

A Term Paper on

NATURAL REGENERATION

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Roll Number: One

Master of Science in Forestry, (2007-2009)



Submitted To

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July, 2008



Table of Contents

Abstract	2
1. Regeneration	2
2. Natural Regeneration	2
2.1 Purpose	3
2.2 Significance of Natural Regeneration	3
2.3 Succession: A Natural Regeneration Process	4
3 Natural Regeneration from sexual regeneration (By Seed)	5
3.1 Seed Production	5
3.2 Seed Dissemination	6
3.3 Seed Germination	6
3.4 Seedling establishment	6
3.5 Natural Regeneration under Various Silvicultural Systems	7
4. Natural Regeneration by asexual Regeneration (Vegetative parts)	8
4.1 The coppice reproduction	9
4.2 Natural Regeneration by Root Suckers	10
4.3 Natural Regeneration under Various Silvicultural Systems	11
5. Management Option for successful natural regeneration	11
5.1 Manipulation of Upper Canopy	11
5.2 Manipulation of lower canopy	11
5.3 Seed Supply	12
5.4 Soil Condition	12
5.5 Control fire (control burning)	14
5.6 Slash disposal	14
5.7 Competition	15
5.8 Protection from Animals and Pests	15
5.9 Natural hazards and controls	16
6 Management and monitoring	17
6.1 Some Basic Rules	17
6.2 Guidelines	17
7 Factors Affecting the Choice between Artificial and Natural Regeneration	18
8 Advantage and Disadvantage of Natural Regeneration	18
8.1 Advantages	18
8.2 Disadvantages	19
9 Successful Example of Natural Regeneration	20
10. Conclusion	20
11 References	21

Abstract

Forest regeneration is the act of renewing tree cover by establishing young trees naturally or artificially-generally, promptly after the previous stand or forest has been removed. The method, species, and density are chosen to meet the goal of the landowner. It is affected by various factors like source of seed, soil/ site condition, competition, predation of young plants, natural hazards, etc.

Forest regeneration includes practices such as changes in tree plant density through human-assisted natural regeneration, enrichment planting, reduced grazing of forested savannas, and changes in tree provenances/genetics or tree species (UNEP/WMO, 2008). Natural regeneration suitable and preferred because it is less expensive, closer to nature and have more resistance power against climate and biotic influences.

Key Words: Seed, Coppice, Natural Regeneration, Climate

1. Regeneration

Regeneration is defined as the renewal of a forest crop by natural or artificial means. It is a forestry practice aimed at the establishment of new trees as the old trees become mature and are harvested. Reproduction is a synonym for regeneration but it is more usually applied to a forest crop obtained by natural methods. It also refers to the coup so obtained (Khanna, 2004a). Forest trees rely on two general methods to reproduce - natural means and artificial means, but in practice a combination of the two methods is also adopted.

Natural regeneration (as the name implies) is that established from seed, sprouts, or root suckers of trees on or formerly occupying the land. Conversely, artificial regeneration is that established from seed or seedlings brought on site by man expressly for purposes of tree re-establishment. Artificial regeneration involves direct seeding or planting.

Large areas of tree regeneration can be created by extreme natural catastrophes (such as fire and windstorm) while smaller areas are created by individual tree mortality and gradual change (succession). Natural phenomena can be simulated by various forms of timber cutting for stand improvement or harvest, followed by or in concurrence with natural or artificial regeneration. Numerous options are available for forest regeneration. Each selection will show influence on the species composition, age class distribution, density, growth, and other attributes of the new stand, and benefits to be obtained (VDoF, 2008).

2. Natural Regeneration

Natural regeneration as reproduction from self-sown seeds or by vegetative recovery (sprouting from stumps, lignotubers, rhizomes or roots) after the tops of the plants have been killed by any of the disturbers factors like fire, cutting, browsing (Cremer 1990).

In most part of the world the most common natural disturbance is fire (Mooney et al., 1981). Fire, by itself, generally kills small trees more effectively than larger ones. Primary succession starts with landslides, the melting of glaciers, or the formation of new land by water, wind or volcanism. Man-caused erosion or earth-moving can also expose soli parent materials that are free of organic matter and deficient in nitrogen or other nutrients. The natural regeneration can be obtained from the two sources via sexual regeneration from seed and asexual from various mode of vegetative sprouting (Smith, 1986).

Natural regeneration includes both seeding and vegetative reproduction. Most species of hardwoods combine both seed and vegetative regeneration for reproducing. Most pines reproduce principally from seeds. Hardwoods such as oak, maple, and yellow poplar commonly sprout from the stump after being cut or burned. These sprouts often form clumps. Beech, sweetgum, and black locust commonly sprout along the roots (suckering). Based on numerous factors, vegetative reproduction is fairly predictable. Follow-up management practices can be influenced significantly by the form of natural regeneration.

2.1 Purpose

The main purpose of natural regeneration is to provide new plant growth that can extend the area of remnant vegetation. It also provide replacements for over-mature plants when they die.

