Forest Ecology and Ecosystem Services:
A Guide to Forest Ecosystem Management

Himachal Pradesh Forest Department

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HP-FES

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0. Introduction

Natural ecosystems don't need humans to exist, but humans do need ecosystems to exist. Humans have been altering ecosystems since we exist as a species on this planet. We have changed the shape of earth to an extent that no other species has done. Purely natural ecosystems cannot be said to exist anymore. We manipulate ecosystems to increase our wellbeing, to get more of what we want from our environment than it would give without our management efforts. But very often we have changed ecosystems that we depend on in a manner, that some benefits derived from them are impaired or lost to future generations. To manage ecosystems in a way that the benefits for them remain sustainable for us and for future generations requires to manage them in the best possible way we know how.

The benefits we get from nature are called services. These can be anything from fuel wood to the peaceful feeling we get when we take a walk in a forest. Nature comprises many different ecosystems and they are all linked. From these ecosystems we obtain certain services called "ecosystem services". And if the services are from the forest, we call them "Forest Ecosystem Services" or FES.

This manual provides information about the vital links between ecology and the benefits that we obtain from forests. The manual outlines basic management principles that we need to consider, whenever we want to manage the ecosystem services that are important to us. The manual is organised in three main chapters: Chapter 1 Forest ecology - addressing basic ecological principle, chapter 2: Ecosystem services which establishes the link between ecology and the benefits that we derive from natural ecosystems and chapter 3 that states the principle management methods on how these interactions can be modified.

The manual is intended for natural resource managers, foresters, farmers, rural landowners, communities that rely on the land base for part of their income and the interested public.

1. Forest ecology

1.1. The principles of natural dynamics

In this chapter we address the principles of dynamics in nature. We look at the conditions that enable the ecosystems around us to function, how different species interact with each other and how the diversity of species is linked to the dynamics of ecosystems.

1.1.1. Important trends of terrestrial forest ecosystems

If we would see nature as a person that is acting consciously, we could state that it has four objectives to enable the maximum development of life:

1. solar energy conversion or photosynthesis
2. retention of precipitation or water storage
3. the build-up of biomass or growth
4. the build-up of biodiversity

1. Solar energy conversion

Life on earth depends on energy coming from the sun. Only a small portion of the light energy is used by plants to produce biomass. The process used is called photosynthesis by which plants convert the light energy into chemical energy which is used to produce biomass. Biomass contains chemical energy. It stores the light energy, just as a battery stores energy to be used as needed, by the plant, for example, for plant growth and reproduction. All the organic matter (living or dead) found in an ecosystem is called biomass. The organisms (nearly all are plants) that can perform photosynthesis are called "primary producers". All other organisms must live by either consuming the primary producers, for example grass or leaves, or they must eat something that has eaten primary producers e.g. leopard that eats a rabbit that's eaten grass. Neither a rabbit nor a leopard can perform photosynthesis. The energy, or a percentage of it, is thus transferred from one organism to another loosing energy with each transfer. This capturing of sunlight by leaves is ongoing when the sun shines. An undisturbed terrestrial ecosystem can maximise its capacity to capture the suns energy and store it. Growth results in more biomass, like branches, roots and leaves. The greater the leaf area the primary producers have, the more they are able to photosynthesise and produce biomass.

2. Retention of precipitation

Water is also essential for life. There is no life, as we know it, that can live without water. Undisturbed terrestrial ecosystems may improve their capacity to retain water as they mature and, over time, produce more biomass. Specifically, ecosystems accomplish this by the following means:

- Roots penetrate and grow through the soil creating channels for water to infiltrate and percolate through the soil,
- Dead plant material like leaves and twigs form a layer of litter on top of the soil that hinders water from evaporating back into the atmosphere,
- Uncountable numbers of small organisms in the soil decompose the organic material and combine it with mineral soil particles which increases the soil water retention capacity,
- The roots of plants such as grasses, shrubs and trees help bind the soil thereby preventing erosion and slowing down surface water runoff which is lost to the site. Water that does not run off stays on the site and can be used by on site by plants for growth.

