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Silvicultural Systems in the Restoration of Normal Forest: A Review

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KEYWORDS

Silvicultural systems
Normal forest
Regular normal forest
Irregular normal forest
Restoration

ABSTRACT

This paper review show different silvicultural systems help to restore normal forests, their usefulness and limitations. It is based on a desk review of various secondary data. Nature of ownership, management objectives, and site quality determine the silvicultural system to be adopted. In regular (even-aged) forest, normality is carried out by the clear-felling system, uniform shelterwood system and coppice system while irregular (uneven-aged) normal forest is managed using the selection system. As perfect normality is unattainable, the role of the manager is to reach maximum attainable position. It regulates the supply of forest products on sustainable basis as well as restoring the health and vitality of the forest.

Introduction

Since the beginning of forest management, research has primarily focused on the ideal way of forest regulation. Many systems have evolved along the road, but one that deserves pressing study is the concept of normal forest. The normal forest is a basic concept of forest management throughout the ages. It is believed that normal forests have evolved during scientific forest management in western Europe. Thus, the concept of normal forest is based on the principle of sustained yield. Formally, the theory of normal forest was developed in the early 19th century by German foresters (Leslie , 1966).

Normal forest is an ideal state of forest condition providing an even flow of timber volume without deterioration to the future productions. “A forest which containsa regular and complete succession of age-gradations or classes (several age gradations thrown together) in correct proportion so that an annual or periodic felling of the ripe woods results in an equalization of the annual or periodic yields is known as normal forest” (Parkash, 1986). The structure of a normal forest is characterized by the presence of a normal series of age gradations or age classes with a normal increment and a normal growing stock leading to continuous production in perpetuity. Even aged forest is identified by the normal distribution of age classes whereas these attributes form a major difficulty in uneven-aged forest management since the forest entirely

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consists of a mixture of all the age classes in an equi-productive area. So, the normality of an uneven-aged forest can be ascertained by the balanced distribution of size classes equivalent to the normal distribution of age classes by area of the normal even-aged forest, as pointed out by de Liocourt (Parkash , 1986).

The normal forest is fundamentally a dynamic idea and its requirements are such that some of these might not be found over a whole area. Normal structure is only applicable under specific circumstances, and if these circumstances change, the normal forest will also change as its requirements get disturbed easily. Maintaining of normality is impossible in long period. So, the nearest approach to attain normality should be used for forest management. Also, normality facilitates comparison with existing conditions to identify the deficiencies and work over it.

Forest product demand is increasing geometrically; however, existing forests are either understocked and overstocked. Both these situations can fulfill the demand of the present, but that they can fulfill the demand of the future generations is doubtful. Also, the present management practice of normality is related to both rotation and system of management; so, it envisions maintaining a balanced structure of forest capable of regulating sustained yield.

Globally, forest restoration or re-establishment to a conventional and sustainable state has been a major issue (Stanturf et al., 2014). Many efforts have been made for the restoration of normal forests, and this all comes up with the use of different silvicultural systems. A silvicultural system is an organized application of silvicultural treatment for the operating cycle of harvesting, regeneration, and tending in a forest over time. The silvicultural system so applied determines the types of forest structure (Coates & Burton, 1997). Based on felling intensity, the silvicultural system applied to a normal even-aged forest is a clear-felling system, uniform system, and coppice system whereas a single-tree selection system and group tree selection system are employed for a normal uneven-aged forest.

In the context of Nepal, the sustained utilization of forest is a major gap in forest management system. In Nepal, where a large number of forests are undercommunity-based forest management, normal forests have been found to be endowed with a lot of opportunities. These forests support the socio-economic conditions of the user group through provision of forest-based products and services. By maintaining regular and complete succession of age gradation, the yield can be regulated. This system ensures the best ecosystem for improved livelihood and economic returns, along with environmental services like carbon sequestration aiding climate change mitigation (Pandey & Pokhrel, 2021). Furthermore, it helps attain forest health and vitality.