2.2 Significance of Natural Regeneration

Natural regeneration is a powerful tool for re-establish vegetation in a minimum cost and a part of managing a bushland area. Areas that are managed in a way that enables natural regeneration to occur can be self-sustaining and may not require further expensive establishment costs. Natural regeneration ensures that the plants established on a site are from parents that currently occupy the site. Hence it helps to preserve genetic identity and variation within plant species. This natural ‘conditioning’ to a site means that these plants are capable of withstanding long-term natural fluctuations and should do well, once established. Natural regeneration is particularly useful for establishing plants on a broad scale but can also be used in localized areas. Natural regeneration has also been used as a means of producing seedlings for planting in other areas (Platt, 1992).

Supplementary planting or the introduction of seed from other areas is often required to attain full natural diversity. Natural diversity is essential to re-establish a ‘healthy’ ecosystem. Natural regeneration can be a sporadic event. It is therefore not as reliable to produce results in a given season as planting might be, however, when it is successful; the results are often dramatic. For many species, natural regeneration is effective only near the parent plant. In a healthy ecosystem natural regeneration is an in built part of the process that maintains the ecosystem, its

communities of plants and animals. Under natural conditions, human interference is not desirable (Khanal, 2007).

2.3 Succession: A Natural Regeneration Process

The natural regeneration of vegetation is a dynamic process by which life recolonises land when the vegetation has been partially or totally destroyed. Life recovers the lost ground through the mechanism of the succession of species. The dynamism of the succession of species complete in following stages.

The first stage: Pioneer plants initiate as a process of vegetation succession. They create the first elements of living soil through the interaction of their root systems with the mineral medium. These plants, not more than a few millimeters in height, spread in large patches using and storing tiny amounts of moisture and nutrients which further enable them to propagate themselves on and within the mineral surface.

The second stage: Over time the amount of soil created by their activity is adequate for the next generation of pioneers. Often these pioneers are members of the grass family Gramineae. The combined action of their root systems on the minerals below and the accumulation of organic matter from the decay of their annual growth on the surface create conditions of soil-depth and capacity of water retention enabling the establishment of the following generation of pioneers: woody annuals and other herbaceous plants, deeper-rooted stragglers and shrubs.

The third stage: As the humus content and soil-depth increase, larger and larger specimens can exist and thrive in the slowly-improving conditions. Perennials eventually replace annuals. Sun-loving species are slowly displaced to the periphery of the expanding system and are replaced by permanent species requiring a sheltered environment at the beginning of their life cycles. In time, a stable community is established allowing an increasing diversity in the number of species, increasing density per unit of surface and increasing height of the canopy and depth of soil.

At this stage, the fauna has already begun participating in the process, concentrating and recycling nutrients, and most importantly serving as a vector of the vegetation e.g., seeds in the form of burs which cling to the body of small animals or seeds which travel in their digestive tracts. The flora uses the fauna in its strategy of seed dissemination.

The last stage: Ultimately, within the limitations of climate, soil and hydrology, the vegetation will reach the stage of maximum biomass per unit of surface and maximum stability, diversity and sustainability, which is called, by convention, climax vegetation.

It has been estimated that this process could take as little as a thousand years in the humid tropics, though much longer in drier tracts, the moisture availability being the limiting factor in this case. In temperate lands it is much slower, the limiting factor being cold temperatures: the

longer the cold season, the slower the evolution. (For example, in the north of Sweden today one can see that the process towards climax vegetation is not yet complete 10,000 years after the polar caps have receded.)

3 Natural Regeneration from sexual regeneration (By Seed)

When regeneration obtained from seed forms a crop, it is called a seedling crop which is defined as a crop consisting neither of seedling neither planted nor of coppice or root sucker origin but origination in situ from natural regeneration. When this seedling crop grows into a forest, it is called a high forest. Natural regeneration from seed depends on the Seed Production, Seed Dispersal, Seed Germination and Seedling Establishment.

3.1 Seed Production

The most important consideration for natural regeneration from seed is the production of adequate amount of fertile seeds by the trees of the area or in the vicinity. Seed production depends upon various factors such as species, age of the tree, Size of Crown, site, weather conditions, attack of insects and fungi, and other external factors (Dwivedi, 1993). Good Seed production in a tree varies from year to year. *Some species* produce good seed every year where as some other produce good seed in alternative year or long intervals;

Species	Moderate Seed years	Good Seed years
<i>Shorea robusta</i>	2	3-5
<i>Terminalia tomentosa</i>		3-4
<i>Pinus wallichiana</i>	2	2-3
<i>P. Roxburghi</i>	3	4-5
<i>Cupressus torolosa</i>	3	7-8
<i>Cedrus deodara</i>	3	4-5
<i>Picea smithiana</i>	3	5-6
<i>Abies pindrow</i>	6	10

Some species like *Bamboos* and *strobilanthes* flower gregariously after a long interval. After such gregarious flowering, plants usually die off. During the period of gregarious flowering, seed production is abundant.

The *age of trees* also affects the production of adequate amount of fertile seeds. Abundant amount of fertile seeds are produced from middle aged trees when height growth is culminated and during this period carbohydrate produced is translocated to seed formation. As a general rule the bigger the *crown* the larger the seed production. *Climate* also affects the seed production. As a general rule warmer climate favors larger seed production. Heavy rainstorms at the time of pollen dissemination reduce chances of pollination and good seed production. *Injury* by fire and insect attack reduces seed production by damaging the crown

3.2 Seed Dissemination

Seeds are carried away from the parent tree. Seed dissemination gives the young seedling a better chance of survival for they are saved to a large extent from competition with the parent plant. The means of dispersal adapted by the seeds of different species vary widely. The important agencies involved in seed dispersal are; wind, water, gravity, birds, animals and explosive mechanism. Some examples of seed dispersal by various agencies are given below. Seed dispersal is affected by direction of wind and presence of hills.