- The tree canopy intercepts rain water. Some of the intercepted water evaporates, some makes its way through the canopy and some flows down the stem. A small percentage of the rainfall, called throughfall, reaches the soil.
- The plant roots absorb this water for immediate use by the root system or it is transported to where it is needed in the plant e.g. for growth, or the water is stored in plant cells for later use.

The soil acts like a sponge that absorbs water when it is available and then releases it slowly to plant roots, the atmosphere streams and rivers.

3. The accumulation of biomass

Well managed ecosystems capture, utilise and store greater amounts of water and sunlight. All ecosystems are not capable of producing equal amounts of biomass. Like a financial investment earning interest, the interest rate varies depending on the condition of the financial system. A high rate of biomass production depends on factors within the ecosystem that enable it to use water, nutrients and sunlight optimally for growth. Generally, the more biomass an ecosystem has, the greater is the potential to capture sunlight as there is more leaf area exposed to sunlight and a greater capacity to capture water due to an extensive root system and an increasing soil humus content characteristic of intact ecosystems. However, ecosystem processes may be interrupted or degraded by many different types of disturbances, both natural and human, (fires, storms, floods, diseases, poor timber harvesting practices, improper pesticide use and others). The accumulation of biomass goes on until the capacity of the land to carry this biomass is reached. To illustrate, on a steep slope the forest might move in a land slide once so much biomass is accumulated that it is too heavy to be carried on the slope. If this happens, the slope is barren soil, and the forest starts to develop again via successional processes. This process of building up biomass does not happen in isolation; it is not performed by plants only. It is a result of the cooperation between all species. And, in general, we can say that, the more species there are the better these processes function. That's why the diversity of species (biodiversity) is so important.

4. The build-up of biodiversity

The same trend continues. Besides some interruptions (disturbances), the biodiversity of terrestrial ecosystem tends to continue increasing when the ecosystem is left to natural processes. And again, it stops when the capacity of the land is reached. This process can be fast or slow, depending on the climate and other factors. Especially if it occurs in by small increments we do not see it.

If, for example, we imagine a grassland covered by only one species of grass, we know that the result is that only one type of grain or seed is produced. This will limit the different types bird species that can feed on these grasses, it will provide only very few resting opportunities for birds to come and disperse, via their excrement, undigested seeds of other plant species etc. A grassland that has more grass species and some trees or shrubs, will provide a greater variety of habitats for a greater variety of bird species. These birds in turn will bring seeds from other parts of the landscape this will increase the plant diversity of the grassland even further. By this even more bird and other species can dwell on the grassland and enable the growth of more plant species (see also Chapter 3). This trend continues until the carrying capacity for biomass and species is reached.

1.1.2. Site conditions and their implications for actual development

We have looked at some of the principles influencing the development of ecosystems, which is more a view on the system behaviour. To understand the limits that this process has, in other words, how much biomass and biodiversity can be built up or how far the system can develop, depends largely on the environmental conditions the ecosystem is located in. We call these environmental conditions site factors: the factors that determine the performance of nature at a given site. The site factors are:

- Climate
- Land (soil and topography)
- Hydrology
- Vegetation
- The human factor

Climate

The climate is the weather of a given area over the entire year. The climate is often expressed as climatic factors like the annual number of sunny days, their seasonal distribution, monthly mean temperature, the amount of precipitation during the growing season and its seasonal variations. Other important factors used to describe climate are the extremes of these climatic factors including the extremes of temperatures and precipitation. These extremes determine the type of existing vegetation. If, for example, an area experiences frost (temperature below 0°C), frost-sensitive plants cannot regenerate. It is important that we are aware of weather extremes that appear daily, monthly and yearly.

Apart from temperature and precipitation some other climatic factor such as wind play important roles. Wind is one factor that influences the loss of water from surfaces like the soil surface or water surface (evaporation) and the surface (leaves) of plants (transpiration).

Land

The land is the base upon which all the interactions between the five factors occur. How the land is formed (the geology and geomorphology) determines these interactions. The steepness of a slope determines the speed and impact of water running off of it. It also determines how much soil can be built up (the steeper the slope the shallower the soil) and this again controls which and how much vegetation can grow on this spot. The exposition (north, south, east or west) regulates the intensity of the sun: south facing slopes receive more sun than north facing slopes and this again determines the temperature and the occurrence and number of days with frost.

