tion of cover increases, runoff decreases. The effectiveness of mulch in stabilizing the soil surface is a function of coverage and durability.

Usually, the minimum amount of mulch coverage needed for surface protection is 75 percent. It has been shown that, when compared to a bare site, a mulch coverage of even 50 percent reduced the erosion rate by 35 to 40 percent for a wide range of steepness and length of slopes.

POSTMINING LAND USES

Agriculture

Agriculture often is equated with the highest and best use for reclaimed surface-mined land. This seems to be justified primarily on economics, especially on nonprime farmland areas where costs to revegetate usually are lower and economic returns potentially quicker and greater for such agricultural uses as pasture than for such uses as forestry and wildlife habitat. Agricultural uses obviously are appropriate and suited on many reclaimed mines, especially on areas identified as prime farmland. Agricultural uses, especially pasture, also are being proposed in mining areas where agriculture historically has not been an important part of the economy and where absentee land ownership is commonplace. In such situations, the immediate economic advantage of establishing vegetation for pasture rather than forestry, for example, may not justify the conversion of premining forest land to postmining pasture in view of the likelihood of little or no future management of the reclaimed area.

Change from premining nonagricultural land uses to postmining agricultural uses is a trend taking place in some agricultural regions. Here an important consideration is the loss of nonagricultural plant communities that provide the primary sources of wildlife habitat, woodland, recreation, and landscape diversity in predominantly agricultural environments.

Row Crops and Small Grains

Where the postmining land use is to be agricultural, it is important that the type of use and crop selection be compatible with the characteristics of the soil and overburden materials. The production of row crops is most often associated with and most likely to be successful on reconstructed prime farmland that can be tilled, managed, and harvested in the same way as unmined farmland. Such crops as corn, sorghum, and soybeans are most likely to be confined to such areas. Grain crops, such as wheat, oats, and barley, can be produced on some nonprime farmland areas, even where little or no topsoil is replaced. However, in some such cases, continued cropping may not be feasible because of minesoil conditions, such as stoniness, that interfere with tillage and harvest operations.

Soil erosion is a potential problem on cultivated cropland. The use of annual cover crops, especially for overwinter protection, and incorporation of organic materials, such as barnyard manure and crop residues, will help stabilize the soil and reduce erosion. It is especially important that soil conservation practices applicable to normal agricultural operations be used on minesoils reclaimed for cropland uses.

Pasture and Hayland

Pasture is a common and widespread postmining land use, particularly in the eastern half of the United States. Some reclaimed mines also are suitable for producing hay, particularly areas free of steep slopes, stone, and other obstacles that would interfere with the cultivation and harvest of the hay crop. Plant species used for pasture and hay often are the same as those used for cover and erosion control. However, because of differences in palatability and nutritive value to livestock, some species are preferred over others. For example, KY-31 tall fescue is used widely in the East for erosion control. It is also used widely for pasture and hay, but other grasses, such as orchardgrass, timothy, and smooth brome, are considered to be more palatable and nutritious as livestock forage. Legumes, such as sericea lespedeza and flatpea, are excellent cover and erosion control species, but are less desirable than alfalfa and some of the clovers for forage.

Nearly all of the grass and legume species used in improved pasture and haylands throughout the United States are introduced (not native), though they are naturalized. Productivity of these pasture and haylands usually is maintained by periodic application of fertilizer and, in the Eastern U.S., lime. In some situations where soils are naturally fertile and good land management is practiced, productivity of legumes alone and grass-legume mixtures may persist for several years without fertilizer. Productivity of mixtures is most likely to persist where the legume component is maintained in about equal proportion with the grass.

Annual and short-lived perennial species are sometimes used for hay or temporary pasture in agricultural situations. Such use may be feasible on newly revegetated mined land only in management situations where these types of species are sown in association with perennial forage species and harvesting or grazing them would aid the development of the perennials. However, in most situations, early or premature grazing by livestock or harvesting of any new or recent seeding may be injurious to the successful establishment of vegetational cover.

Native species for postmining pasture and hayland use seldom are used in most mining states east of the 100th meridian. Exceptions are found primarily in the Western Interior Coal Region and the coal mining areas of eastern Texas, where several grass and forb species native to the Tall and Mid-Grass Prairie types have been established successfully on mined land. However, restoring native prairie on mined land is virtually impossible because some 200 to 300 species of grasses, forbs, half-shrubs, and shrubs are known components of the Tall Grass Prairie. In practice, only a small percentage of these species can be reestablished in artificial plantings.