Wind: *All conifers and several dicots (Acer, Betula, Populus, Alnus, Salix, Terminalia, Dalbergia, Acacia, Adina and Bombax)*

Water: *Mangrove, Dalbergia, Teak, Cocus, Cerbera, Acacia Catechu, Casuarina Spp.*

Bird: *Prunus, Mulberry, Diospyrus, Vitex*

Animals: *Acaica nilotica, Prosopissis juliflora, Zizyphus, and Anthocephallus.*

Gravity: *Oak, Juglans, and Asculus.*

Stick with body of animals: *Desmodium, Flemingia, Andropogan, Rumex*

3.3 Seed Germination

After dispersal insect birds and rodents destroy a lot of seeds. Germination of seed depends on several internal and external factors (Khan, 2008).

Internal Factors

Permeability to water
Permeability to O₂
Development of embryo
After ripening
Viability of Seeds
Size of seeds
Germination capacity
Germination energy

External factors

Moisture
Air
Temperature
Light
Seed Bed

A large part of the seed is usually lost due to various factors like; Climate and edaphic Fungi and bacteria causing decay, Insects, Animals.

3.4 Seedling establishment

Establishment is defined as the development of new crop 'naturally or assisted' to a stage when the young regeneration 'natural or artificial' is considered safe from normal adverse influences and no longer needs special protection or tending operation other than cleaning, thinning, and pruning. Large scale mortality occurs during the succulent and juvenile stage of seedling due to

various factors. Sparhwak 1918 reported that in pine forest, 80 percent of the seedlings which had come up were killed in the first years and 50 percent of the remainder disappeared in the second year, 25 percent of the rest perished in the third year and about 16 percent in the fourth year and hardly 0.1 to 1 percent of the seedlings were able to establish themselves under normal conditions. The percent is much less under difficult conditions (cited in Dwivedi, 1993). A large number of factors are responsible for the mortality of seedlings. The extent of damage by a single factor may vary from place to place. The factors responsible for seedling establishment are as follows;

Climatic: Lights, Temperature, Frost, Drought, Light, and Rainfall

Edaphic: Soil condition, Moisture, Aeration, Nutrients, Drip (Slash erosion)

Biotic: Fungi and Bacteria, weeds, Grazing, Browsing and Fire

Genetic Factor: Development of root, Resistance (to grazing, insects, drought), Composition of the crop.

Light is very important factor in seedling establishment but its requirement varies from species to species and even in the same species according to climatic conditions and age. i.e. Teak seedlings must have sufficient light but in dry localities seedlings require protection from sun. Sal is able to persist in moderate shade in the beginning but it needs complete overhead light later

Light Demander: *Pinus roxburghii*, *Pinus wallichiana*, *Populus ciliata*, *Shorea robusta*, *Tectona grandis*, *Dalbergia sisso*, *Adina cardifolia*, *Bombax ceiba*, *Quercus incana* etc.

Shade Bearer: *Picea smithiana*, *Cedrus deodara*, *Cupressus torulosa*, *Quercus glauca*, *Toona ciliate*, *Dalbergia latifolia*, *Petrocarpus marsupium*, *Artocarpus sp.*

Shade Demander: *Abies pindraw*, *Taxus buccata*, *Mallotus phillippinensis*, *Litsea glutinosa*, *Syzizium cumini*

3.5 Natural Regeneration under Various Silvicultural Systems

Clear felling system, Shelterwood system and Selection system are the three main high forest systems which are used in the regeneration and management of forests.

Clear felling system is defined as the system in which the mature crop is removed in one operation. In other words, the area having a mature crop is clear felled. This area is regenerated either naturally or artificially. The natural regeneration of the area depends for seed or seedling from one of the following sources.

- ☞ From the adjacent standing mature forest,
- ☞ Seed already lying dormant in the clear felled area,
- ☞ Ripe seed on the mature trees before they were clear felled,
- ☞ Advance growth already present in the clear felled.

Shelter wood systems are defined as the systems in which the mature crop is removed in one or more operations, the first of which is the seeding felling and the last is the final felling. Other fellings if any are called as secondary felling. The regeneration is obtained under a shelterwood, which is removed in final felling only when the natural regeneration is established.

The number of required trees is a function of: Desired amount of regeneration, Seed production by individual tree, Expected seed survival, Height of trees and Projected tree mortality (loss).

The number of seeds required depends on the species and given in number of tree per hectare

☞ <i>Adina cardifolia</i>	1-2
☞ <i>Shorea robusta</i>	30-40
☞ <i>Pinus wallichiana</i>	25-30
☞ <i>Cedrus deodar</i>	45-50
☞ <i>Picea smithiana</i>	45-50
☞ <i>Abies pindraw</i>	75-87
☞ <i>Pinus roxburghii</i>	12-18 on cooler aspect
☞ <i>Pinus roxburghii</i>	20-25 on warmer aspect

The basic principle of shelterwood system is that some trees of the mature over wood may be retained to supply seed while other may be felled to admit light on the forest floor so that regeneration may come in the openings. The regeneration is then tended to grow up under the shelter of the seed trees.