In Himachal, the uplift of the Himalayas (which began about 50 million years ago), defines the broad characteristics of the overall landscape. Weathering, erosion and sedimentation have created its present shape. Soils are are comprised of materials weathered from the underlying parent geological layers and are then either left in place or transported mainly by water and wind and then deposited, called sedimentation. The sedimentation of soil particles resulted in areas with deep soils where agriculture could thrive.

Hydrology

Hydrology concerns the study of water. It seeks to explain and describe things such as where water appears in a landscape, how it moves, what properties it has and how it interacts with other environmental factors. The hydrology of a given landscape is an outcome of the interaction between climate, topography and the vegetation. Landscape units, or watersheds, intercept and store the precipitation within the soil, the biomass and the aquifers below ground.

The precipitation that hits the soil surface can go in one of two ways. Depending on the characteristics of the soil and the intensity with which the rain hits the surface, some water penetrates the soil and some runs off, called surface runoff. If the soil particles are very small like clay, the soil is very sticky and can take up water only slowly. A rocky and sandy soil will take up water much more easily. Once the soil is saturated with water, the excess water moves within the soil downslope (base flow) in addition to the water that moves on the surface (surface flow). The water will enter the system of perennial or seasonal streams and is lost to the landscape. Watershed managers aim to increase the water holding capacity of the watershed.

Vegetation

The type of vegetation growing on a site is guided by site conditions (climate, topography, hydrology, soils). It is therefore a product of the site conditions. But it is also a factor influencing site conditions: it influences the development of soil, the hydrology and the presence and distribution of many other organisms.

The state of the vegetation, or its absence altogether, is the most obvious indicator of the carrying capacity of a landscape. Its role in maximizing solar energy conversion through photosynthesis and in intercepting and absorbing precipitation is so important that it must be given the highest attention.
As recently as several centuries ago, human population density was such that the human impacts on what is today Himachal Pradesh would have been negligible, if man would not have made fires in the landscape. There are no exact figures on how this affected the landscape, but it can be expected that the greater part of the land below the tree-line would have been well established dense forests.

The human factor

Humans are the only species on earth that can make complex decisions. This enables us to modify our environment in ways that suit us best. And this enables us to have a strong impact on natural functions. No other species can do that. The most important tool that our species must carry out this modification is fire. Even species of our genus that existed before us (*Homo erectus, Homo neanderthalensis*) used fire intensively. The use of fire goes back around 1.7 million years. This is a very long time of burning terrestrial ecosystems and we got so used to this burning and the results, that we think this is what nature does. Fire helps humans in many ways like clearing land for agriculture, creating pastureland, maintaining useful vegetation formations and defence against dangerous animals. For these purposes fire is still used today on a large scale, even in India, even in the Himalayas.

Agriculture

As we learned above, nature tends to maximise the production of biomass and the number of species to the point where they best fit the given site conditions. Whatever can be done to catch solar energy and water is done. If humans modify this system to increase the production of the plants they are interested in the most, which are mainly grass species like wheat, rice and grasses for fodder they are in danger of weakening these natural systems. Artificial, man-made systems are simplified, and need energy inputs to be sustained and can often not cope with climatic extremes (long droughts, periods of excessive rains). This can have disastrous consequences for the well-being of society.

1.2. Succession: Vegetation helps itself and others

A mature forest is a most effective system. It functions to capture sunlight and precipitation, which it transforms into biomass. This mature forest state does not consist only of trees and plants, it also includes all kinds of birds, mammals and microorganisms that interact and work with each other to make the system fully functioning. Such a fully matured forest has a long-term resilience to climatic extremes.

But how does this forest system establish and develop? It is done by a sequence of different communities that enable each other's existence. It is a bit like building a house. The foundation enables the walls to be put up and walls enable windows and doors to be installed and the roof to be put on. Rooms can now be made and flooring, pavements, furniture etc be added. The house gets more and more functional and supports the wellbeing of the people living in it. The process of different development stages in the development of a forest is called succession.