Materials and Methods

This paper is based on a systematic literature review process. Initially, the topic was 'Silvicultural Systems in the Restoration of Normal Forest' and the research question was: 'How do different silvicultural systems help to restore the normal forest type in different forest types?' Then, all potentially relevant studies were sorted from secondary sources like journal articles and reports and online portals like Google Scholar and Research gate. Keywords like silviculture systems, normal forest, restoration, irregular normal forest, and regular normal forest were applied. A total of forty-one articles were gathered. Examination of what silviculture systems are applied around the globe, how they help to attain normality and what their relevance is was carefully done to gain a deeper level of understanding of the domain. For better understanding, silvicultural systems for restoring normal forest were studied under regular and irregular forests. Finally, results were presented using narratives, figures and tables. Furthermore, the implications of the topic for future research and managerial practice were discussed.

Findings and Discussion

Silviculture is the deliberate manipulation of a forest to achieve defined objectives (Leslie, 1966). Silviculture studies trees and forests as a biological unit, laws of their growth and their behaviour in a given set of environment condition (Khanna, 1977). It deals with the entire process of obtaining regeneration, tending and other operations to fulfill the preset objectives. Silvicultural system is a cycle of activities by which a forest stand is harvested, regenerated and tended over time (Coates & Burton, 1997). It results in the development of either regular (even-aged) or irregular (uneven-aged) forest stand.

Regular forest is the woods of approximately same ages. Professional foresters characterize a forest as regular if the total range of ages present is less than 20 percent of the rotation age (Wittwer et al., 2009). Usually, they are plantation forests and have similar height and a single canopy. Regular forests are worked under clear felling, coppice and uniform system. In contrast, irregular forest is the one with a wide range of ages. In this type of forest, young trees grow in the shade of older, overtopping trees. They are worked under the selection system.

Silvicultural system for restoration of normal forest can be studied on the basis of existing forest type.

Silvicultural system in the restoration of regular normal forest A normal series comprising equi-productive areas of each age class up to rotation age is simply known as normal even-aged forest (Leslie, 1966). As the age class range is narrowed, the regeneration period will be short, resulting in a more even-aged stand. Conversely, less even-aged stand results from wider age range classes having a longer regeneration period.

The silvicultural system applied for restoration and management of regular normal forest could be a clear-felling system (100% felling intensity), uniform shelterwood system (70–90% felling intensity) (Subedi et al., 2018), and coppice system. If the target is to regenerate a new stand of shade-intolerant trees like maple, pine, etc, the clear-felling system, which involves harvesting all trees in one cut in an area, is applicable (Wittwer et al., 2004).

Every main unit of the forest is divided into many compartments and sub-compartments. To illustrate, a forest of an area of 400ha consists of two compartments having rotation age (R) of 100 years and regeneration period (Rp) of 10 years.The number of sub-compartments (periodic block) can be calculated as (Rotation (R)/generation period (Rp)(Subedi et al., 2018). In the first block, all trees are completely cut, felled and removed in one operation, which is followed by mostly artificial regeneration (planting) rather than natural regeneration (by sowing) of a new species. The same procedures of felling and regeneration is followed in the next periodic block adjoining the formerly treated block, which has the species of an aged one. This will be followed for the next ten years, and, after ten years, the species in block 1 will be ten years of age, which is now ready for harvesting timber (Hassani, 2018). This system results in the production of a normal even-aged forest.

A clear-felling system is comparatively least desirable for both landscape and nature conservation. In Williams et al. (2001), species richness and total abundance of birds declined by 58% and 96% respectively after clearfelling. In addition, concentrations of sulphate, sodium