Selection systems described so far are based on concentrated felling and produce a new crop which is regular. In the selection system, on the other hand, the mature crop is removed either as single trees or in small groups over the whole of the felling series and the resultant crop is always irregular. The following three operations are carried out in selection system:

- removal of trees of and above the exploitable diameter
- thinning in trees below the exploitable diameter
- cultural operations

4. Natural Regeneration by asexual Regeneration (Vegetative parts)

Normally tree species regenerate by seed but some species have the power to regenerate themselves by vegetative parts, viz. root, stem, branch, etc. Reproduction obtained from these parts is called vegetative reproduction (Khanna, 2004a). Out of different methods of vegetative reproduction, coppice and root sucker are the methods that is applicable for natural regeneration. Most of the species of the dry areas are able to regenerate through coppice shoots or by root suckers.

4.1 The coppice reproduction

a. Seedling Coppice: Seedling coppice is defined as the coppice shoots arising from the base of seedlings that have been cut or burnt back. This method of obtaining natural regeneration is used for cutting back woody shoots and established reproduction which is not making any progress so that they may produce vigorous shoots and soon develop into saplings and later into poles. It is generally used in case of Sal and Teak.

b. Stool coppice and root collar shoot: Stool coppice is the coppice arising from the stool or living stump. In this method, regeneration is obtained from the shoots arising from the adventitious buds of the stump of the felled trees. The coppice shoots generally arise either from near the base of the stump or from its top. Of the two, those arising from the base are better because it establishes easily while shoots arising from top is liable to be damaged by the rotting or wind. Eucalyptus in Sagarnath is first planted and natural regeneration from coppice is obtained for 2nd, 3rd rotation.

c. Pollard Shoot: Pollarding consists of cutting a pole tree at some height above the ground level so that it produces new shoots from below the cut. Pollarding is done at a height of 1.0 meter to 1.25 meter above the ground level.

4.1.1 Factors Affecting Natural Regeneration by Coppice

The following factors affect natural regeneration by coppice:

i. Species: all species do not coppice and even in the species that coppice, the power varies with species. The important Nepali Tree species have been divided according to their coppicing power as are follows:

Strong Coppicers: *Acacia catechu*, *Albizia spp.*, *Anogisus latifolia*, *Azadirachta indica*, *Dalbergia spp.*, *Cassia fistula*, *Eucalyptus globules*, *Morus alba*, *Salix spp.*, *Shorea robusta*, *Syzygium cumini*, *Tectona grandis*, etc.

Fair Coppicers: *Pterocarpus marsupium*, *Juglans regia*, *Quercus incana*, *Q. lanuginose*, *Q. semecarpifolia*, *Terminalia tomentosa*, *T. belerica*, etc.

Poor Coppicers: *Acacia nilotica*, *Adina cordifolia*, *Bombax ceiba*, *Madhuca latifolia*, *Populus ciliata*, etc.

Do not coppice: *Abies pindrow*, *Cedrus deodara*, *Picea smithiana*, *Pinus roxburghii*, *Pinus wallichiana*, etc.

ii Age of trees: the older the tree, the lesser is its coppicing power because old bark prevents the emergence of dormant buds. Younger saplings and poles, as a rule, coppice readily and profusely.

iii. Season of coppicing: the best season for coppicing is a little before growth starts in spring because delay results in reducing the growing period. This season has another advantage that at this time there is large reserve of food material in the roots and all of it is utilized in the growth

of coppice shoots. The greater the delay after the growth season has started, the more depleted will be the food reserves and consequently the growth of coppice shoots will be affected.

iv. Height of stump and method of cutting it: the effect of height of stump varies with species. For example, some bad or indifferent coppicers, e.g., *Casuariana equisetifolia*, *Hardwickia binata*, produce better coppice shoots when the stumps are higher. Usually, lower the stump; the better it is for coppice because they are not liable to be damaged by wind or animals. Such coppice shoots also develop independent roots and rotting of the stump does not affect them. Stumps are usually kept, 15-25 cm high. (10 cm for eucalyptus)

v. Rotation: since most of the trees coppice best during the early age, coppice rotation must be short. Long rotation encourages seedling regeneration and for that reason, coppice rotation is generally shorter than the age at which tree produce viable seeds.

vi. Silvicultural system: the coppice shoots are strong light demanders and therefore they must be worker under systems involving clear-felling. When natural regeneration is obtained from seedling coppice, the silvicultural system is a high forest system because the essence of coppice system lies in obtaining the new crop from stool coppice under short rotation. Thus, seedling coppice is used to obtain natural regeneration of Sal and Teak under clear-felling system where as stool coppice is used under simple coppice system, coppice with standard or coppice with reserves system.

