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By Z. A. Zasada, Forest Economist

UNITED STATES DEPARTMENT OF AGRICULTURE
FOREST SERVICE
Lake States Forest Experiment Station

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ECONOMIC SIGNIFICANCE OF ASPEN

Aspen,[3/] the most extensive forest type in the Lake States occupies almost 20 million acres or 39 percent of the commercial forest area in the region (8). It occupies twice the area of the next largest type, the northern hardwoods. It is, therefore, of tremendous importance to the economy of the region.

However, there are several things which mitigate against the management of aspen. Some of them are:

1. More than half of the aspen type is in seedling and sapling stands, and only about 6 percent is classed as saw timber (table 1).

2. Nearly 5 million acres of land classified as aspen are so poorly stocked as to be practically denuded (table 1).

3. About 31 percent of the total aspen type is estimated to be on poor sites, mostly poorly stocked and in the seedling and sapling classes (8).

4. A small percentage of the area in aspen must be considered noncommercial because of inaccessibility.

It appears, therefore, that little more than half of the aspen type can be counted on to produce timber of commercial importance. So the two major problems become: (1) how to manage the productive aspen stands, and (2) what to do with the noncommercial aspen areas. Only the former will be considered in this analysis, and chief emphasis will be on silvicultural applications in full recognition that financial aspects are deserving of much more attention than is given here.

1/ Prepared in collaboration with the Director's staff.
2/ Maintained by the U.S. Department of Agriculture, Forest Service, in cooperation with the University of Minnesota, at University Farm, St. Paul, Minnesota.
3/ As used here aspen refers to quaking aspen (*Populus tremuloides*) and bigtooth aspen (*P. grandidentata*). The former accounts for at least 90 percent of the volume.

Table 1.--Distribution of aspen type, by size class, for the three Lake States (7)

State	Saw timber	Pole timber	Seedlings and saplings	Poorly stocked and denuded	Total
			Thousands of acres		
Minnesota	550	1,070	4,120	1,760	7,500
Wisconsin	290	1,095	3,225	1,848	6,458
Michigan	327	1,454	2,902	1,217	5,900
Total	1,167	3,619	10,247	4,825	19,858

ORIGIN AND CONDITION OF PRESENT ASPEN STANDS

Logging and fire are the principal agents credited for the large acreage of aspen stands now in existence. One authority (13) explains that aspen probably occurred in the original forest only in groups or as scattered individuals, and that repeated fires provided the means for the aspen type to expand, by root-suckering. Another (28) calls fire the "great introducing agent" of aspen, and explains that one fire in a virgin forest allows the establishment of a scattered stand of aspen seedlings and that subsequent fires are followed by an abundant crop of aspen sprouts from the roots of the seedlings.

The ability of aspen to reproduce by both root suckering and seeding and to grow rapidly on most soil types fits it well to take over unstocked lands. Because of its sprouting ability, aspen also maintains itself on lands it has invaded even after clear cutting or killing by fire. Even if not logged or burned, aspen appears perfectly capable of reproducing by suckering (23). On the other hand, aspen's seeding ability should not be counted on strongly as a means for perpetuating itself (18) on lands it has invaded.

Aspen has taken over land formerly occupied by other forest types. In many places the original species replaced have come back and now form a definite understory in the aspen stands. In the past aspen's ability to dominate these species has been aided by repeated burning, since the tolerant hardwoods, balsam fir, and spruce, and such species cannot reproduce following fire as well as aspen. With good fire control now in existence, aspen undoubtedly will be replaced gradually on much of the land it now occupies.[4/] However, such natural conversion to other species will be a slow process.

Present utilization practices usually require the leaving of a considerable number of unmerchantable aspen trees after logging. When such trees are left, aspen suckers are less prolific and less vigorous than after complete cutting. Moreover, brush, which thrives better than aspen in partial shade, competes with and suppresses the aspen reproduction more severely where unmerchantable trees are left than on completely exposed areas. As a result, many stands that have come in following the cutting of aspen, even on the best sites, doubtless will be poorer in stocking and productivity than the original stand (34).

Enemies of Aspen

The principal agents injurious to aspen are fire, disease organisms, and insects. Animals, windstorms, sleet or heavy snow also are causes of injury. Frost, which is harmful to many tree species, does not appear to damage aspen severely.