There is potential for greater use of native species, especially warm-season grasses, for pasture in all of the Eastern States. In experimental plantings on minesoils,

forage production from these grasses greatly exceeded production of introduced cool-season species during drouthy summers. One deterrent to the use of native grass species in the East is that traditionally they have not been used for pasture and potential users lack knowledge about their management and value for summer forage. The seeding of native species for forage is associated primarly with range use in the coal mining areas west of the 100th meridian.

Rangeland

Rangeland or range is the major land use in most of the coal mining regions in the arid and semi-arid western half of the United States. Range usually denotes land producing native vegetation (forage) for animal (livestock and wildlife) consumption. A major concern and consideration in revegetating mined rangeland is the reestablishment of plant species native to the region and affected sites. One important reason for this is that native species are adapted to the environmental conditions of the area and sites where they naturally grow and are more likely to persist and develop permanent plant communities than introduced species. Some introduced species also are adapted to rangeland conditions and sites and are useful for providing ground cover and forage for livestock. Some introduced species are adapted to an even greater range of sites and environmental conditions than most native species, and these are an important part of the grazing management program on many ranches. Pastures of some adapted introduced species, such as crested wheatgrass, can be grazed in periods preceding and following normal periods for grazing native range.

Mixtures of adapted grasses, forbs, and shrubs are desirable for revegetating mined areas for range because they offer greater potential for establishing species adapted to differences in site conditions. In some cases, there is opportunity to plant species that will enhance the premining range condition and productivity. On some sites, unadapted introduced species, usually annuals, can be planted either before or with permanent species to temporarily stabilize the site and aid in the establishment of permanent species. But on other sites, especially where moisture is limited during the establishment period or where soils are low in fertility, the use of such nurse or companion species will delay or prevent the establishment of the planted permanent species. In these cases, seeding and planting only adapted species capable of plant colonization usually will be more successful.

Forestry

Forestry is a logical land use for many areas currently being mined, as well as for many abandoned or orphan mine sites. However, reforestation efforts have been minimal in recent years due to changing economic, political, legal, and social policies and pressures. Previously, the planting of trees often was considered an expeditious way to revegetate mined lands in the Eastern United States. Recent evaluations of 25- to 50-year-old forest plantings on mined sites throughout the Eastern States show that, on many of the sites, forest ecosystems are being reestablished from a combination of planted and naturally established vegetation. Some of the trees now are approaching or have reached marketable size, and such species as black walnut show promise for producing a favorable economic return.

Factors to consider in selecting tree species for reclamation include the forest management objective, species preferences in current markets, predicted preferences in future markets, the proposed level of management, and site and minesoil characteristics. The forestry objective can range from short-term crops, such as pulpwood, to long-term crops for timber production. Levels of management can be intensive, requiring regular care and treatment, or extensive, requiring little care or treatment. Obviously, markets for the harvested crop need to be within a hauling distance that is economical.

The best results with tree species can be expected where they are matched with site and minesoil quality. In the East, preferred sites for planting high-value hardwoods, such as black walnut, yellow-poplar, and sugar maple, have slightly acid to neutral loam and silt loam minesoils that are well drained but not drouthy. Conversely, many of the pine species are a better choice for sandy acid soils on warm (south-facing), moderately drouthy sites. However, attempting to match species to soil series that were present before mining may not be a productive effort. In the past, tree growth sometimes was better on spoil banks of mixed overburden materials than on nearby unmined native soils.

Pulpwood Production

Revegetating mined land for pulpwood production can involve either intensive or extensive management. Intensive management usually entails the planting of one fast-growing pulp species, such as shortleaf, loblolly, or longleaf pine; European alder; hybrid poplars; cottonwood; sycamore; or bigtooth aspen. Management practices may include periodic inspections for detection and control of insects and diseases, thinning, control of competing vegetation, and fertilization. With hybrid poplars and some of the other hardwoods, two or more rotations of pulp may be obtained from sprouts that originate after the first harvest.

Extensive management for pulpwood can be accomplished with pure or mixed planting. Trees cut for pulpwood may consist mainly of those removed when thinning stands designated for timber production or when creating openings for wildlife habitat. Only selected trees would be left uncut to develop into veneer or sawlogs.