4.1.2 Precaution during felling and tending

- ☞ Stump should not split during felling trees and bark did not get detach from the wood.
- ☞ Stump should slope slightly in one direction.
- ☞ Cleaning is done to remove climbers and inferior sp. and to reduce the no. of shoots to two or three.
- ☞ Thinning if necessary is carried out in fifth year and the no. of shoot is reduced to one/stool. This is called as singling out operation for pole or timber.

4.2 Natural Regeneration by Root Suckers

Natural regeneration by root suckers is not being attempted on any large scale anywhere not only in Nepal but also in India. This method is suitable for *Dalbergia sissoo*, *D. latifolia*, *Garuga pinnata*, *Butea monosperma*, *Diospyros melanoxylon*, *Anogeissus pendula*, *Bombax ceiba*, etc. (Dwivedi, 1993). Sometimes, this method is used in *Dalbergia sissoo* for canal bank plantations in UP, India. Where this method was followed, it was usual to dig continuous or discontinuous circular trenches with diameter of about 6 m round the isolated trees so that their roots may be severed and root suckers produced which, with tending, could be developed into trees.

The trees produced in this way are liable to wind throw and poor in growth and therefore this method is not being favored now. *Diospyros* root suckers are sometimes encouraged in India because the root suckers produce best *biri* leaves (Khanna, 2004a).

4.3 Natural Regeneration under Various Silvicultural Systems

Natural regeneration by coppice is generally obtained by simple coppice system, coppice with standard system and coppice with reserve system.

The **simple coppice system** is that coppice system in which coupes are clear-felled on short rotation to get new coppice crops. Naturally, this system is applicable to species which coppices strongly and rotation is usually kept as 20 to 40 years.

The **coppice with standard system** is that coppice system in which part of the crop is retained to form an uneven-aged over-wood. Thus the resultant crop is two storeyed, the upper storey being of standards standing over the lower storey of coppice crop. The rotation of standards is a multiple of that of coppice.

The **coppice with reserve system** is a coppice system in which well grown saplings and poles are retained in coupes to form part of new crop and the rest is felled. The reservation is done with the object of improving the condition of the crop, providing protection against frost and erosion, supplying seed, protecting valuable species as well as species with edible fruits, etc. thus the regeneration of the area is not only by coppice but also by saplings and poles grown from seed.

5. Management Option for successful natural regeneration

A number of factors, both natural and man-made, are believed to be involved in the control of natural regeneration. Some of these are discussed below

5.1 Manipulation of Upper Canopy

Purpose: for improving Light and moisture condition of grounds and to create favorable condition for regeneration. Light affects the soil conditions, undergrowth, and seed germination, so adequate light should reach the forest floor. This is achieved by manipulation of canopy. The requirement of light varies with species and their variation in light requirement in different conditions and at various stages of their development. Wide opening is required for the light demanding species where as shade bearer or shade demanding species require closer opening.

5.2 Manipulation of lower canopy

Removal of dense low branchy understory tree is an important operation for ensuring regeneration. The dense understory occurs usually in tropical moist hardwood forest and complete absence of understory in coniferous forest. We should manage this by comprised felling of understory and controlled burning.

5.3 Seed Supply

Absence of fertile plants with viable seed: In some instances seed may not be available at the site immediately but may be carried in from nearby sources by water, wind or wildlife. In this case, simply waiting can produce results. Direct seeding or planting may be the only option in areas cleared of native vegetation. It should be noted that native plants do not produce seed in equal quantities each year. Heavy seed fall in some eucalypts is infrequent. Monitoring of seed fall may be necessary using a suitable seed trap. It may be necessary to wait for a better season, plant individuals of the other sex (in plants with separate males and females), or pollinate existing females from elsewhere.

Seed harvesting by ants and predation by other insects, birds and mammals: Light raking of the soil during seed fall may hide sufficient seed from ants that consume seeds. Insect numbers vary seasonally and in most cases no action is required to prevent opportunistic predation of seeds by other species.

Lack of fire: Use fire to promote seed release in woody-fruited species (e.g. *Banksia*, *Hakea*) and for seed germination (e.g. some *Acacia* spp.). Fire can also be used to reduce pest insect populations. Timing should be as close to natural occurrence as is permissible under fire restrictions.

Lack of pollinators: Supplementary planting of local natives to improve natural diversity and support natural pollinators, by providing habitat for them, may assist. Connecting remnants to other remnants with corridor plantings may encourage reestablishment of pollinators. Use of honeybees (*Apis mellifera*) as pollinators is not recommended. Note that honeybees may adversely affect wildlife by occupying hollows used by wildlife, by denying large quantities of nectar to wildlife, by increasing in-crossing (pollination by a plant of its own flowers) of native plants and may also have adverse effects on native bees.

Seasonal variations: Seed supply, dispersal and viability will vary seasonally due to a range of climatic and biological factors. These factors should be considered as 'natural events' and should be planned for rather than reacted too (Platt, 1992).

5.4 Soil Condition

Seed germination and establishment will be impaired by 'unhealthy' soil conditions. Such conditions might include: no suitable site for germination as a result of soil compaction, loss of topsoil, an unstable site, lack of mycorrhizal fungi (fungi which associate with plant roots and assist with nutrient uptake), lack of an 'ash bed' (nutrient pool created by fire), loss of the cryptogamic (lichen & moss) mat or changes to soil chemistry.