Fire, although a great factor in the establishment of aspen, is very destructive to young trees. Stoeckeler (25) points out that repeated burns have reduced the site quality on a large portion of the aspen area. Meinecke (16) rates fire wounds as most important for spreading disease in aspen.

4/ That this has happened in the northeast is disclosed in a recent communication from the Northeastern Forest Experiment Station.

Insect attacks have caused heavy losses in aspen in the past. The forest tent caterpillar (_Malacosoma disstria_) probably has caused the most widespread damage. The larvae feed on the leaves of aspen and thus have defoliated many square miles of aspen stands for several successive years. Only extremes in weather have stopped their attacks. Other insects injurious to aspen are the poplar borer (_Saperda calcarata_), the bronze birch borer (_Agrilius anxius_), and the carpenter ant (_Componotus herculeanus_).

Hypoxylon canker (_Hypoxylon pruinatum_) is described by Lorenz and Christenson (15) as "probably one of the most important diseases throughout the range of the tree." Gruenhagen (10)in studies in Wisconsin found 24 percent of all popple infected by this disease. Bier (6) reports that this canker is caused by a wood parasite and that "bark punctures resulting from insect attack commonly served as centers of infection." He also points out that attacks are not confined to young trees but rather to young bark on all trees. Thrifty trees are as susceptible to the disease as suppressed trees. Gruenhagen (10) found the canker most prevalent on poor sites and less infection on large trees. Baxter (4) apparently supports the latter view and suggests maintenance of vigorous growth throughout the life of the stand as a control measure. Zehngraff's (32) observations in Minnesota seem to indicate that canker is found most frequently on poor and medium sites, and on sites deteriorated by fire; that the disease is much less common on good sites, especially when aspen is growing in mixture with hardwoods or with balsam fir and spruce.

Another canker on aspen is caused by _Cytospora chrysosperma_. It attacks young stems and twigs which are thereby killed by girdling. It, however, is not considered a primary invader of living trees.

The false tinder fungus (_Fomes igniarius_) and the butt rot fungus (_Fomes applanatus_), both wood rots, are the most important diseases affecting the utilization of aspen. The rots enter the trees through wounds and bruises which expose the wood. They are more prevalent in older age stands than in young stands and usually are found in all overmature stands. These diseases can cause older stands to be total losses.

Aspen is a favored food for a number of wildlife species. It is the most important food for beaver. Deer and rabbits feed freely on the young trees (26). It is evident that large populations of wildlife can have a damaging effect on young aspen stands.

The aspens frequently are broken or uprooted by wind, heavy snow, or sleet. Their weak wood and slender boles offer poor resistance against these elements, even after the trees are almost full grown. The root systems are not adequate to anchor mature trees against the force of strong winds, especially when they have been left isolated in logging. Decay in the stems or roots, of course, greatly increases the danger of windfall.

Silvics of Aspen

The range of aspen extends across the North American continent through Canada into north central and northeastern United States and into the higher elevations of the Rocky Mountain region. The three Lake States are thus on the southern edge of the range. Since aspen is a species of cold climates it may be difficult to manage on a permanent basis in central Wisconsin and the Lower Peninsula of Michigan.

Aspen is a very intolerant species throughout its range. Weigle and Frothingham (28) suggest that trees of seedling and sucker origin may differ in tolerance.

For best growth, aspen requires a deep, fresh or moist, porous, well-drained loam soil; but it occurs on all soil types in the Lake States (19). However, the growth, development, vigor, and maturity of aspen are governed to a large extent by the site on which it occurs.

Aspen trees begin to bear seed when 20 to 25 years old (28, 32). Seed is produced every year and heavy crops are borne every 4 to 5 years (27, pp. 278-281). The staminate and pistillate flowers are borne separately on different trees and appear in May in the Lake States. The seed usually ripens within one month after pollination. The seed of aspen under natural conditions is short-lived, usually not longer than two or three weeks (18). A very large portion of the seed is abortive (28).

Aspen occurs in pure stands and in mixtures throughout the Lake States. In northeastern Minnesota it grows with paper birch, jack pine, balsam fir, and spruce. In north central Minnesota it occurs in mixture with northern hardwoods, paper birch, white pine, and balsam fir. In the Upper Peninsula of Michigan its associates are paper birch, the northern hardwoods, white spruce, and white pine. In Lower Michigan, it often occurs with oaks, pine, red maple, or northern hardwoods.