Timber Products

This management objective implies a long-term commitment. The overall level of management is extensive but it can become intensive periodically when trees would benefit from thinning, pruning, and other cultural practices. Access for periodic inspection, cultural treatments, and fire protection is desirable. Due to the long timespan until timber harvest, interim benefits, such as wildlife habitat and nondestructive recreational uses, also can be considered.

For some timber production programs, especially with

conifers, planting only one or two tree species may be desired. With hardwoods, mixtures of several species usually are preferred. Herbaceous and shrubby species can be included to provide initial site protection and to add vegetational variety for esthetic values and for the enhancement of wildlife habitat as an interim land use. The number and arrangement of shrubs may vary for different forestry management objectives, but shrubs (and trees planted primarily for wildlife use) should be limited, probably to 25 percent or less of the total planting, where timber production is the planned postmining land use. For the benefit of wildlife, planting shrubs in small blocks or bands rather than interplanting uniformly throughout the plantation is recommended.

Trees can be planted either in pure stands of one species or in mixtures of two or more. In general, stands of one species are easier to plant, manage, and harvest; but they are more susceptible than mixed plantings to insect and disease epidemics, and they lack diversity for visual quality and wildlife habitat. Mixed plantings improve the possibilities for natural regeneration and diversity, and usually occupy the site more fully than pure plantings.

Examples of several hardwood mixtures for timber production are shown in the chapter on Revegetating Coal Surface-Mined Lands in the Eastern Coal Regions. Obviously, many combinations of species are possible, and the choice of species may be influenced by several factors. For a given locality, consult appropriate natural resource agencies or services and State revegetation and forestry guides for additional advice on forestry procedures and species selection.

Wildlife

The basic components of habitat for wildlife are food, cover, water, home range, and interspersion. All are essential for survival. Food provided by a variety of plants must be available during all seasons and within range of protective cover. Different types of plant cover are required for different purposes, such as brooding and nesting, escape, and shelter. Some species of wildlife require open water; others obtain moisture from succulent plants, dew, or their own metabolic processes. The home range of a species is the size of its habitat or living area. The required size varies for different species. Interspersion is the arrangement of food, cover, and water within the living area of a species. Food and cover that otherwise meet the needs of a species may be of little value where they are not interspersed properly.

Habitat for wildlife can be developed either as the primary land use or in association with other land uses. However, it should not be assumed that every revegetation effort will automatically develop or improve wildlife habitat. Nearly every vegetational community will in some degree contribute to habitat, but the best habitat is developed by planning and providing for the needs of the desired wildlife species. In revegetating surface-mined areas, the maximum benefit for wildlife usually is obtained by establishing vegetational communities that are not presently available or that are in short supply in the vicinity. In a region that is predominantly deciduous forest, establishing communities of coniferous trees will provide greater diversity of food and cover than planting mixed hardwoods. Establishing shrub communities in forested and agricultural area where they often are lacking is especially beneficial to wildlife.

Each species of wildlife has different habitat requirements, so the vegetation established for different land uses will affect the diversity and productivity of wildlife populations. Bird populations in the East are most diverse and productive in a mixed hardwood forest. Different species of birds are attracted to and inhabit open grasslands; others prefer edges between forest and grassland that are partially vegetated with shrubs and small trees. Thus, even in a forested region, the overall diversity of bird species is increased by developing shrub and grassland vegetational types on surface-mined areas. Similarly, planting tree and shrub communities in grassland and agricultural regions increases the diversity of birds and mammals.

Habitat can be developed on mined land to favor one or two species, several species, or wildlife in general. But newly revegetated surface mines cannot be expected to provide habitat for all resident species of wildlife. Squirrels, for example, inhabit forests in advanced stages of succession. Ruffed grouse and wild turkey may derive benefit only from those newly revegetated sites that are adjacent to or interspersed with natural undisturbed forest or woodland. For bobwhite quail, cottontail rabbit, white-tailed deer, and other species, how little or how much of the habitat requirement is derived from the early stages of revegetation depends on the size of the area; type, age, and interspersion of planted vegetation; and the type and interspersion of land uses in the surrounding unmined areas. Habitat requirements should be determined before attempting to establish habitat for particular species of wildlife.