Soil compaction: The heavy hooves of stock, including cattle, sheep, horses and goats, can compact soil and destroy soil structure. This diminishes the air spaces in the soil and reduces its capacity to absorb and retain water, leading to greater runoff, and has detrimental effects on biological activity in the soil. These changes may prevent or restrict germination by excluding penetration by seedling roots, increasing the chance of desiccation (drying out), killing helpful soil micro-organisms which associate with plants and decay organic matter, and by causing other effects.

Loss of topsoil: Topsoil contains most of the organic material from which plants obtain their nutrients. Where it has been removed, such as by erosion, seedlings may be unable to establish due to a lack of nutrients.

Unstable site: Soil provides anchorage for plant roots. If there is movement of soil, plants may fail to remain stable and may fall over, have their roots damaged and opened to infection or suffer other ailments.

Cryptogamic mat: The 'cryptogamic mat' provides a sheltered, moist environment at the soil surface. Its presence in some vegetation types (e.g. grasslands) may play an important role in assisting seedling establishment.

Soil structure

Exclude stock by fencing or reduce stocking rate. If necessary, lightly scarify compact soils at time of seed fall. Follow up weed control with a knockdown (not residual) herbicide (e.g. glyphosate) may be required. In severely degraded soils, where no topsoil remains, addition of weed-free, pathogen-free topsoil may be necessary.

Alternatively, use native pioneer species such as *Cassinia* which can, over time, re-condition the soil. Sterile hybrid grasses (e.g. ryecorn) have been used as 'cover-crops' to arrest erosion. Addition of a small soil sample from healthy vegetation of the same type can reintroduce lost soil microorganisms. Care must be taken that the soil sample is from healthy vegetation and is free of weed seeds and potential pathogens. Mulching will aid water retention, slowly add to the organic content of the soil and reduce weed competition but if applied too heavily will prevent germination. Where erosion is severe, other erosion control practices should be employed.

Soil chemistry

Application of chemicals: Many soils contain naturally low levels of elements that are important to plant growth, such as phosphorous and nitrogen. Much of our native vegetation is adapted to these low levels of soil nutrients and has developed efficient strategies for recycling nutrients.

Application of superphosphate ('super'), weedicides and pesticides has changed the chemistry and biology of the soil (worms and 'super' don't mix). 'Super' favors the rapid growth strategy of

introduced pasture annuals over native species. The resulting competition from weeds may effectively exclude native plants.

Do not apply fertilizer to areas that are to be regenerated or managed to retain native vegetation. Other chemicals should be used with care and in minimal quantities to achieve a management aim. Fire may be used to promote conditions for germination (e.g. ash bed for germination) in appropriate vegetation communities.

Lack of an 'ash bed': Some native plants have specific soil-bed requirements for germination. For example, some species need a fire to release nutrients for use during establishment.

5.5 Control fire (control burning)

Controlled burning is used as a tool to obtain natural regeneration in certain types of Sal, Chir and Teak forests. In the very moist and moist Sal forest annual and periodic burning is used to reduce the density of shrubs and soil moisture and to burn leaf litter to provide clean seed bed for natural regeneration. Burning is harmful in dry types of Sal forest. In Pine Forest controlled burning is done before carrying out seeding felling. Burning destroys needles and shrubs and provides clean bed. After a good seed year burning is not done. The controlled burning is again done when the natural regeneration has reached a size that the area is to be put outside the regeneration area. So, before carrying out final felling, the natural regeneration is controlled burn for three years to harden the natural regeneration against accidental fire. (November or December is suitable for control burning). In moist teak forest controlled burning induces regeneration and suppresses weeds.

5.6 Slash disposal

Felling of trees for canopy manipulation or timber harvesting results in leaving large quantities of slash in the regeneration area. This has to be removed to make the area clean for seed germination as well as to reduce the hazards from fire, insect and fungi (Khan, 2007).

- i. Slash in relation to forest fire.
- ii. Effects of slash on regeneration.
- iii. Effect on soil (decomposition of slash onsite)
- iv. Slash in relation to insects and fungi
- v. Slash in relation to Aesthetics and wildlife.

Methods of Slash disposal:

- i. Broadcast burning of slash.
- ii. Spot burning
- iii. Lopping and scattering of slash
- iv. Clipping and yarding of slash.

5.7 Competition

Competition from the same or other plant species may prevent successful seedling recruitment. This may be due to weeds, parent plant allelopathy (chemical inhibition) or fungal attack.

Competition from weeds: There are several options available. The technique employed will depend on your situation (natural bush versus pasture), time constraints and area being managed. Briefly, the options are: hand weeding using an appropriate technique such as the Bradley Method; mulching, although this can prevent regeneration if applied too heavily; chemical methods (application of weedicides can be very effective although note concerns above re: soil chemistry); use of fire as a means of selecting out fire sensitive species (e.g. Sweet Pittosporum *Pittosporum undulatum*) or to remove above-ground vegetation for a short period. Fire may be particularly useful where it is necessary to retain the binding capability of plant roots in areas subject to erosion. Removal of the top few centimeters of soil (scalping) can be used to remove unwanted seeds and can be a useful technique if done at the time of seedfall of the species to be regenerated.

