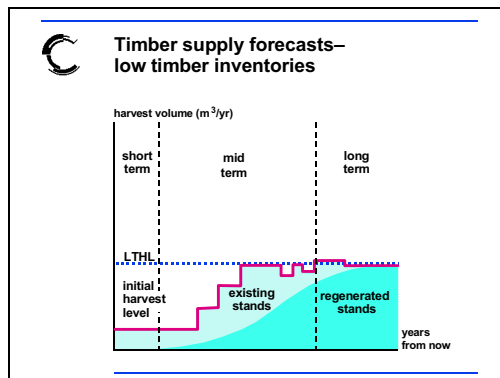
We say that there is a *surplus of timber* in existing stands when lands allocated to timber production can provide more harvest volume from existing stands than is needed to maintain the harvest at the LTHL.

**Figure 2. A typical forecast when there is a surplus of available mature timber.**



The situation shown in Figure 3, where current harvest levels are less than the LTHL, is due to a *deficit or scarcity of mature timber*.

**Figure 3. A scarcity of mature timber available for harvesting.**



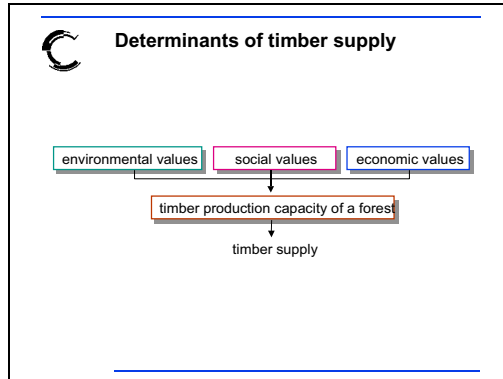
### What are the key influences on timber supply?

The key influences on timber supply are environmental values, social values, and economic values (Fig. 4).

In this context, we can restate the definition of timber supply as: the flow of timber is driven by economic forces, shaped by social and environmental values, and limited by productive capacity of the forest.



**Figure 4. The key influences on timber supply: environmental, social, and economic values.**



### Alternative pathways to the LTHL

It is important to understand that the shape of the harvest forecast is *chosen*. It is controlled through policy. An example of a harvest policy is:

*In the first two decades maintain the current harvest at the highest possible level, thereafter increasing or declining to LRSYA, without varying between decades by more than 12% per decade.*

Note that this is an example, not legislation or firm policy.

The harvest forecast is not a technical attribute of a forest, it is a decision-maker's choice. There are many possible pathways for transition to the long-term harvest level. The four forecasts shown in Figure 5 are all technically (physically/biologically) feasible. All four begin at the same initial cut level, and all end at the same LTHL. Choosing one over another is a matter of policy.

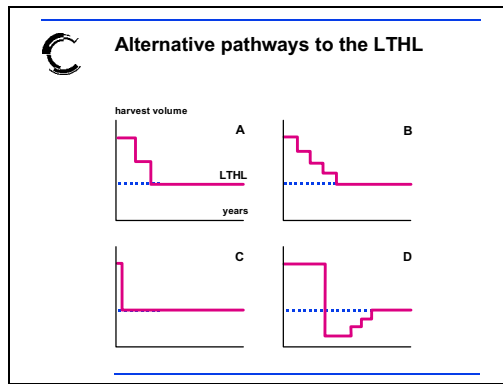
Scenario A maintains the current AAC for two decades, followed by two relatively large decreases to the LTHL. Scenario B reduces the AAC in a series of smaller steps down to the LTHL. Scenario C shows an immediate drop to the LTHL. In scenario D, the current harvest level is maintained as long as possible, but eventually has to make a precipitous drop to a level below LTHL, from which it can only increase up to the LTHL when second growth stands reach minimum harvest age.

In evaluating these alternatives, the forest manager must consider biological, economic, and social objectives. Scenarios A and B would both likely be acceptable to the Chief Forester or CEO of a woods operation supporting a large mill in a small community. It is unlikely that the people in that community would be pleased with scenario C or D.

The point is that these are choices, not technical decisions.