Rapid growth and high mortality are characteristics of young aspen forests whether of seedling or sprout origin. Growth is rapid for the first 35 to 50 years, and the peak yields are reached at about 40 to 60 years. Thereafter stands open up. Windthrow and ice breakage eliminate individual trees and decay[5] takes a heavy toll of both large and small trees (23). Stands on poor sites become decadent as early as 25 years of age (20); those on the best soils may maintain a good crown canopy until 60 years of age. At 80 years usually only a few decadent veterans remain (23).

Reproduction

According to present knowledge seeding is not a very effective means for obtaining aspen reproduction because (1) a very large portion of the seeds are abortive, (2) those which are fertile lose their germinative capacity within two to three weeks, and (3) unless the seeds fall on mineral soil--on recently burned-over or cleared land or on other open spots not covered

5/ Hypoxylon canker has been recently recognized as being responsible for much mortality.

with vegetation or decomposed leaf litter--their chances for growth are very poor (18, 28). Many observers have stated that it is very difficult to find aspen seedlings in the forest.

Although seedlings are scarce in the forest, claims are made that seedlings are superior to sprouts for growing stock. Weigle and Frothingham (28) state that seedlings are superior to sprouts in tolerance. Barth (3) contends that European aspen trees resulting from seed have better form, thinner branches, and better height growth, and are less susceptible to rot than trees of sucker origin. Shirley (23) indicates there is no available evidence to show that stands of sprout origin are less vigorous than seedlings.

The suckering of aspen has received considerable study which can be summarized as follows:

1. Suckering is aspen's principal method of regeneration.

2. The aspen root system is contained mostly within the top 2 feet of the surface. The roots follow an undulating course rising toward the surface and sinking again (2, 9).

3. Suckering takes place at those points in the roots which are less than 6 inches from the surface (28). Barth (3) believes that suckers develop from dormant buds on roots near the surface in the presence of strong light. Weigle and Frothingham (28) suggest the necessity of well-aerated soil.

4. Suckers may develop from seedlings only two years old, by which time the roots spread out 4 to 6 feet from the stem (9). Trees 70, 90, and 110 years old have suckered after cutting, indicating that trees do not lose this ability as they get old (2, 28).

5. Fires severe enough to kill full grown trees will not destroy the suckering capacity of roots (28). Light burning stimulates aspen suckering (22).

6. Baker suggests that certain roots are devoted primarily to reproduction (1).

7. Summer cutting reduces the suckering in aspen as compared to winter, spring, or fall cutting (2, 24, 28, 30). However, Baker and Weigle and Frothingham point out from observations in the Rocky Mountains and in the northeast, that such reduction is not enough to prevent full restocking three years after cutting. Summer fires discourage suckering. Suckering will take place for two years after cutting and after that time will practically cease (1). Zehngraff (32) indicates that brush competition shades out late-summer and second-year suckers. Baker (1) found little difference in height growth of suckers of summer cutting versus winter cutting after three years; however, Stoeckeler (24) found a wide difference after five years.

8. Weigle and Frothingham (28) state that suckers will soon form independent root systems. However, others have shown that the root systems stay joined for many years, but how actively the trees support each other through their root systems is not known.

9. Disking has been used as a means of stimulating aspen suckering three years after cutting (31).

Although aspen suckering has been studied a great deal, many questions on this subject remain unanswered. Moreover, results have been inconsistent in much of the work that has been done, so that basic studies in this field continue to be important.

Artificial regeneration by planting and seeding is still untried in this country. Europeans, particularly the Scandinavians, are giving considerable time and effort to this means of regeneration as a method of improving the quality of their stands (3). If by repeated suckering, aspen stands tend to run out or deteriorate, planting may be necessary to continue good quality stands of this species. When that time comes superior strains will be in demand.

Rotation and Yield by Sites

The rates of growth and yield of aspen at any given age vary with the productivity of the soil (quality of the site). Site quality for aspen now is expressed as height of the average dominant tree in a stand at 50 years or the height that the average dominant tree in a younger or older stand would have at 50 years (14). Stands under 20 years of age are too young for accurate site determination by this method. Hence some other methods involving soil or other factors are needed to evaluate site potential (25). A reliable method of early age site determination for aspen would be of great value to forest land managers.