Positive weed control strategies in areas abutting 'improved' pasture are usually required. For example, a buffer (e.g. screen of tall plants, weeded area) may be needed to prevent *Phalaris* spreading from paddocks into fenced natural areas.

Parent plant allelopathy: Landholders need to be aware of this effect. The area managed for regeneration should not be restricted to the base of the parent plant. If only a small area can be fenced, it should be offset downwind.

Fungal attack: Sterilization of the soil is neither practical nor desirable. Fungal problems are likely to be seasonal, so repeated attempts may be necessary. Revegetation of areas with contaminated soil containing *Phytophthora* or other soil pathogens must be avoided.

Other seedlings: Where there is a range of plants all germinating together (same or different species) there will be competition between individuals for the available resources. Some plants (of a species), or other species, may do better than others. This should not necessarily be seen as a problem unless the successful competitors are weeds (see above). Some seedlings may die whilst stronger and more successful ones survive. If the aim of management is to increase diversity, you may wish to selectively remove competition against 'rare' species by selectively weeding around them using a suitable technique (e.g. hand-weeding).

5.8 Protection from Animals and Pests

Seedlings may be destroyed by predators such as insects and other invertebrates; stock; rabbits and hares; or wildlife. Seedlings and young stems may lack natural deterrents (toxic or unpalatable chemicals, hard leaves or leaf structures such as thorns and hairs) and so be

relatively defenseless compared to mature plants. Grazers may select particularly palatable species. Thus, some species may be particularly vulnerable.

Insects or other invertebrate: Caterpillars, crickets, beetles, mites, nematodes, and other invertebrates eat seeds and seedlings.

Stock: Stock, including cattle, sheep, horses and goats eat seeds and seedlings and may selectively choose a particularly palatable species.

Introduced species: Deer, rabbits and hares eat native plants. Rabbits & other species may strip bark from young plants and ring bark them.

Native wildlife: Native animals including kangaroos, bandicoots, Swamp Rats and others may feed on seedlings.

The most effective control for larger predators is good fencing. Reducing the stocking rate has also been effective in some instances, particularly if commensurate with a rabbit control program. An effective rabbit control program is essential in areas subject to large numbers of rabbits. Invertebrates are difficult to exclude and are likely to be bad in one season and less of a problem in another. Snail and slug baits could be used over small areas or natural predators encouraged by providing cover, feeding and breeding requirements. 'Benign' chemicals, such as white oil, may be useful in specific instances.

5.9 Natural hazards and controls

There may be natural climatic, biological and physical constraints upon natural regeneration. These include fire, flood, wind, drought, temperature extremes (e.g. frosts), time of year and light conditions.

Natural events can affect the survival of seedlings. Drought, fire or flood may kill seedlings. Some species require natural events to occur prior to germination. For example, acacia seeds germinate following fire, whilst River Red Gums respond to flooding. Severe wind may be hazardous to young plants, particularly in exposed situations. There is some evidence that large-scale regeneration events are more likely to be successful in particularly 'good' years (years with above average rainfall when the soil is warm). Lack of light or water can prevent germination (e.g. in a rainforest the collapse of a mature tree may allow light to the forest floor and initiate germination). Germination may fail to occur in a vegetation community during drought. The first heavy rains may initiate germination on a massive scale.

There is little that can be done to prevent nature taking its course. It is advisable not to put all your effort into one season. Where it is obvious that a lack of natural events due to man-induced changes is to blame for a deficiency of regeneration you can seek assistance and advice from nearby forest office.

6 Management and monitoring

Implement a monitoring program that allows the rate and nature of natural regeneration to be assessed

6.1 Some Basic Rules

A number of management options have been outlined above to deal with many factors that may be preventing natural regeneration. The practical application of natural regeneration techniques is considered next. What is done, where it is done and when it is done are all important.

It is suggested that you take note of the following general principles:

- ☞ Do not apply a technique to the whole area under management until you have tested it on several small representative areas.
- ☞ Do not put all your effort into one season.
- ☞ Don't be surprised if at first you fail. Your chances of success, as with all techniques, will improve with experience. The rewards are great for those who are prepared to show some dedication, are open to investigation or experimentation and can learn from experience. There are no guarantees with natural regeneration. Talk to those people who have experience in your area.
- ☞ Be patient, if it doesn't happen this year it may next year.

6.2 Guidelines

- ☞ Carry out a survey of remnant vegetation to determine and map the distribution, density, condition, size and species composition.
- ☞ Identify the species composition of the remnant vegetation by referring to vegetation surveys, database, and relevant publications.
- ☞ Prepare a Natural Regeneration Management Strategy that is coordinated with any planting program that may be required. Clearly define priorities and a sequence of management actions, including fire management, weed control, public access, supplementary planting and fencing.
- ☞ Identify undisturbed areas that contain vegetation similar to that occurring on the site or nearby. This will provide a benchmark or reference for the regeneration process.
- ☞ Identify appropriate the fire regime required to induce germination of particular species if necessary.
- ☞ Assess the extent and nature of weed infestation and determine the extent to which it is suppressing germination and growth of remnant indigenous species.

- ☞ Devise and implement a Fire Management Strategy in consultation with the relevant fire brigade.
- ☞ Devise and implement a weed control plan to provide suitable conditions for germination and growth of indigenous species.