As for the house, to build a forest it needs parts that are brought in at the beginning and others that come at later stages. Depending on what stage of the development the parts appear, they must suit different conditions. Environmental conditions are very different at the beginning from the end of the development of a forest. These different conditions meet at the forest edge, where the forest is bordering open land. Open land has much more wind, much more fluctuation in temperature (often frost), full sun, full exposure to rain and often shallow and poor soil while inside the forest the conditions are the opposite.

Plant species that appear first in the development of a forest need to be able to withstand the conditions present in open areas. They must be able to establish on poor soil, with high wind, cold and hot temperatures and in the full sun. These plants are called "pioneers" or "early successional species". Not all pioneers are the same. Some come at the very beginning (primary pioneers like grasses) and some come a bit later like some shrub species (following pioneers). Species that need better soil, that can withstand shade when they are young and are sensitive to full sun and temperature extremes are called "late successional species". Between the pioneers and the "late successional species", we have the mid successional species.

For the forest, the stages of succession are one continuous process. To observe and understand this process we must break it up into several stages that are distinguishable from each other. We give here the example of forest succession in the Pine-Oak belt of the Western Himalayas, which stretches approximately between 800 and 1800 above M.S.L (this is approximately in many areas from Nahan to Shimla).

Stage 1

Barren ground is first colonized species that are able to withstand harsh conditions. They grow and regenerate in the full sun, shallow soil as well as a wide amplitude of climatic conditions (e.g. changes in temperature). Typically, one of the first stages will consist of annual plants, mainly grasses, if soil is present. Mosses and lichens will colonize bare rocks. Only very little humus is formed in the soil. Under their very tiny canopy the temperature fluctuates less and there is more shade and moisture available than in the open dry areas. This paves the way for Stage 2.

Stage 2

The conditions created by the primary pioneers allow for the establishment of shrubs and the beginning of longer-lived woody plants. The first pine trees establish. Other deciduous species able to survive on shallow soils arrive as propagules e.g. seeds and establish. These two first stages of succession are very important precursors for the following stages. They catch the urgently needed water from precipitation and create a microclimate that supports many other life forms, mainly microorganisms and insects that aid in the creation of fertile soil. In locations where the climate does not support the growth of trees, like above the treeline, the succession of species does not advance beyond this stage.

Stage 3

In this phase, shrubs and tree communities start to develop and to cover more and more ground. These species are still very much light demanding. Some more, some a bit less. We could say, that first pioneers are more abundant while following pioneers start to establish. The trees, other than pine are deciduous, a strategy enabling them to withstand long dry seasons by arresting transpiration through the shedding of their leaves.

Stage 4

The primary pioneers will now form a more or less closed canopy. The soil is deeper and contains more nutrients. With the improvement of the soil more deciduous trees become part of the plant community, especially in the canopy. The decomposing organisms can function better, if the litter layer on the ground contains some easy to digest leaves besides the hard pine needles. In the soil there are now also many more microorganisms that are decomposing the dead organic matter and form humus, that in turn provides nutrients needed by plants. In such an environment plants that are more sensitive cannot establish. They include e.g. evergreen trees like many oak species (*Quercus*) and Rhododendron (*Rhododentron arboretum)*. Pioneers would also grow very well in the fertile soil, but they need much more sun (shade intolerant) to survive and grow. However, their seeds might remain in the soil (seed bank) for a long time, but they will only germinate once the canopy is removed (disturbance occurs) and allows direct sun to reach the ground. But as the microclimate on the forest floor is much better in terms of moisture and extreme temperatures as well as in the supply of nutrients, the first evergreen species arrive and start to establish.

Stage 5

This stage shows an already well-established understory of evergreen trees and shrubs. Within the community of evergreen woody plants, there is also a separation in some that need more sun and some that can tolerate more shade. This will lead to a difference in the arrival of these plants in space and in time. The evergreen trees, which here are mainly oaks, will start to grow into the canopy of pioneer trees and, over many years, start replacing them. These trees bring along a completely new set of all kinds of species. From microorganisms up to birds and large mammals a totally new community arrives.

