STAND INVENTORY AND ANALYSIS - EVALUATION AND MODELLING OF FOREST PRODUCT SUSTAINABILITY THROUGH AREA REGULATION:

FOR

GREEN RIDGE STATE FOREST
GENERAL FOREST MANAGEMENT AREA

Prepared by

Mark D. Beals, Forest Manager
Jesse Morgan, Asst. Forest Manager

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Background: Green Ridge State Forest (GRSF) has been managed under the Forest Regulation strategy of Area Control for achieving sustained yield of forest products since 1969. Furthermore, the Long-term Sustainable Forestry Management for Green Ridge State Forest (2011) specified that the General Forest Management Area (GFA) will continue to be managed under the principles of area control. Area control forest regulation is defined simply as regeneration harvest of an equal amount of forest per year. This acreage to be harvested each year is determined by dividing the total forest area by the rotation age. The rotation age selected for the GRSF general forest area is 100 years.

The current methodology used for applying area control within the GFA at GRSF is to "Manage" approximately 250 acres annually for end of rotation regeneration harvest. This slight variation to the principle of area control allows the forest manager to account for the sustainable amount of acreage to be managed annually while retaining areas within for specific ecological and/or environmental attributes. This methodology makes it easy to model long-term sustainability of the silviculture schedule and assure that harvest levels are not exceeded on the general forest area. However, additional information is needed to assist the forest managers in regulating a balanced supply of wood products yielded within the annual harvests. Up until now, factors that influence the volumes of wood products coming off the annual managed areas were not quantified. Additional forest stand level data is needed to illustrate and verify this model for sustainability.

Inventory: A five year stand level forest inventory project commenced during the fall of 2010. The objective of this inventory is to obtain stand level forest inventory data for the entire forest. To date this project is 70% completed. 95% of the General Forest Area is completed. The entire project is planned to be completed by July 2015. Necessary forest inventory data collected for each stand includes stand age, species composition by forest type, mean dbh, trees per acre, basal area, stocking, and site index.. Once the data is collected and analyzed, the results are recorded in the GIS attribute tables for the corresponding stand map.

Isolation of Existing General Forest Area that is inoperable and/or inaccessible. Another factor that should be considered in accurately managing for even-aged silviculture sustainability through area control is the operability and/or accessibility of the timber. In order for the area to be managed under this scheme, it must be available for harvest. If it is not, this unavailable acreage should be removed from the acreage used to calculate the annual harvest or allowable cut. This variable has been loosely accounted for by adopting the "Managed" variation mentioned above. However, if extensively large areas of inoperable or inaccessible area exist within the current General Forest Area, it may be more appropriate to identify them as reserves and eliminate the acreage from the annual allowable harvest calculation. A combination of ARC GIS tools and careful study of geographical features have been employed to locate and isolate such polygons from the existing general forest areas. Areas that should be considered for isolation from the General Forest Area acreage include large areas with slopes exceeding 40%, and areas that are landlocked in terms of accessing for forest harvest operations. To date this study

is not complete. A preliminary gross estimate is that 5000-6000 acres will be isolated within the GFA as the result of this study.

There are also large areas within the GFA that are operable and do not have major barriers to access but would require development of new logging roads in order to access the stands for harvesting timber. Such areas will be identified in this study. Such areas should be reviewed by the Inter-disciplinary team and a determination be made whether new road construction will be permitted. If new roads will not be permitted into such areas, this acreage should also be removed from the allowable cut calculation.

Based on the preliminary results of studying inoperable and/or inaccessible areas within the GFA, it is recommended that the annual allowable cut or "managed area" be reduced from 250 managed acres to 200-220 managed acres annually.

Stand Inventory Analysis Results:
The following conclusions are based on analysis of the data collected within the GFA to date which includes approximately 80% of the area. It is pertinent to note that these results are somewhat biased because the highest proportion of the stands that have not yet been inventoried are the stands that have already been managed or regenerated. Therefore, it is expected that the younger stands are not proportionately represented in the data set.

Species Composition: All stands were assigned a forest type based on the predominant species or group of species within the population. Based on the stand data collected so far, the GFA is comprised of the following forest types: Mixed Oak (72%), Hardwood/Hard Pine (12%), Hardwood-White Pine (6%), Northern Hardwoods (3%), White pine (3%), Hard Pine (2%), Cove Hardwoods (1%), and Non Forest (1%).