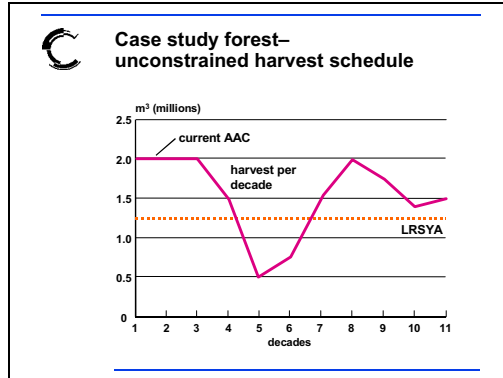
Figure 5. The shape of a harvest forecast is chosen.



**How do we arrive at such a schedule?**

If we were to log every stand at culmination age, and apply no flow constraints, the resulting “pure” timber supply for a forest might look something like Figure 6, in which the schedule of harvests varies greatly from decade to decade.

Figure 6. An unconstrained harvest schedule.

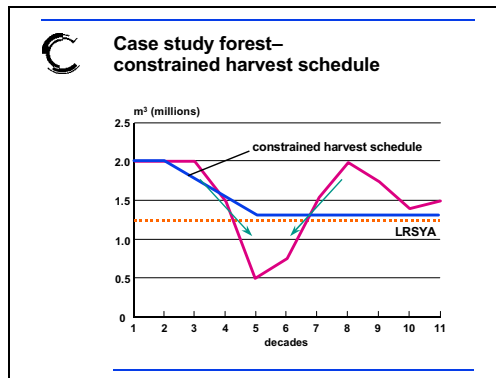


In real life, the fluctuations of such a schedule are undesirable. Constraints are used to smooth the flow of volume to make it less variable. As shown by the arrows in Figure 7, some stands that would have been logged in decade 3 are instead held longer to help make up the shortfall in decades 5 and 6. Other stands that would have been logged in decades 8 and 9, are instead harvested early to help make up the shortfall.

The supply forecast resulting from applying flow constraints is shown in Figure 7 as the constrained harvest schedule. By the way, the shape of this forecast is very typical of many forecasts for Timber Supply Areas (TSAs) in British Columbia.



**Figure 7. Flow constraints temper harvest-level fluctuations.**



## Analysis

### What is timber supply analysis?

Timber supply analysis is a process of exploring the timber supply effects of alternative forest management strategies and timber harvesting levels. We undertake timber supply analysis with what might be called a forest modelling system. Figure 8 is meant to represent the process described in the ALFS Interim Forest Planning Manual.

At the top, we have goals, indicators, and objectives that define the future forest we are trying to create. They are determined through a process called Landscape Assessment, which is the planning manual process aimed at evaluating biological, economic, and social needs for a management unit to ensure that forest management activities do not “unduly impact” opportunities to utilize or access other values. Goals define the desired future forest in broad terms; indicators are the criteria for evaluating progress toward a goal; and objectives are clear, quantitative statements of expected results—specific levels of indicators.

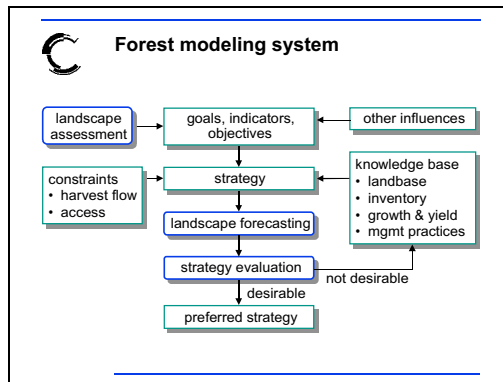
There may be other influences that affect our vision for the future forest. For example, some management decisions, including the management objectives for the forest, are made elsewhere (e.g., legislation, Canadian Council of Forest Ministers, Canadian Standards Association sustainability criteria and indicators).

A strategy is formulated to create the forest defined by the specified goals, objectives, and indicators. Typically, these include harvest schedule options such as order and timing of harvest, silvicultural inputs, forest health, and protection. Next, in a process known as landscape forecasting, the evolution of the forest is projected into the future using information in a knowledge base and projection rules embedded in the model. Indicators of the state of the forest are produced (e.g., age-class distribution) and used in a strategy evaluation. A preferred strategy is chosen, or a new strategy is formulated, forecast, and evaluated.