Stage 6

This stage is considered the last stage of succession. A stage where an increase in biomass and diversity is no more measurable and where the number of species are at the highest level. However, the environment is not stable, and it might be, that this stage experiences a disturbance on a major or minor scale, like drought, storm or a landslide. Such an event will set the succession back to a previous stage and the development starts again. If undisturbed, the forest can mature fully being home for many species, including epiphytes of all kinds like lichens, ferns etc. that dwell in the branches of trees. The forest is not only rich in total number of species but also in the number of species interactions. The soil fertility improves incrementally. Many different fungi have associations with specific tree species supporting them in the take up of nutrients and water. The result of all these species in the forest interacting with each other is a great joint work force that supports many species to exist. One is us humans.

1.3. Disturbances are part of the development

One step of the succession follows the other one and finally a mature forest is in place. If this would be the case, we would eventually see a closed forest everywhere. From the plains up to an elevation where forest cannot grow any more (the tree line). But what we see instead is a patchwork of units of different amounts of tree cover, and many open spaces. Does succession not work on these places? Where is the forest?

Succession is always working. The world that we are living in and evolved in, is dynamic. Everything is changing all the time. An open land below the tree line always trends towards increasing biomass and increasing diversity. Like a bucket that stands below a running tap gets filled with water. Only in a few places forest cannot grow like where it is too wet, too dry, too cold, or too hot for forest. But these are only a few places.

The reason why we do not see forest everywhere is either because site conditions don't permit this or it gets removed. The factors that are preventing forest from establishing or that remove or alter them are called disturbances. We have natural disturbances and disturbances driven by us humans. Let's look at the natural ones first.

Natural disturbances are for instance landslides, floods of all kinds, natural fires or insect outbreaks. Such events are normal phenomena in nature. They e not only appear regularly; they are also an essential part of life. In fact, without disturbances life on earth would not be able to develop and improve. Disturbances allow life to evolve, develop response mechanisms so they adapt to changes that come along. In this way ecosystems and their living and non-living components change constantly. As we have seen in the earth's history chapter, this trend is clearly visible if we look at long time durations.

Disturbances are therefore a must in nature. Without disturbances many species would not exist, like pioneering trees and shrubs.

Human disturbances (for example tree-cutting, fodder collection, man-made fire, over-grazing and ploughing) are therefore interfering with a nature that is used to it and can react to it. In this sense, our management of natural resources are also disturbances. We are using the ability of nature to react to disturbances for our own purposes, but we must do this wisely.

Wherever we reduce the biomass in a landscape, we move the vegetation back to an earlier stage of succession. Depending on the intensity of our impact, the efficiency in the capture and utilization of solar energy and precipitation is reduced. The effects of this regression are accelerated surface-runoff and soil erosion, a diminution of biomass, its productive potential and the overall diversity of species. To ensure that the forest, in a given landscape can serve us the best, especially in conserving soil fertility and water, we have to keep damage causing impacts to a minimum.

2. How we benefit from natural dynamics?

We are impacting on the dynamics of nature all the time. We cut plants that we want to use and cut others that we want to get rid of, we graze our animals on the land, we burn certain areas, we till land and grow crops and we plant trees we find useful. We do this to steer the dynamics of nature so that we get certain benefits. These benefits can be food, fodder, water, fuel, timber or even religious inspiration or recreation. We call these benefits that we derive from nature "Ecosystem Services" as they are a product of Ecosystems. The services that we get from forest ecosystems we call "Forest Ecosystem Services" or just FES. Now we learned in the previous chapters, that forest ecosystems are dynamic, constantly changing. Our management practices are modifying and directing these changes. This management is so normal to us that we often are not aware of it anymore. To understand what we are doing, we must look back to succession covered in Chapter 3. There we learned about the different stages of succession. Each stage provides us with a different set of FES.

Succession is an automatically ongoing process. This is a great gift as it supports our effort towards a dense and diverse forest. Within the limits set by the site factors we can direct this natural drive according to our wishes. Therefore, can we make a choice of tree species that we would like to have at later stages of the development, we can influence the dimension and quality of trees and we can influence the vertical and horizontal structure of the forest. But we can also put a halt to this development at early stages if we want a forest that is good for grazing or grass cutting or other services that we require.