Woody Plants

Trees and shrubs are important components of wildlife habitat. In fact, development of wildlife habitat is a major reason for planting shrubs on reclaimed surface mines (Figure 20). For wildlife plantings, shrubs and trees usually are planted in rows, clumps, or blocks of a single

Figure 20. An informal planting of bicolor lespedeza that provides cover and food for wildlife.

species. Adjacent rows of different shrub or tree species can be planted to develop a "teepee" effect; that is, the tallest species are planted in the center of a strip or block and shorter species are planted in the outer rows.

Many woody plants provide both food and cover, but the relative importance of these values varies with different species of wildlife. Time of fruit or seed maturity and the duration of fruit or seed retention on the plant differ among tree and shrub species. Planting several species that differ in maturity and retention of fruit extends the period that food is available to wildlife.

The benefits of woody plants to wildlife do not occur as quickly after planting as with some herbaceous plants. For most woody species, 3 or more years of growth are required before they contribute effective amounts of cover and food to wildlife habitat. Some tree species, for example, some of the oaks, may require many years before they contribute mast to the habitat. Ideally, wildlife plantings that include a variety of woody plants will provide food for relatively long periods.

Planting Patterns

Diversity is the basic principle in developing habitat for wildlife. Planting patterns that provide variety and diversity in types and arrangement of vegetation are the most beneficial when all species of wildlife are considered as a group. For example, planting trees and shrubs in rows, strips, clumps, and blocks in and around open areas seeded to herbs creates a desirable interspersion of food and cover types and provides for better distribution of wildlife (Figure 21).

A suggested pattern for expansive sites would include grass-legume mixtures in strips 100 to 150 feet wide alternating with shrubs and trees in strips 30 to 50 feet wide. In some strips of woody plant, the inner rows should be trees and the outer rows shrubs. Clumps of fruit-producing trees also can be placed randomly throughout the open areas. Where an area is less than 150 feet wide, one to three rows of woody vegetation through the middle, or scattered clumps of woody plants, may create sufficient diversity in habitat. Open areas of at least 1/2 acre but no more than 5 acres seeded to grasses and legumes are recommended.

Figure 21. Interspersion of trees, shrubs, herbs, water, and landform provides habitat diversity that is essential for wildlife.

Wildlife habitat can be incorporated with other land uses chosen for the reclaimed mine. Single rows of dense shrubs between small pastures and crop fields can provide escape cover, shelter, and variety in food for game birds and small mammals. Extensive tracts revegetated for pasture, hay, or range can be diversified with occasional strips (up to 20 feet wide) of shrubs that produce fruit and cover. Similar plantings also can serve as woodland-field borders at the edge of pastures or cropland. Several rows of conifers and shrubs or small, fruit-producing trees planted at right angles to the direction of the prevailing winds can provide windbreaks for cropland or pasture while improving nesting, escape, and winter cover for game birds.

The boundaries or edges of plantings need not be uniform or exacting. Ragged, irregular edges increase the value of a planting to wildlife, and they can add esthetic interest to a site.

Mixed forest plantations provide good habitat for most species of wildlife that naturally inhabit forest land. Establishing blocks of conifers, up to 1 acre in size, within larger plantations of mixed hardwoods increases the variety of available food and cover types while providing potential wood products. Blocks of hardwoods separated from the conifers by grass-legume strips will provide more edge and open areas. Food patches of 1/8 to 1/2 acre, seeded to species such as partridge pea, soybean, wheat, white clover, or orchardgrass, will benefit some species of wildlife in a forest area. One food patch in about 40 acres is suggested. Prescribed harvesting of pulpwood and timber also may create diversity in wildlife habitat.

Vegetation, especially forest vegetation, changes with time. In turn, the quality and quantity of food and cover available for wildlife will be altered as the forest canopy closes in. To counteract this natural process of change, maintenance procedures are necessary. Open areas that become overgrown with woody plants may require cutting, discing, or controlled burning and reseeding to extend the longevity of the desired type of habitat.

The preceding discussion focuses on planting patterns for habitat for wildlife in general. Obviously, where habitat is desired primarily for one or two species of wildlife, variations in planting patterns must be provided that are most beneficial to those species. Additional recommendations on habitat requirements, management of the wildlife, and maintenance of habitat are available from professional biologists and other reference sources.

Horticulture

Developing mined land for horticultural purposes requires intensive management of both the soil and plants under cultivation. For the purposes of this handbook, the definition of horticulture is limited to the care and growing of woody species. To avoid confusion with forestry as a land use, horticulture as used herein refers to the culture of woody plants requiring some type of treatment at least once a year.