Landscape forecasting is done with a forest planning model. Strategy evaluation is based on an evaluation of indicators.

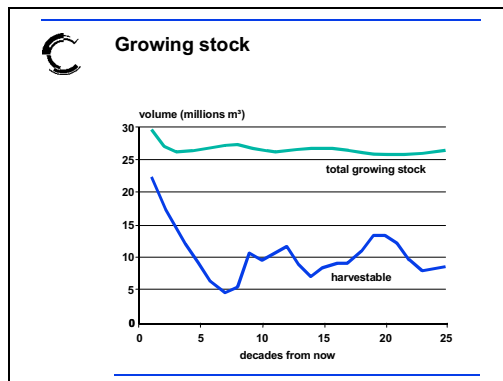


Figure 8. A forest modelling system that meets the requirements of the ALFS Interim Forest Planning Manual.



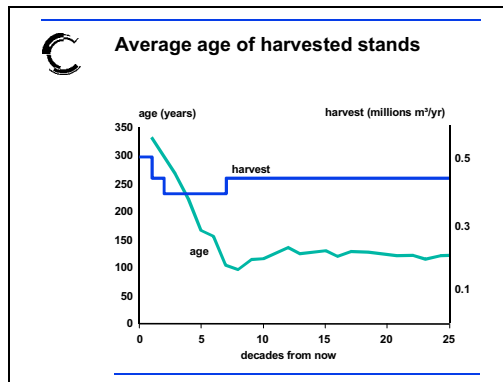
Today, we usually use computerized models of timber supply to approximate the effects of various policy and management “levers” on a simulated forest. Such levers could include harvest level, timing of harvest, and amount of planting or other treatments we might undertake. The model forecasts the future values of key indicators such as total growing stock inventory and the harvestable component of growing stock inventory (Figure 9). The average age at which stands are harvested is another useful indicator (Figure 10). Notice that once the original legacy of existing timber has been harvested, the average harvest age stabilizes. In this figure the harvest forecast has been overlaid to show the relationship between harvest flow and average age of harvest--the decade in which the rate of harvest can be increased (decade 7 in this example) depends on when second growth reaches minimum harvest age.

Figure 9. Growing stock inventory indicators.





**Figure 10. Average harvest age indicator.**



## Data

Our knowledge base for timber supply modelling can be divided into four categories of information: landbase, growth and yield, management practices, and forest inventory.

### Landbase Determination

Identifying the timber harvesting landbase is the “netting down” process that reduces the landbase to the parts that will be available for harvesting. The following list shows the types of areas that are excluded from timber harvesting:

- non-productive land
- inoperable areas
- incompatible/single use
- environmentally sensitive areas
- not satisfactorily restocked areas
- unmerchantable stand types
- roads and landings
- riparian buffers
- subjective deletions

Frequently these areas that cannot be harvested are not deleted from the database. They have attributes that contribute to non-timber values, so we leave them in the database but do not allow them to be harvested.



### Projecting stand yield

Two sets of yield curves are used in a typical timber supply analysis: one representing development of natural, untreated stands, and another representing managed stands.

Our interest at this conference is in stand density management treatments. If such treatments are to have an effect on timber supply, the effects of such treatments must be recognized in the yield tables. To put things simply, if we don't incorporate the effects of stand treatments in the model, they won't show up in timber supply forecasts.

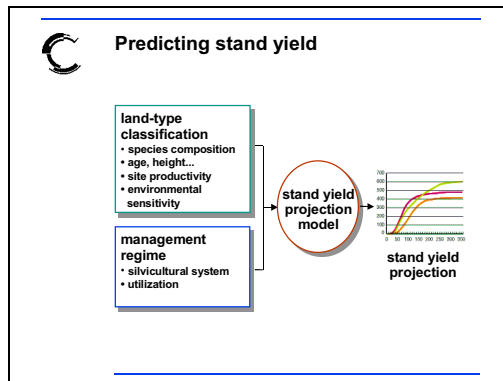
### Yield classes

For modelling purposes we usually aggregate stands that have the same attributes and will be managed in the same way. A *yield class* (or *analysis unit* as it is called in British Columbia) is an aggregate of all stands with the same tree species, the same level of site productivity, on which we expect to apply the same management regime, and from which we expect the same growth and yield.