Studies of forest soils show that there is a general relationship between soil types and rate of growth of the various forest types (19). The rate of growth of trees is usually determined by moisture relationships of the soil. In these studies aspen occurred to a great extent on all soil groups and was not characteristic of any of them. The following general relationships between site and soil, however, were noted: (1) Poor sites--sand soils with low water table; (2) medium sites--loams or loamy sands underlain with clay with ground water somewhat higher; and (3) good sites--clay loams with a moderately high water table.

Stoeckeler (25) points out that knowing the original forest cover is helpful in predicting sites for aspen.

The rotation, yield, and development of aspen on various sites can be summarized as follows (32):

1. Good sites.--Aspen reaches sawlog size at the rotation age of about 55 years. Yields of 9,100 board feet, or 46 cords per acre and higher, are attainable.

2. Medium sites.--The trees produce small logs and pulpwood at the rotation age of about 45 years. Estimated maximum yields are about 6,000 board feet or 33 cords per acre.

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3. Poor Sites.--Aspen seldom reaches more than pulpwood size at the rotation age of about 30 years. Maximum yields may run up to 18 cords per acre, but more often they are substantially less. Aspen on poor sites is very susceptible to disease and insect attacks. Much of the poor site aspen is noncommercial at the present time.

Although sound trees over 100 years old have been found in northern Minnesota and Ontario, aspen stands in the Lake States usually deteriorate very rapidly after age 70 on good sites and after rotation age on medium and poor sites. Decay in aspen is so rapid that 10 years after rotation age, 50 percent or more of the volume often is unmerchantable (21, 28, 33). Zehngraff (33) states that early estimates of volume yields were too high because proper weight was not given to high natural mortality and natural slowdown in growth with increasing age.

Thinnings and Intermediate Harvests

Under natural conditions aspen stands thin themselves very rapidly. In northern Minnesota, natural thinning reduced an aspen stand from more than 3,500 trees per acre at 13 years, to about 1,500 trees at 23 years, and to about 1,000 trees at 29 years (32). Young aspen stands show little tendency to stagnate (17, 23).

Experience in stand improvement and commercial thinning is still on a sample-plot basis. This experience shows that aspen responds well to thinning, especially during early life. In northern Minnesota, stands thinned at age 13 to an 8x9-foot spacing gave a volume of 17 cords per acre at age 23 as against 7 cords per acre in the unthinned check plot (32). Canadian plot experience on medium sites, however, does not show as good results (5). Thinnings thus far are recommended only for good sites.

Present thinning experience recommends leaving the largest, most thrifty trees and cutting "from below." This recommendation is based on the finding that decay is more prevalent in trees of lower than of higher crown classes (32). There is a possibility, however, that cutting "from above" could be used in early commercial thinning. Some sample plot work, for instance, indicates that this may be possible if the stand is not over 25 or 30 years old and is thrifty (32).

There are other advantages to thinning besides growth stimulation. Thinning may help to control the Hypoxylon canker (4, 32). The salvaging of merchantable trees that normally die in unmanaged stands can increase yields considerably. Thinning also can serve as a means for quality improvement for aspen.

The best thinning practices known from experimental work should be applied on a wider scale to determine how they will work out in practical forest management. However, there is need for continued study to determine the best spacing for various ages, how far down the "site scale" thinning will be workable, and how aspen stands of the young merchantable sizes (25 to 30 years) respond to thinnings from above.

Yields Under Management

The yields of aspen under management can only be estimated at present on the basis of plot work done in northern Minnesota. No intensive management has been initiated using this knowledge. Sample plot work indicates strongly that on good sites careful management can increase yields, improve quality, and shorten rotations. The recommended system of management for good sites consists of a noncommercial thinning before age 20, intermediate cuts at ages 30 and 45, and a final cut at age 55. This should produce more board-foot volume than is now obtained from unmanaged stands, plus a substantial volume of pulpwood (32).

No thinning plots have been established on medium and poor sites, and what will happen there can only be surmised.

Extensive management which should recognize rotation age by sites will, no doubt, permit a more orderly harvest and improved yields from aspen stands.