Age: A reliable statistic of stand age can not be derived for the GFA since we know that the lion's share of the data remaining to be collected is made up of the youngest stands. However, stand age factors pertinent to area control and modeling long-term sustainability can be discussed based on the current analysis. One pertinent statistic is that approximately 26% of the GFA is currently 100 years or greater. In other words, 26% of the GFA is currently mature or over-mature based on the rotation age selected for managing the GRSF GFA under area control. This statistic does not indicate that the regeneration harvest rate needs to be increased but it does indicate that there may be forest health and productivity challenges to be considered

Stocking: The stocking level within a stand is a measure of competition within the population and a good indicator of forest health and productivity. In general, overstocked is an indicator that the health, vitality, and productivity of the stand could be enhanced by applying a silviculture treatment to reduce the stocking to a more optimal level for individual tree growth within the population. One concern that has been raised for GRSF

is that there is not enough work being done to address the health and productivity of overstocked stands.

Preliminary analysis of stocking in the GFA indicates that 10,932 acres is currently overstocked. This number would roughly indicate 50% of the GFA is overstocked. For forest management and modeling purposes, it is important to break this number down into functional classes that can be further discussed from a sound silviculture and operational perspective. For this purpose, the overstocked stands were broken down into three age classes as listed below:

Stand Age (yrs)	Acres Overstocked
0-40 (*Precommercial)*	116
41-80 (*Intermediate)*	1877
>80 (*Mature)*	8444
Total	10437

Precommercial – This age class represented the fewest acres of overstocked stands. This number is likely to rise as the remainder of the inventory is completed because most of the stands remaining to be inventoried fall within this age class. None-the less, this age class grouping was selected because institutional knowledge and experience has illustrated that stands on GRSF can not be thinned to achieve optimal stocking without cost until they reach at least age 40. Ideally, stands in this age class would be thinned to the optimal stocking level at least once during this phase of their development. However, this work is too labor intensive and cost inhibitive to the current state forest operation.

Intermediate – Overstocked stands in this age class is significant and an indicator that an increase in intermediate silviculture practices may be warranted. This grouping for age class was selected because it represents the earliest age that stands likely could be thinned to an optimal stocking level that is cost neutral or generate some positive revenue for the state forest operation. Furthermore, stand age 80 is the upper limit where intermediate treatment may enhance the residual stand prior to the end of rotation harvest without negatively impacting the regeneration of that stand.

In recent years, silviculture prescriptions have been applied in some overstocked stands in this age class. The lessons learned in such projects include that the preparation includes a lot of man hours of skilled employees to mark the thinning by prescription. Furthermore, the success of the project is dependent upon the availability and dedication of the most responsible and properly equipped operators.

Based on the preliminary results of the inventory analysis, it is recommended that the forest managers take a closer look at the overstocked stands indicated in this age class to discern the feasibility of carrying out the optimal silviculture prescriptions for such stands. Once this is done and all the data is compiled and analyzed, a plan to address these overstocked stands over the next 10-20 years should be developed. Certainly the plan would require a significant increase to staff resources dedicated to silviculture activity.

Mature- Overstocked stands in this age class represent approximately 60% of the overstocked stands. This statistic is not surprising nor alarming because they are the oldest and likely never had intermediate treatment to reduce stocking. These stands are near or over the 100 year rotation age. Since these stands are mature, any silviculture work to be applied should be directed by regeneration objectives. Therefore, intermediate treatments to reduce stocking in these stands is not recommended at this time.

From the even-aged silviculture perspective, all of these stands should be considered for regeneration at this time. However, this would not facilitate long-term sustainability of forest products or even distribution of age classes within the GFA. The principle of area control implies that it will take a full rotation to regulate a forest. In the GRSF GFA model, it will take approximately 60 more years until regulation is achieved and there is an even distribution of age classes from 0-100 years. Until that time, some stands may reach 140 years before being regenerated.

The combination of managing for long-term sustainability and the silviculture of regenerating even-aged stands does create a paradox when the current mean age of the forest is so close to the rotation age calculated for achieving area control. This paradox will be described more below. This is an area where there is not a lot of institutional knowledge available to draw upon for suggesting sustainable solutions to these issues. The data analysis for the GRSF GFA does suggest that there may be ample opportunity to do some experimental research regarding these issues on this state forest.