It's impossible to show all possible stages that ecosystems can have. For example, can we manage a forest in such a manner, that we get the best possible timber (straight trunks with a diameter that we want). Or we can manage to have a mix of several stages of succession in very small patches next to each other. We might introduce other tree species to those that are naturally growing to enrich the fodder.

Important is that we realise that the services that can be obtained from our environment are closely linked to how we treat the environment, in this case, the land. We need to understand which action and how much time is required to build a forest formation for a certain service, that we ourselves might not benefit from, but future generations will and, very important, is that we cannot have all the services we want from one place. We must know what we want and that if we manage the forest for one service, we might not get another.

To get one service while but not another is called a "trade off". If, for example, we decide that a piece of forest land be protected so that it develops into a dense forest with very good water regulation and storage capacity, the trade-off is that it will not be available as a grazing ground anymore. If we decide to use this piece of land for grazing and we maintain an open forest with no ground vegetation except grasses, then we have a grazing ground, but its water regulation capacity is diminished or lost. This might mean that during a period of drought we may run out of water and conversely during times with heavy rains flooding in lower parts of the watershed may result.

Therefore, we must be clear which FES we want from a forest and apply the management practices that maintain the delivery of these FES.

3. Principles of Management

The word "watershed" is often used in the field of landscape management. It is an important term. A watershed describes a system of streams and nallas that release their water to one particular outlet. Therefore, everything that happens in this area impacts the amount, quality and seasonality of the water flow at this outlet and the streams that are connected to it in the watershed. A watershed combines all uses of the landscape and it is of upmost importance that we understand that these units are interacting. We have seen the gift that we have of the tendency in nature of ever-increasing biomass and diversity. The more biomass and diversity we have, the more can we benefit. It is this formation that provides most stability and security within a watershed. Therefore, most of the space of the watershed should be given to this formation. In the following we outline the principles of WS management for optimal delivery of FES.

Watershed as a management unit

The landscape is a unit of surface perceived by the humans living in or managing it as one geographical unit. That means that the boundaries of a landscape are defined by those who are defining the reason for whatever reason. A landscape can be any size, sometimes it is big sometimes small. It normally contains features such as mountains, valleys, plains and water bodies. The landscape is a dynamic system. It has been shaped by geological processes, climatic influences, diverse life forms (mostly the vegetation) and more recently, by humans.

Watersheds are subunits of a landscape. And they have clearly defined boundaries. They are delineated by the high points, from which water drains out into other watersheds, and the outlet at the lowest point from where it merges with a larger watershed, a body of water and ultimately the sea. Any such area can be a watershed and it is up to the manager which outlet point is taken into consideration. The choice of this point defines the size of the watershed. The choice of the outlet point will depend on the purpose of the management. To illustrate, if a village wants to improve the water regulation capacity of their forest so that they have a constant water flow in the river near their village, the outlet point, to delineate the watershed in which the measures will take place, will be the point where they take the water from.

Settings of a watershed

How the watershed is managed depends very much on the aim of the management. Most of the people in Himachal Pradesh and nearby states need water and it is therefore seen as the most important service coming from a forest. As we have seen above, a well matured forest contributes the most to the regulation of water. Such a forest also brings many other benefits the most important of these is the conservation of soil and its fertility which is vital for agricultural land. We could say, as a rule of thumb, that 70% of the watershed should be covered with dense forest to bring about the most benefit in terms of water and soil fertility to the remaining 30%.

Zonation

We see already that there are different areas in the watershed that are important. Areas of forest and areas of agricultural production. There are other areas like settlements, roads, wetlands or waterbodies, as well as areas that are used for fuel wood, grazing, mining and other land uses. It is of upmost importance, that each of these uses is restricted to a well-defined zone. These zones are called FES-Zones as each of them serves the delivery of one or more Forest Ecosystem Services. The zones must be distinguished and mapped after a discussion amongst all stakeholders involved. This will minimise conflicts in the future. The management and use of these zones should focus on the purpose that each zone is designated for. The biggest challenge in forests of Himachal Pradesh will be the regulation of fire and grazing.