PRESENT PROGRAM OF RESEARCH IN ASPEN MANAGEMENT

The Lake States Station, the colleges and universities of the region, and some private companies are carrying on research in aspen management. The present program for the Station is given below; that for the schools and companies is also included, so far as information is available.

Reproduction

1. For a period of about 15 years, numerous harvest cuttings on a good site have been made on the Pike Bay Experimental Forest in northern Minnesota. Periodically these cuttings are examined to determine adequacy of the reproduction and stand development.

2. Harvest cuttings in aspen on a poor site have been carried on at the Cloquet Forest Experiment Station of the University of Minnesota, and observations made on regeneration. A new study of suckering is being started.

3. One test of disking of cut-over aspen land has been made at Pike Bay Experimental Forest (Minnesota). This resulted in regenerating a cut-over stand that had not reproduced well. Observations will be continued. A similar test was initiated by the Consolidated Water Power and Paper Company in Wisconsin in cooperation with the Northern Lakes Forest Research Center. A stimulation of aspen suckers was reported. Another test of the same sort is planned for the spring of 1950 by the Northern Paper Mills at Amasa, Michigan, in cooperation with the Upper Peninsula Forest Research Center.

4. A survey of aspen cut-over areas in Wisconsin was started by the Northern Lakes Forest Research Center in 1947 to determine the effect of season of cutting on aspen regeneration, rate of conversion to other species, etc. This is scheduled for completion in 1950.

Thinnings

1. At the Pike Bay Experimental Forest, thinning experiments were started over 20 years ago on fairly good sites. These have been maintained and expanded. At present there are thinning tests in:

   (a) Noncommercial stands.--Established over 10 years ago in a 13-year-old sapling stand.

   (b) Pulpwood stands.--Put in over 10 years ago in 30-year-old timber.

   (c) Young stands for production of veneer.--Established over 20 years ago, primarily as spacing tests to develop good diameter growth and match-stock timber. These have been thinned the second time.

2. Thinning tests in several stands of aspen were established a few years ago at the Dunbar Forest Experiment Station (Michigan State College) near Sault Ste. Marie, Michigan. It is too early for results yet to be available.

3. In 1949 thinning tests in noncommercial stands were established by the Northern Paper Mills near Amasa, Michigan.

Diseases

1. A study of Hypoxylon canker of aspen was initiated by the Bureau of Plant Industry (USDA) in 1949, in cooperation with the University of Minnesota and the Northern Paper Mills. The 1949 work was confined mostly to the Upper Peninsula of Michigan, although a start was made in Wisconsin. The work will be expanded in Wisconsin and extended to Minnesota in 1950 in cooperation with a number of pulp and paper companies.

2. The University of Wisconsin has made selections of aspen that appear to be resistant to Hypoxylon canker. Further research will be done along this line and an extension into the field of breeding for disease resistance is contemplated.

3. The Minnesota and Ontario Paper Company and the University of Minnesota are cooperating in a study of old "conky" stands to determine the proportion of wood that is too far gone with heart rot to be usable and the proportion that still can be utilized for pulpwood.

4. Michigan State College at its Dunbar Forest Experiment Station is studying Hypoxylon canker in stands thinned in various ways.

5. The Northern Lakes Forest Research Center in Wisconsin will follow up intensively on the incidence of Hypoxylon canker in cutting experiments in aspen-balsam to be initiated in the spring of 1950.

6. The Headwaters Forest Research Center expects to cooperate with the University of Minnesota and BPI in an evaluation of cultural practices in aspen on the Pike Bay Experimental Forest with respect to the control of Hypoxylon.

7. Northern Paper Mills will follow their thinnings to observe the effect on Hypoxylon canker.

Insects

The University of Minnesota for some time has been investigating the forest tentless caterpillar, the aspen borer, and other insects. This work is being continued with the active cooperation of the Minnesota Conservation Department.

Managment of Mixed Stands

1. Experimental timber stand improvement operations in aspen-northern hardwood stands were started at the Upper Peninsula Experimental Forest, Dukes, Michigan, in 1933. Periodic evaluation is made of this work.

2. Commercial intermediate cuttings in mixed aspen-balsam stands are being initiated in 1950 by the Station at two locations:

   (a) Argonne Experimental Forest - near Hiles, Wisconsin.
   (b) Pike Bay Experimental Forest - near Cass Lake, Minnesota.