Site Index: Site index is a relationship between the total height of dominant or co-dominant trees and their age used as a measure of site quality or productivity. Site index is another variable that should be considered when managing for long-term sustainability of forest products through area control. The practice of applying end of rotation harvests within 220 managed acres ach year models silviculture sustainability. However, this does not imply that the volume of wood products yielded will be stable each year. One factor for this annual variation may be the productivity potential of the site. In general, a lower site index site will yield less wood products than a higher site index site. There are many other factors including silviculture prescription and the amount of retention that contribute to the variation in yield from year to year. Such factors are stand specific and can not be accounted for or modeled in advance. However, Site index can be included in modeling sustainability now that the proportion of the site index ranges within the GFA are known.

Following is the break down of the site index classes by acreage found within the GFA:

Site Class	**Acres**	**Percentage of GFA.**
Good (Site index = 65-74 for mixed oaks)	6466	30%
Moderate (Site Index = 55-64 for mixed oaks)	9533	44%
Low (Site Index = 45-54 for mixed oaks)	5245	24%
Poor (Site Index <45 for mixed oaks)	340	2%
Total	**21584**	**100%**

Based on the results above, it is recommended that the 200-220 managed acres selected annually should be proportional to the site index. In other words, on average 60 acres on good sites, 95 acres on moderate sites, 50 acres on low sites, and 4 acres on poor sites should be selected to be managed each year for regeneration silviculture. Using this model to help direct the future forest management should facilitate some stabilization of forest products yielded from the forest on an annual basis. Furthermore, this scheme will lead towards an even distribution of age classes across the site classes and eliminate bias that occur being directed by stand age and stocking.

MODELLING:

The compilation and analysis of the stand inventory allows the forest managers to model the forest using ArcMap. The data for each stand is contained in attribute tables within GIS. This allows the data to be queried to prioritize the stands to be managed in the future. Furthermore, a combination of attributes can be queried to locate the priority stands for treatment in every given year. As management is completed within these stands, the data will be updated in data base and essentially create a complex fluid model of the state forest GFA.

Other Considerations:

Spatial distribution and large stand dissection

The model described above will be used to direct the future silviculture program within GRSF. However, it is limited to using the silvical attributes. This model can only generate outputs based on science. Forester managers should still use their knowledge and experience in combination with the model to guide the actual silviculture program on the forest. Two specific factors that the model doesn't consider include spatial distribution and size of harvest. For example, the model will select the priority stand for regeneration based on the current stand conditions. However, this stand may be located between adjacent stands that were regenerated within the last five to ten years. To regenerate the model selected stand in this case would not provide non silviculture objectives that are important to the overall ecological diversity of the forest.

Some stands within the GFA are very large because they originated at the same time as the result of the previous expansive harvests during the Mertens era. The model therefore may select a large stand as the priority for regeneration for a given year. However, for non silviculture reasons, it may not be recommended to regenerate the whole stand but rather to dissect the stand into functional units based on other factors such as forest opening size, and spatial distribution.

There are many other factors that should be considered in decision making about the silviculture program beyond what the model can compute. The future of the silviculture program should be based on a combination of the model generated outputs and the logic of the practitioners.

Partial harvests in over-mature stands – a topic for discussion and opportunity for experimental research.

In general mature to over-mature even-aged stands should only have silviculture treatments directed toward regenerating the stand if it is to remain in even-aged management. Therefore, partial harvests such as thinnings are not generally recommended because it will favor regeneration of shade tolerant (often undesired e.g. red maple) species within the stand . This would lead to the species composition being changed when the final harvest does occur because the propagules are still present at the time of final harvest. This would likely cause problems for regenerating the stand to a desired composition. However, little is known how stands would respond to a thinning if the final harvest is planned for 25-40 years out. It may be that regeneration can still be achieved since the over-mature stand wont actually be harvested until it is 120-140 years old. It is recommended that this issue be researched some more and that a few stands may be selected to study.

Another application to be considered for addressing overstocked and over-mature stands may be multi-phase regeneration methods such as shelterwood or thinning from below. The objective of a multiple phase shelterwood harvest is to enhance the stand to promote establishment of desired regeneration and then return to the stand to harvest the mature timber once the desired regeneration is established. It may be cost inhibitive to do this in many stands but some may be cost neutral while improving the health and vitality of the mature stand and facilitate advanced regeneration. It is recommended that this application be experimented with on some over-mature stands to study the feasibility. This may be most practical in conjunction with a final harvest in an adjacent stand. The best application is likely in the large stands that need to be dissected to reduce opening size and provide for spatial distribution objectives.