### Information used to generate stand yield predictions

The growth and yield information, which is essentially a yield table, is produced with a stand yield projection model (Figure 11). These yield tables represent the way in which stands are expected to develop. So we frequently use different tables for existing or natural stands than for managed or regenerated stands.

**Figure 11. A yield projection model is used to produce the yield tables for timber supply modelling.**



### Links to forest-level values

When trying to understand how a particular management activity might affect timber supply, it is helpful to identify the mechanism by which timber supply could be affected. Anything we do in the forest affects timber supply through one or more of three types of mechanism: landbase effects, growth and yield effects, and policy effects. Understanding the link between silvicultural activities and timber supply requires understanding these effects. While there is overlap among them, it is still helpful to use these categories to guide development of silvicultural regimes and options.

### Landbase effects

By *landbase effect*, I mean that a treatment will change the area available for harvesting.

Stand density management can allow some harvesting where it would not otherwise be allowed, e.g., commercial thinning if the stand is younger than minimum harvest age. Treatments can also change the



order in which stands become available for harvesting by reducing minimum harvest age. However, on the whole, stand density management activities don't have a significant landbase effect.

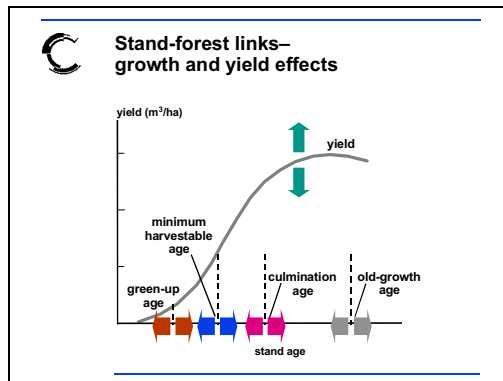
### Growth and yield effects

As stand managers, we often argue about the final volume yields attributable to a particular stand type under different management regimes. But when we are concerned with timber supply, the timing of availability of the volume yield is often far more important than the final yield itself. For example, when stands reach minimum harvestable size is crucial in many timber supply situations.

In Figure 12, the double headed arrows signify that stand density treatments can be used to alter some important milestones in a stand's development: green-up age, minimum harvestable age, the age at which MAI culminates, and the age above which stands are considered to have old-growth characteristics.

By managing stand density, we can influence timber supply, particularly if we focus on the physical attributes of stands rather than their age. For instance, can silvicultural treatments be used to create the physical attributes of old-growth in a stand at a younger age than would otherwise occur? If so, then we can have a significant effect on timber supply in forests where it is constrained by the amount of old-growth.

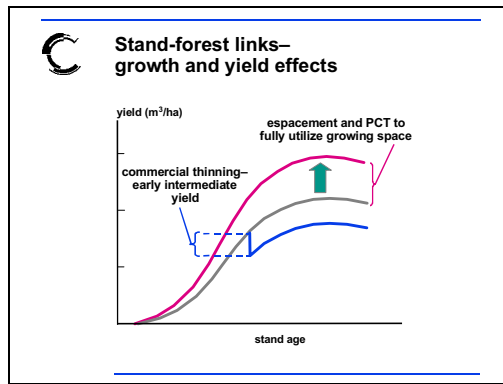
**Figure 12. Stand development milestones that can affect timber supply.**



Proper espacement and pre-commercial thinning can be used to increase yield. Commercial thinning can be used to produce intermediate yields in stands that would otherwise be excluded from harvesting until they reach minimum harvestable age (Figure 13).



Figure 13. Yields can be affected by certain stand density management treatments.