Growth and Mortality Studies

Aside from the general growth figures obtained on the Forest Survey, the Station has under observation on the Pike Bay Experimental Forest 621 1/10-acre growth plots established in 1947. Of these, 271 are in sapling stands 10 to 30 years old and 350 in pole stands. The latter are chiefly 30 to 50 years old, but a few are older. Individual tree records are available on all plots.

NEEDED EXPANSION TO ROUND OUT THE PROBLEM

Basic Studies

Studies of aspen site should probably be given top priority in the field of fundamental research in aspen. Site quality as now expressed (height-age relationship) is unreliable for young stands. A reliable method of early site determination will be of great value to forest managers. Specific questions are:

1. What are good site indicators in young aspen stands?

    (a) Can seedling establishment and growth be used as a site indicator?
    (b) Must soil and water table be determined to classify site?
    (c) Can sites be classified by measuring growth of young trees over short periods of 2 to 5 years?
    (d) What are the comparative values of seedling and suckers as site indicators?

2. Can ratio of diameter growth to height growth of dominant trees be used as site index?

3. How fast is aspen site quality building up as a result of fire protection?

4. Are second-generation aspen stands equal, poorer, or better in quality than the stands which came up on recent burns?

5. What are the relationships of site and soil or moisture conditions to the conversion of aspen stands to other species?

Seed and seedling studies need much more attention. In particular:

1. How much viable seed is produced by aspen trees?

2. How often do crops of good viable seed occur?

3. Are seeds of young trees viable?

4. At what ages do aspen trees have the best seed production?

5. What are the best methods of establishing stands by seeding and planting. 6/

6. Are seedlings superior to sprouts in vigor, tolerance, and disease resistance?

7. If aspen deteriorates as a result of several generations reproduced by suckers, what is the best method for bringing "new blood" into the stand?

6/ Seeding and planting of aspen, although not at present considered to be practical may, in the future, be a necessary method for maintaining good aspen stands. Such studies also may give valuable clues to natural regeneration.

Suckering, although it has been studied more than seeding, must receive further attention to confirm general observations and theories on its importance:

1. How long after cutting of the parent tree will roots continue to produce suckers?

2. Can portions of the roots be transplanted and still produce suckers?

3. What is the structure of roots that sprout and how does this compare with that of nonsprouting roots?

4. Do suckers develop their own root systems and how soon are they independent of the parent system?

5. After thinning, do roots of the cut trees serve the residual trees?

6. Does the capacity of trees to sucker run out after repeated suckering?

7. What is the theory behind disking to produce suckers? Do all old roots sucker, or are the suckers predominantly from the few scattered new trees?

8. Is there a relationship between sprouting and site?

9. What are the light, air and soil temperatures, or other conditions needed for sprouting?

10. Do all aspen roots sprout or are there special reproduction roots?

11. What is the relationship between root sucker and bark peeling? ("Pinpoint" the relationship of time of cutting and sprouting.)

12. What is the relationship between season of cutting and the degree of restocking of aspen stands 2, 5, 10, and 15 years after cutting?

Applied Studies

Past and current management studies have given some good leads in handling aspen stands, particularly on good sites. Nevertheless, there is need for a number of applied studies; and much of the past work should be expanded and tested on different sites and conditions.

1. Of what general usefulness is disking as a regeneration measure on various sites and in various age classes?

2. What is the relation of rot to crown and vigor class on different sites and in different age classes?

3. What is the relation of season of cutting to production of suckers on various sites and age classes, and how does this tie in with the development of vegetation?

4. What are the approximate yields of aspen by site classes? How does Hypoxylon canker affect the yields?

5. When and how should aspen be thinned for best results (noncommercial and for pulpwood, sawlogs, and veneer)?

6. What are the best growing stock levels for aspen of various ages by site classes?

7. What are aspen yields under different systems of cutting?

8. To what extent should aspen be maintained in mixture with other species on good sites, and what methods can be used to accomplish such an objective?

Pilot Plant Studies

As soon as silvicultural or other practices are developed on a small scale, they should be tried out on a pilot-plant basis at several locations in the region where costs and returns can be determined and their economic usefulness evaluated.

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