Within these limits, horticultural applications to mined lands include Christmas tree production, fruit orchards, nut orchards, vineyards, and berry production.

As with all land-use options, site protection is of primary importance. An herbaceous cover must be established as quickly as possible to prevent erosion. As soon as some degree of stability is achieved, the desired woody species can be planted.

Christmas Tree Production

Planting and management for Christmas trees is a moderately intensive practice. Species selected should be marketable in the region. Scotch pine, for example, is popular in the Eastern States and can be grown in all but the southernmost coal-producing areas. Other pines used for Christmas trees are red, eastern white, Austrian, ponderosa, and jack. Norway and white spruce, Fraser fir, and Douglas-fir also are used, but generally do not reach marketable size as quickly as pine. Pure plantings of a proven species usually are recommended, but mixed plantings of two or three species may reduce the risk of loss from insects and disease or from a change in market demand. Low-growing herbaceous species are recommended as a ground cover. Mowing and the use of herbicides may be needed to reduce competition from herbaceous plants.

Management requires a road system for maintenance, harvest, and fire protection. Fencing may be needed to protect the plantings from livestock, theft, and vandalism. Care of Christmas trees also includes shearing to shape trees for market; application of fertilizer; and protection from insects, disease, and fire. Specific information on Christmas tree production is available from State universities, agricultural extension agents, and Christmas tree growers associations.

Fruit and Nut Orchards, Berry Farms, and Vineyards

The complexity of establishing and managing an orchard, berry farm, or vineyard is beyond the scope of this handbook. Development of fruit or nut orchards, berry farms, or vineyards is a postmining land use that requires a highly intensive level of management. To be successful, the land manager must be knowledgeable about the crop he wishes to produce, or be willing to hire someone with that expertise. Any species of fruit, nut, berry, or grape that is indigenous to the region or has been introduced successfully has potential for use on a reclaimed mine site.

Planning the establishment of an orchard, berry farm, or vineyard before mining begins will ensure proper overburden placement, landforming, and site preparation. It is advisable to plant a cover crop for 1 or 2 years before attempting to establish fruit or nut trees, berries, or grapes. The site will be better stabilized, and the cover crops will help build a better soil structure.

Management of most horticulture crops requires gently rolling to flat terrain that allows complete access with tractors or trucks for spraying and transporting the harvested crop. Distance to market and road conditions between the mined site and the market are important considerations; some fruits and berries damage easily if transported over rough roads. An available and adequate labor force is needed because many activities in an orchard, berry farm, or vineyard are highly labor intensive. A good water source is needed for spraying and, where necessary, irrigation. Adequate acreage is needed to conduct a commercial venture, at least 200 to 250 acres for fruit orchards, for example. Other finer points of developing one or more of these horticultural activities should be obtained from experts in fruit, nut, berry, or grape culture.

Recreation

Recreation as a secondary use includes such activities as hunting, hiking, and bird watching. These activities can be enjoyed on lands reclaimed to forestry or wildlife with little or no modification to standard reclamation plans. If forestry is the primary land use, planned species diversity will enhance wildlife habitat and improve this type of recreation.

Trails for hiking and cross-country skiing would require slightly greater modification in the reclamation plan. However, the primary land-use objective would not be changed.

Other forms of recreation such as fishing, downhill skiing, camping, or activities requiring specialized facilities will have to be planned in advance of reclamation, preferably in the premining stage. These are mainly exclusive uses, but probably will occupy only a small portion of the area disturbed by mining. Fishing, for example, may require ponds with access roads and space for parking. If boating is included, launching ramps must be designed.

For campgrounds it is necessary to design a road system with parking spurs, and sanitation facilities must be considered. Skiing facilities require tows, a trail system, sanitation, and possibly concession stands. If the location is right, construction of a golf course or driving range is another option.

Where any of these structured recreation activities is the land use objective, the landowner is advised to engage the services of a competent designer to prepare plans and specifications for the desired facility.

Other

Other postmining land uses include those such as airports, housing developments, schools, shopping centers, and commercial buildings that are constructed primarily of concrete and steel. These land uses as such are not addressed in this handbook. However, these types of uses do require vegetation for land stabilization and erosion control before construction, followed by landscaping following construction. To that extend, revegetation activities considered within the realm of this handbook may apply.