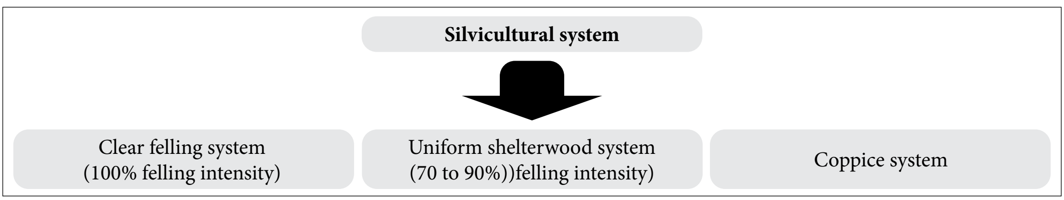

Figure 1 : Silvicultural system in restoration of regular normal forest

and chloride in soil declined as a result of felling and remained lower at the end of the study (Adamson & Hornung, 1990). However, these drawbacks can be reduced by creating small coupe fellings (Murali, 2017). This system lures foresters because of its cost-effectiveness inharvesting as well as forthe rapid growth and regeneration of early successional, shade-intolerant species, which, because of their timber qualities and growth rates, are often preferred for wood production (Keenan &

Figure 2: Forest management cycle

Kimmins, 1993).

Likewise, "In uniform shelterwood system, a relatively even distribution of trees is retained in situations where regeneration is difficult to establish after clear-felling" (Keenan, 1986). The uniform shelterwood system consists of preparatory felling, seedling felling, secondary

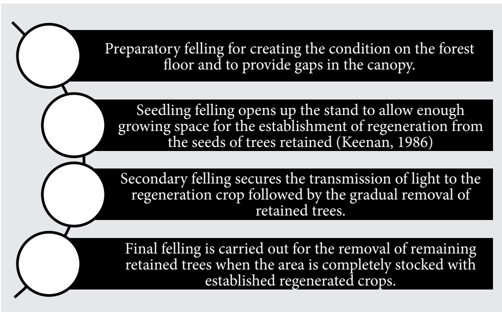

Figure 3: Steps of regeneration felling in uniform shelterwood system

felling, and final felling (Manso et al., 2014).

According to Wittwer et al. (2004), if the preferred type of trees to be regenerated requires nearly full sunlight, the retained trees are cut from below to 70 or 80 percent crown cover discriminate against undesirable species which are scarified to remove existing vegetation and a seedbed is prepared where as if the preferred type of trees is partially shaded tolerant, the first cutting may remove only 25 to 50 percent of the overhead shade. Such seedbeds retain moisture and increase surface soil temperature for the germination of light-seeded species. While marking for the light-seeded species, shelterwood should be based on the percent crown cover and not basal area, because basal area is not a good indicator of crown cover from species to species or in stands with various diameters. Crown area tables can be used or percentage can be estimated with a little experience (Godman, 1992).

This system offers protection, i.e. shelter to understorey species against adverse climatic factors. Besides, this system is useful for regenerating most of the trees except those that can not tolerate any overhead shade (Wittwer et al., 2004). It leads to increased soil moisture capture and storage because of increased precipitation throughfall (relative to uncut condition) and extended snowmelt period (relative to clearcut situation) (Pike and Scherer , 2003). Furthermore, reduced cover and vigour of competing vegetation and invasive plants improve the survival and growth of regeneration (Troup, 1928). However, with the retention of an overstorey, harvest volumes are lower and a greater area is required to provide the same harvest volume as a clearcut. Furthermore, the planning and implementation of shelterwood systems require more experienced personnel than clear cuts do, and, timber marking, if done, adds to layout costs (Phillips, 1996; Dunham, 2001).