### Policy effects

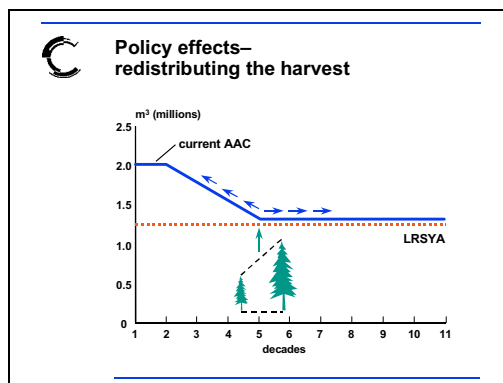
Policies concerning non-timber values underlie many forest cover constraints in timber supply models. In some timber supply situations these constraints limit timber supply. Green-up and old-growth constraints are the most common examples.

We can affect timber supply in such situations if stand-density management treatments can be used to alter the attributes of stands so that the important non-timber values are created sooner or in different amounts than would otherwise be the case.

### Policy effects—redistributing the harvest

Timber supply can be very dynamic, and difficult to predict—hence the need for computer modelling. It is not enough to just calculate LRSY. For example, increasing harvest yield can have an unpredictable effect on the harvest flow (Figure 14). Increasing volume production in decade 5 allows the harvest of some stands to be rescheduled to ages at which yields will be higher. That is, it may release older stands (that were being held because of flow policy constraints) for earlier harvesting, converting them to higher-yield managed stands sooner. It could also allow young stands to be held longer, increasing their production or filling subsequent “holes” in the supply forecast.

Figure 14. Treatment can redistribute the harvest through time.

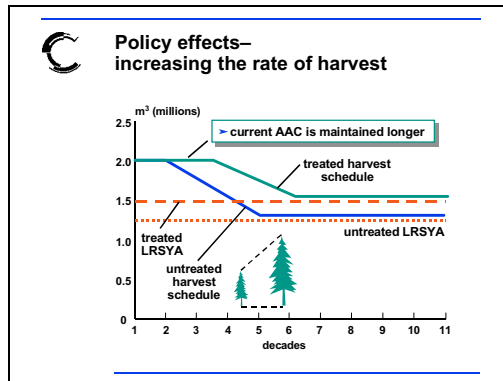




*Policy effects—increasing the rate of harvest*

Silviculture treatments can change the shape of the harvest forecast (Figure 15). Here we see that not only is the LRSYA increased by treatment, but the shape of the forecast is changed as well. The initial harvest level is sustained much longer, the transition is more gradual, and the LTHL is reached later.

**Figure 15. Changing the shape of the harvest forecast.**



**Analysis-based strategy development**

Stands are managed within the context of a larger forest or landscape unit. Therefore, silviculture strategies cannot be based only on stand attributes—a forest-level, analytical approach should be taken. Such an approach involves first defining biologically feasible regime options. Those stands having attributes that make them candidates for treatment will be considered.

Forest-level objectives related to timber supply, targets for specific products (e.g., sawlogs of a specific grade), or employment will be defined in the “landscape assessment” phase of the planning process described in the Alberta Land and Forest Service Interim Planning Manual.

A *regime table* can be used to catalogue feasible treatments, candidate or opportunity areas, and how each contributes to forest-level objectives. Using the results of forest-level modelling (e.g., shadow prices from linear programming), these opportunities can be ranked (Figure 16).

**Figure 16. A regime table can be used to catalogue feasible treatments and candidate areas.**

**Develop a regime table**

Treat-ments	Opportunity Area	Contribution to Objectives	Rank



## Summary

1. Timber supply is driven by economic forces, shaped by social and environmental values, and limited by the productive capacity of the forest.
2. Stand density treatments influence timber supply through landbase, growth and yield, and policy effects. Understanding the link between silvicultural activities and timber supply requires understanding these effects. Then an objective analytical approach can be used to guide development of regimes, and plan strategic silvicultural programs.
3. If stand density management treatments are to have a recognized effect on forest-level values, they must be worked into a forest-level analysis. If the effect of treatment is not incorporated into the timber supply analysis, no forest-level effect will be recognized.
4. Silvicultural activities cannot be planned based on stand-level objectives alone. A properly constructed forest-level analysis integrates multiple objectives and provides the basis for strategic and tactical planning.

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