Managing the forest under an FES-Zone concept

Across all zones the management aim should be to increase the productivity of the land. This benefits not only the forest, but also other land uses like agriculture. As we have seen above, the productivity of any forest depends on annual precipitation and solar energy. It is also dependent on the existing total biomass. If the forest can become very degraded there will be a corresponding decline in biomass, and it will also produce very little more biomass. Only when it increases, meaning, if less biomass is removed than harvested, can the production of biomass increase. To achieve the overall aim of increased productivity, the actual management strategy needs to be adjusted so that a steady yearly increase in the total biomass is allowed.

This strategy should, in the long-term, lead to an improvement in the carrying capacity of the land, which means an increase in the amount of total extraction possible on an annual basis. For example, if the forest is managed in such a manner to increase fodder, the number of bundles of fodder that can be annually harvested will increase until it reaches a maximum.

Water

The most crucial zones for water supply must be clearly identified and delineated. If the forest in this area is degraded, meaning less diverse in structure and species, low crown cover and growing on poor and hard soil, it will take some time until it can develop its full water regulating function. It needs a complete rest from all human impacts, full protection from fire and from grazing. In open grazing areas trees should be planted.

Water retention is such an important factor that soil and water conservation measures will in many cases be necessary to improve water conservation and increase percolation at the micro-watershed scale. They may take the form of terracing, bunding on the land, small check-dams in the upstream parts of the drainage systems or any other measures to improve water retention for the benefit of the existing vegetation or recently established plantations. The goal of such measures is to minimize total runoff, especially during extreme precipitation events. The design of such measures needs to consider these weather extremes.

Fodder and firewood

It is most beneficial for the forest and the services it supplies if fodder and firewood is produced outside the forest on marginal or abundant agricultural land, wasteland etc.   These options should be intensely checked and utilised. Fodder and firewood collection should be reduced to a minimum in the forest and should be restricted to well defined zones that are not overlapping with the zone intended for water regulation. In many places people have user rights in the forest. These rights must be determined and then adjusted according to the present use. This means that right to collect fodder or fuel need to be compensated. Not water sources for cattle to drink should be provided in this zones as they make grazing attractive.

Grazing

Grazing should also be avoided in forest areas. If this is not possible, then any grazing zones should be put where they do not negatively affect the water regulation zones of the forest. Intentional fire, to maintain the grass cover, should not be allowed. It is very important to ascertain grazing rights and adjust them to the actual grazing demand.

Minor forest products

These are products which are not timber, fuelwood or fodder such as honey, flowers, food, bamboo etc. As each of these products require a special management system, the forest managers and users, must be clear if he use of such products conflicts with the management aim of the specific zone or if special zones must be delineated. For instance, a well-developed forest in the mid Himalayas will not only regulate water but also provide rhododendron flowers. Therefore, there is no need of a special zone. Only the time and amount of harvesting needs to be regulated to avoid overexploitation. But if the local community wants to harvest bamboo to make products like baskets out of, it needs a well-defined zone for this use where an open tree canopy can be managed for without hampering other important services.

Managing unwanted species

Some areas of Forest Department land may exhibit the presence of so-called unwanted species. Great care should be taken to understand the often-unperceived beneficial role of such species for water conservation and soil protection. Many a time eradication programs have catastrophic results such as increased surface water runoff and soil erosion thus preventing the rapid establishment of species belonging to the next stage of succession.

Mapping and management Plan of FES zones

The HP-FES project has published a manual on how to access and map the areas important for different FES zones (provide reference). The basic principles are

1) the assessment of the FES required from forest,
2) the assessment of the state of the forest and
3) the delineation of zones for the FES most in demand and a management strategy that sustains the delivery of these FES.

- this needs to be done in close cooperation with the stakeholders that manage and use the forest and should be done with much care,
- this must provide a good enough overview on the structure of the forest with a special focus on the existing regeneration. It should also be understood, which impacts are hampering the development of the forest.
- these zones must be clearly mapped and it must be very clear what needs to be done in each of ther The map must be readable for all stakeholders, also for them who might be less educated.

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