The coppice system has been proved as one of the best silvicultural systems for the restoration of the normal even-aged forest as it enhances the productivity to the initial production by two to three times (Basnyat et al., 2017). In 2000, about 16% of the productive forests in Europe were managed as coppice, covering a total area of about 23 million ha (Kofman & Unrau, 2017). Simple coppice refers to a low forest silvicultural system where the old crop is completely clear-felled with no reservation and regenerated through sprouts or suckers having a comparatively short rotation period. However, the duration of rotation is affected by species, re-sprouting ability, maximum productivity, targeted wood dimensions, and local conditions. It has been reported that rotation periods are usually between 5years (Willow osier) and 40 years (Oak, Hornbeam, Beech) and can reach up to 60 years (Alder) (Nicolescu et al., 2017). Regeneration in the coppice forest is influenced by a cut of mother stand and season of the cut since the inappropriate season of the cut can cause damage to stools on a large scale. Thus, cuts should be regulated from October to March to produce vigorous sprouts (Andersson et al., 2004). Production goals determine the technique of silvicultural operation as 5 to 10 trees per ha should be left after cutting as potential seed trees when using natural regeneration (shoot origin). One-to three-year seedlings are planted with a density of 1,000–1,500 per ha (Eucalyptus) or 4,000–5,000 per ha (black locust) while using artificial regeneration (Forestry Tasmania, 2010). Tending operations such as cleaning–repacking, weeding, and thinning are done to improve productivity. After reaching the rotation age, simple coppice is worked by the method of the annual coupe by area; then, each year one coupe is coppiced (Nicolescu et al., 2017). The coppice system is best suited for maximum production of wood which offers higher market prices. Thus, sustainable management of forest can be achieved as a simple coppice within the silvicultural system (Chatziphilippidis & Spyroglou, 2004).

Silvicultural system in the restoration of irregular normal forest

In today's context, advantages like improved ecological condition, increased wind stability, higher level of resilience to climate change, along with steady economic returns, have attracted a large number of foresters towards the normal irregular forest (Meng et al., 2014). A normal irregular forest describes a condition where the ratio of several stems in one size class to another bigger class shows a negative exponential relationship explained by the 'q' value. It is characterized by biological stability regarding increment in a stand, regeneration of favourable species, and enlistment of new trees to measurable size/diameter class (Cameron, 2007).

The system used for the restoration and management of irregular forests is a selection system which may be either a single tree selection or a group tree selection (Nyland, 2016). Basically, the selection system with uneven-aged diameter distribution, defined by 'q' value, residual basal area, and target tree size are being used (Graham et al., 1999).

At the very beginning, before the application of selection cutting, the residual stocking to be retained after cutting should be determined. It has been found that stands cut up to 60–70 percent of full stocking will show a similar growth as a fully stocked forest (Berntsen et al., 1977). This concept has been found to be adopted in the transformation of degraded Pinus massoniana plantation into an irregular forest where the initial forest was thinned to the density of 70%, which inhibited the good crown development for future trees and 30% of the trees were retained based on the stem quality and vigour (Meng et al., 2014). Type of species, size of tree, diameter distribution, etc play a vital role in determining the residual stocking for best growth. The stocking guide developed by Ben, Bud, and Gingrich can be used for easiness (Berntsen et al., 1977).

Diameter distribution is to be determined for better growth and quality development and to obtain maximum and sustained yield where increment in stand equals the amount intended to harvest (Graham, 1983). The use of the fixed quotient 'q' between a number of trees in successive diameter classes is a widely accepted procedure for determining diameter distribution. Here, as we start from the number of trees in the largest diameter class, the successive smaller class would contain q times as many trees in the next higher diameter class

(Graham & Jain, 2005). The value of 'q' to be used depends on feasibility in terms of species requirement, site quality, and management objective (Graham, 1983). Plotting of a number of trees suggested by 'q' gives an inverse 'j' shaped curve, which satisfies the concept of a

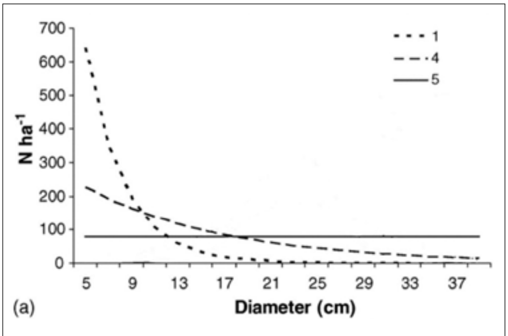

Figure 4: Diameter distribution curve (Lexerød & Eid 2006b)

Distribution no.	Description	*q*-Ratio
1	Inverse J-shaped	0.55
2	Inverse J-shaped	0.65
3	Inverse J-shaped	0.75
4	Inverse J-shaped	0.85
5	Uniform	1.00

Figure 5: Table explaining the nature of graph of diameter distribution with different q values (Lexerød & Eid 2006a)

balanced or normal forest (Baker, 1996).
Similarly, the residual basal area that provides good saw timber growth and ensures reproduction to develop in the understorey as well is to be so selected (Baker, 1996). In the same way, the maximum tree size goal should be set depending on the management objective and site requirement (Graham, 1983).