7 Factors Affecting the Choice between Artificial and Natural Regeneration

Crop composition: Where crop composition has to be changed artificial regeneration should be accepted.

Genetic consideration: If quality of the new crop is to be improved it is absolutely necessary that the artificial regeneration should be adopted and seeds from genetically superior trees should be used for raising plantation.

Yield (volume and value): For better volume and financial yield, artificial regeneration is preferred.

Risk of damage by pest and pathogen: Natural regeneration should be preferred to artificial regeneration because natural regeneration is more resistant to attack by insect, pest and pathogen.

Flexibility of operation: In case of uncertain condition natural regeneration is preferred because work can be postponed without any serious loss of money or effort.

Density of stocking: If uniform stocking is aimed at, artificial regeneration should be preferred.

Risk of loss and deterioration of soil: Natural regeneration should be preferred where there is risk of loss and deterioration of soil.

Shortening of Rotation: Artificial regeneration is preferred for shortening of rotation

Cost: Natural regeneration is preferred because it is less expensive.

In spite of these academic considerations, the recent trend is towards artificial regeneration.

8 Advantage and Disadvantage of Natural Regeneration

8.1 Advantages

- ☞ Climate, soils and fire, and able to withstand insect attack and disease.
- ☞ Restores biodiversity by natural regeneration of the original range of plant species.
- ☞ The initial costs of establishing a forest stand may be lower especially if site preparation is not necessary.
- ☞ Less heavy equipment and labor is required.

- ☞ The seedling has a naturally shaped root system unlike seedlings which have been grown in a nursery.
- ☞ Chance of tip moth damage is reduced.
- ☞ For aesthetic reasons, the landowner may prefer to see a forest stand which is unevenly and naturally spaced versus a stand which is in rows.
- ☞ Natural regeneration is a cost-effective way to revegetate a site with species adapted to the site.
- ☞ Enhances wildlife habitat.
- ☞ Produces vegetation that is more tolerant than introduced species to prevailing

8.2 Disadvantages

- ☞ A seed crop must be available and seed dispersal must be timed correctly with site preparation so that a suitable seedbed is available for the seed germination.
- ☞ Moisture in the soil is necessary for the seeds to germinate; exceptionally dry years or sites may result in poor germination or seedling mortality.
- ☞ Insects and other small seed-eating animals may consume all or most of the seed.
- ☞ Competing vegetation may be a problem for survival and growth for a longer time period than with planting because seedlings are smaller or seed may not be disseminated in the first year.
- ☞ If the seed is abundant and a dense stand results, a pre-commercial thinning may be necessary to decrease the number of trees per acre. For example, if there are more than 2000 slash pine seedlings at age three, growth may be inhibited and the site will require pre-commercial thinning (Duryea, 2000)
- ☞ Because the site is planted with seed versus 1-year-old seedlings, the rotation length (time until harvest) may be increased by one or more years.
- ☞ The seed coming from the seed trees is not genetically improved as when the seed comes from a seed orchard.
- ☞ Natural regeneration may be less expensive initially but more costly in the long run if it is necessary to prepare the site or pre-commercially thin.
- ☞ Open sites without trees such as clear-cut, abandoned fields, and stands after a wildfire or windstorm cannot be naturally regenerated.
- ☞ The landowner does not have any control over spacing between trees or stocking levels and so often these can be very uneven.
- ☞ A successfully regenerated site may take longer to reach harvest than with direct seeding or planting.
- ☞ Natural regeneration requires a source of seed from remnant trees, the soil seed bank or dormant epicormic shoots.

- ☞ Existing dense weed growth may limit the ability of seeds to germinate. Some species require bare ground to germinate and grow.
- ☞ Fire is needed to germinate some species with thick seed coats, while other species may be killed by fire.
- ☞ Stock grazing can severely limit the survival of natural regeneration.

9 Successful Example of Natural Regeneration

A natural regeneration technique has been demonstrated by the Kandrian Gloucester Integrated Development Project (KGIDP) in West New Britain at eight 50 hectare sites. Each demonstration plot will be tended six times over a period of two years. The first tend occurs six to nine months after logging, to allow time for the germination of seedlings (to be used to transplant into gaps in the logged-over forest), and involves:

- *Selection of desirable residuals;*
- *clearing of vines and undesirable tree and weed species; and*
- *transplanting of high value seedlings into gaps which have no desirable residuals.*

At the beginning, forestry officers discuss the technique with local villagers, who are paid to do the tending work, and the desirable species are identified (not only those from a commercial basis, but traditional desirable species that may be used for medicine, food or in the construction of canoes). The identification of these species can be a learning experience for both forestry officers and the local people. (KGIDP,2008)

10. Conclusion

Natural regeneration is a powerful tool for re-establish vegetation in a minimum cost and a most important regeneration technique and frequently used for regeneration of national as well as community forest in Nepal. Natural regeneration technique is one of the It can be obtained by seeds as well as by vegetative parts, coppice or root suckers but by seeds is most frequently used and suitable for many species. Nowadays assisted natural regeneration technique is also used and seems to be best option for restocking of degraded forests. In spite of these academic considerations, the recent trend is towards artificial regeneration.

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