論 文 の 内 容 の 要 旨

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論文題目 A Study on the sustainable management of natural teak forests in Myanmar

（ミャンマーにおける チーク天然林の持続的経営に関する研究）

Natural teak-bearing forests in Myanmar have been managed under the systematic way so called Myanma Selection System (MSS, formerly named Brandis Selection System, BSS) over the centuries. Teak and hardwoods production were conducted under the control of girth limit, periodic limit, and annual allowable cut, AAC. Dr. Brandis, a German forester, initiated the development of yield formula of AAC for the assurance of future consistent supply of teak. This yield formula is still in use for the estimation of AAC, believing that it will provide the sustainable productivity of teak. However, nowadays, Myanmar has been experiencing degradation of natural teak forest, consequent affect of over-exploitation above the prescribed cut limit, and challenging of restoring its degraded forests. This study was aimed to reveal the real situation of teak forests in Bago Yoma Region, which was once famous as home of teak and birth place of MSS, and then proposed an alternative yield regulation for sustainable production of teak.

Chapter 1 of this study provides the important role of teak forests in Myanmar, current situation of those natural teak-bearing forests, current logging system in Myanmar, development of Brandis Selection System (BSS), attributes in developing yield estimation formula for AAC.

Chapter 2 provides a description of the study area in Pyu Kun reserved forest which is one of the reserved forests in Bago Yoma. In this chapter, first a general

description of Bago Yoma, silviculture system and teak forest composition are mentioned. And then, the detail about data availability and data sources of selected study area was explained. The collected data were composed of number of compartments, number of felled or girdled trees, and number of remaining trees, and time intervals of harvest. The records of harvested and left trees are traced back from 1976 up to 2008. These data covers 64 compartments with different sizes in acres and different felling cycles as well even though felling cycle of thirty-year is set up for teak under MSS. Instead of diameter classes used in other countries, the number of teak trees is allocated under seven girth classes of Class:(4’00” $\leq g_1 \leq$ 4’11”;5’00” $\leq g_2 \leq$5’05”;5’06”$\leq g_3 \leq$5’11”;6’00”$\leq g_4 \leq$6’05”;6’06”$\leq g_5 \leq$6’11”;7’00”$\leq g_6 \leq$7’05” and $g_7 \geq$7’06”). The unit for girth class is feet and inches and the area of each compartment is converted into hectare. According to the observation data, the remaining trees are counted starting from 4 feet in girth while the trees with 6.6 feet and above are marked as to be cut. There is no information available for numbers of teak younger than 4 feet in girth.

Chapter 3 aimed to reveal the current teak production from natural teak forest and to make comparative analysis with prescribed and actual cut of teak trees. In this section, three types of analysis were conducted: comparative analysis on girth class distribution of teak over various felling cycles; analysis on actual and calculated AAC of teak; and analysis on actual and calculated stand table projection. In addition, this chapter addressed the disturbance tendency occurring in natural teak forest over time series and over the girth class as well. The enumeration data from study area were applied in this study. The original girth classes were redefined depending on three types of analysis. In the process of harvesting operation, number of teak trees is enumerated by girth class, at the time of (1) before felling, (2) at felling and (3) after felling. These enumeration data (1976-2009) were collected from 123 compartments. However, for the comparative analysis, 64 compartments which have been harvested twice during the period.

Through those enumeration data, first the condition of growing stock of teak over the various felling cycles (FC) was revealed. For the feasibility of data arrangement, felling cycles are classified into A (FC≤10yrs), B (11≤FC≤20yrs), and C (21≤FC≤30yrs) respectively. And then, growing stock conditions of teak over three types of FC were compared. For the second type of analysis, we applied the Brandis Yield formula of AAC. Yield is regulated by number of exploitable trees. Here, only trees left data from 64 compartments were applied that are necessary for future yield estimation by the Brandis formula. According to girth limit prescription by the forest department, the trees which have the minimum girth limit of 6’06” are supposed as harvestable or yield trees. Therefore, all of the trees which have 6’06” and above at gbh (girth at breast height) were considered as girth class one (C_I). Another assumption is that thirty years are required to increase one foot in girth of trees which have 5’06” at gbh. Accordingly, the girth classes were reclassified into four groups: 4’00” $\leq C_{IV} \leq$4’11”; 5’00” $\leq C_{III} \leq$5’05”; 5’06” $\leq C_{II} \leq$6’05”; $C_I \geq$6’06”. As for the third analysis of this section, we used the recently proposed model for the Stand Table Projection. In that model, annual survival rate and periodic mortality rate were adopted and the mean girth increment of teak in Bago Yoma was considered as 0.79 inches per year. For this analysis, the three compartments which were harvested the first time in 1981 and second time in 2001 were chosen. To apply the data in the stand projection formula, the original set of seven girth classes are redefined into six groups with the equal interval of 6 inches in each girth class. The number of both harvested and remaining trees from enumeration data was used.