Once all those goals are set, the stand structure should be regulated, and, for this, several methods are available depending on diameter distribution, residual basal area, and maximum tree size selected. One of the simplest one is that developed by Tubbs and Oberg (1978). Here, they have developed a coefficient called Kfactor for 2 inches (5cm) diameter class, which depends on desired 'q' and maximum tree size. The number of trees in the largest 2-inch diameter(N) is obtained by dividing the residual basal area by K factor. Thus, obtained N is multiplied by q to find a number of trees in next smaller size class, which proceed so on to the smallest class. The comparison between the graph of the actual stand and the desired one gives the tree that can be removed from each diameter class (Graham, 1983).

To obtain the stand to be cut, subtract the intended residual stand from the actual stand. The cut ratio is obtained by dividing original stand to cut stand (Marquis, 1975).

Once the stand structure is determined, the cutting cycle is to be calculated, and its length depends on a residual growing stock that immediately follows a cutting cycle, productivity of a site, growth rate, and the minimum operable cut. Finally, this is followed by marking and harvesting (Baker, 1996).
By applying a selection system following the given operation in the forest already having size classes we can easily get a normal irregular forest. But the complication arises when we have to convert a forest ti normal forest starting from stands that are even-aged or two-storied. For this, the stem selection system and group selection system are commonly practised (Berntsen et al., 1977).
The area where shade-tolerant species are accepted as the future stand is generally worked

Table 1: Calculation of cut ratio

	Largesawn timber (2)	Small sawn Timber (1)	Saplings (.3)	Poles (.04)	Total BA per acre
Original stand	18	37	37	15	107
Residual goal	10	19	22	11	62
Residual stand	10	19	22	15	66
Cut stand	8	18	15	0	45
Cut ratio	2.2	2	2.5	0	

under the stem selection system (Nyland, 1998). In this system, cutting is concentrated on all merchantable size classes while the trees of those species that have not yet reached the target final diameter are retained. Going further, the low value and poor vigour trees are also removed, creating a gap to allow pole-sized high value species togrow vigorously. The extent of cutting is guided by the target basal area (Kelty et al., 2003).

On the other hand, in the group selection method, the first priority is given to the creation of the youngest age class by clear-cutting the groups of trees that have no understorey and encouraging regeneration in those areas. The one-sixth area is clearcut and regenerated in small groups. Still, if additional volume is available for harvest, groups of large trees overlying groups of saplings are removed and proceed towards releasing pole-sized groups. During this operation, both area and volume regulation are used and preference is given to bring the compartment under complete area regulation and establish a stable stand structure for continuous management (Berntsen et al., 1977). This system is generally used to ensure regeneration where some shade-intolerant species are present as a future stand (Kelty et al., 2003).

Conclusion

This paper reviews the possible silvicultural system applicable to the restoration of normal forests. The requisition of the silvicultural system depends on site condition, desired species and its requirement, nature of ownership, and management objective. The regular normal forest is maintained by a clear-felling system, uniform shelterwood system, and coppice system appropriate for the area where the goal is oriented mainly towards timber production, which hassound productive site conditions. In contrast, the irregular normal forest is maintained under a selection system that is suitable to ecological considerations. Maintaining normality in forest sustains good ecosystem service and environment resilience. It plays a profound role in countries like Nepal where vast are as are managed under community-based forestry system. It supports livelihood and provides forest products to users. Beside this, it fulfills the growing demand for forest products, ensuring that our future generations will also have equal access to them. Currently, the silvicultural system is generalized for both site and species; so, site-specific and species-centred research is carried out to further shape the study.

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