To find out of disturbance tendency occurring in natural teak forest over time series and over the girth class, first, time series are defined as t_1, t_2, t_3 and t_4 representing before first harvest, after first harvest, before second harvest, after second harvest. The total number of trees cut and left was allocated under the time series of t_1 and t_3 while only remaining trees were considered at t_2 and t_4.Those trees were distributed under the rearranged four groups of girth class with the equal interval of one foot in girth.

By the result of growing stock condition of teak over three types of felling cycles (A, B, C), the remaining trees for the next cutting cycle are apparently losing in C-type of Felling Cycle compared with A and B types. But, as an effect of long time interval, trees in larger girth class were found increase though trees in smaller girth class in the next cutting cycle of C-type. It is suggested that for keep applying felling cycle of thirty-year which could give enough time to restore the forest after first harvest, intensive care of maintaining the trees left for next cycle is required. By the results of using AAC yield formula in the enumeration data of teak trees, over-exploitation of teak under A-type occurs seriously compared with other types of felling cycle. As a result of applying stand table projection model, actual stand table after 20 years is apparently lower than the projected one. According to results of examining disturbance tendency, disturbance on teak growing stock occurs at the time series t_3. Apparently, 85% and 76.5% of C_{IV} and C_{III} trees are losing at that time series. The harvest tendency of CI trees over two felling cycles (t_2 and t_4) is decreasing from about 12% to 4%. Consequently, significant loss of C_{II} trees at t_4 is probability due to over-exploitation of teak. It can be concluded that silvicultural operation for younger teak generation is seriously necessary such as gap planting and maintenance against disturbances likely occurred at the younger trees.

By checking the applicability of currently using yield formula and proposed one for stand table projection with the current conditions of teak forests, the author proposed an alternative yield regulation method for teak production. The concept of the new model was based on maturity of forests by considering the utility of maturity as an index for sustainable growing stock of teak. Here, the maturity has the unit of number of trees by years. By calculating maturity of each stand, we could decide which stand should be harvested or not. As there is no information for age from uneven-aged natural teak forest, the required year for tree increment between each girth class is calculated by adopting Mitscherlich equation. In this formula, parameters are estimated by applying in the yield table of Indonesia teak plantation which seemed similar to growth pattern of Myanma natural teak. And then, the maturity of teak in total gbh distribution of all compartments was calculated through the formula. By using the enumeration data of 64 compartments from research area, first, the total girth distributions over the measurement of time series t_1, t_2, t_3 and t_4 were examined. The result suggested that the loss of number of remaining trees between t_2 and t_3 were attributed to illegal loggings because the time interval between t_2 and t_3 was the rest-time for next legal cutting. Based on the girth distribution and substituted parameters for the required years for the increment of teak in each girth class.

The maturities in total girth distribution of teak were calculated According to the result of estimating maturity in total girth distribution, the maturity decreased drastically through t_1, t_2, t_3 and t_4. Decreasing maturities between t_2 and t_4 were because of first and second legal harvesting operations. Therefore, the reason of decreasing maturity at t_3 was probability due to human disturbance and natural disaster. Through these results, unsustainable situation of current teak forests could be clarified. We also introduced three patterns of estimated maturities in some specific teak stands. As for pattern 1, the illegal cutting in younger stand was the main factor of decreasing maturity of the stand through all of measurement times. By the results of pattern 2, the decrease in maturity of stand between t_2 and t_3 is relatively small but, after second harvesting, maturity is dramatically decrease and as a result, second harvesting should not be conducted for maintaining maturity of that stand. For the pattern 3, the maturity of measurement time 3 and 4 are found higher than that of time 1 and 2, and as a result, sustainability of that teak stand is relatively good by comparing pattern 1 and 2 results.

Chapter 5 provides a general discussion and conclusion about the disadvantages of existing yield model, lack of silvicultural operations of MSS and advantages of the proposed one with the consideration of current growing stock of teak. It was said that, in natural forests where teak occur scattered in mixtures with other hardwood species, teak was found with the amount of 3 or 5 trees per acre. According to current enumeration data of study site, even one tree could not find in one acre. In that situation, the sustain yield of teak could not rely on only number of larger trees. In the new concept of maturity, the required years for growing up to next higher girth class of teak were taken into account. As long as the number of trees by years is found increasing in each girth class, the maturity of that forest is stable and that stand could be chosen for harvesting operation. While Brandis' method was applicable only for the forests with the excess amount of mature trees, the author proposed that the new one would be feasible to apply in the current situation of natural forests which has been facing the problems of degradation and overexploitation of timber in Myanmar. As for further study to improve this new model, conducting research on growth rate of teak in each girth class from the natural forests by installing permanent sample plots is recommended.