Black Walnut (*Juglans nigra* L.) Agroforestry — Its Design and Potential as a Land-use Alternative

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Abstract

Integrated forestry-farming (agroforestry) management typically involves the planting of trees at a wide spacing with intercrops grown in alleys between trees. A program initiated in Missouri, USA in 1965 establishes eastern black walnut on a 40- × 10-foot spacing with row intercrops (wheat, milo, soybeans etc.) for the first 10-to-12 years followed by cover crops of cool-season forages thereafter. Specialty crops of Christmas trees, balled and burlapped landscaping species, small berry crops and vegetables are also grown during the early years of plantation establishment. Contrary to conventional management of black walnut, short, clear boles (8 to 16 feet in length) with large full crowns for nut production are developed for maximization of profits. Economic analyses show the highest investment returns associated with management practices combining nut and wood production within an agroforestry regime.

Key words: Forestry-farming, agroforestry, eastern black walnut, economics

Résumé

L'aménagement intégré forêt-agriculture (agroforesterie) comprend typiquement la plantation d'arbres le long de rangées très espacées entre lesquelles poussent des récoltes intermédiaires. Un programme initié au Missouri, E.-U. en 1965, a vu l'établissement du noyer noir occidental selon un dispositif de 40 pieds d'intervalle par 10 pieds et contenant entre les rangées des récoltes intermédiaires (blé, millet, soya, etc) au cours des 10 à 12 premières années suivies par la suite de récoltes de fourrage pour les saisons froides. Des récoltes de produits spéciaux tels les arbres de Noël, des espèces ornementales emballées dans de la jute, des récoltes de petits fruits et de légumes sont aussi effectuées au cours de premières années d'établissement de la plantation. A l'opposé de l'aménagement habituel du noyer noir, de courtes tiges sans branches (de 8 à 16 pieds de longueur) avec une cime complète et étendue destinée à la production de noix sont produites pour atteindre la maximisation des profits. L'analyse économique indique le plus haut retour sur l'investissement lorsque les pratiques d'aménagement combinent la production de noix et de bois au sein d'un régime agroforestier.

Mots clés: Forêt-agriculture, agroforesterie, noyer noir occidental, économie

Introduction

The concept of integrated forestry-farming (agroforestry) is not new and has been proposed on numerous occasions for black walnut (*Juglans nigra* L.) [Smith 1942, Garrett and Kurtz 1983a]. Black walnut lends itself to agroforestry due to the high value of its wood, production of a nut crop and its foliage characteristics which allow the penetration of sufficient light to support plant growth in the understory.

Spacing of Trees

Agroforestry management with black walnut dictates initial plantings of individual tree rows at wide spacings to accommodate the biological needs of intercrops. Within row spacings must, however, be close enough to provide a 'training effect' while providing a surplus of plants from which one can select the final crop trees. Since the crown of a mature walnut tree occupies an area approximately 40 × 40 feet and it is one of the management objectives in walnut agroforestry to maximize nut production, suitable space for optimal crown development should be provided. In addition, it is the objective of any management regime to maximize the number of veneer and high value sawlogs produced. Unfortunately, tree improvement programs for black walnut have not advanced sufficiently to provide genetically proven stock at prices affordable by the average landowner. Therefore, a greater number of genetically unproven trees must be planted initially to achieve 27 to 35 (the number one would have on

a 40 × 40-foot spacing) high quality stems per acre by rotation end.

While individual landowner requirements will vary depending on tree management objectives (i.e., emphasis on wood production vs. nuts), light requirements and growth period required for the intercrop and even farm equipment that is available (e.g., width of header, disk etc.), our studies have demonstrated that a 40 × 10-foot spacing (108 trees/acre) is a good compromise. Forty feet between rows provides sufficient light for most intercrop species while 10 feet within the row provides an additional 73 to 81 trees from which the final 27 to 35 quality crop trees per acre can be selected.

Mechanical Weed Control

Mechanical weed control is seemingly as effective as chemical control in maintaining high vigor trees grown under agroforestry management. However, greater caution must be exerted to avoid root damage resulting from tilling or damage to the lower portion of the stem resulting from contact with the tiller. Due to the loss of value that can occur when walnut trees are damaged, operating conventional farming equipment close to trees is not recommended. Weed control around the base of individual stems can and should be achieved chemically when conventional farm tilling equipment is employed. Complete weed control by mechanical means is advocated only with the use of some form of precision, in-the-row tiller such as that marketed by Weed Badger (Litchville, North Dakota 58461). Equipment of this nature is specifically designed to minimize damage to young trees and may prove superior to chemical weed control as a result

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of the benefits derived from soil-surface scarification. Where conventional equipment is used between rows, depth of tilling should be regulated to six inches or less.

Chemical Weed Control

Because of the ease of application and the success realized in the past, chemical weed control is more popular in walnut management than mechanical weed control. Following planting, herbicides are applied in a circle around each seedling creating an opening three feet or more in diameter or, as is advocated in agroforestry management, along both sides of a row of trees. The width of the control zone along the row will vary between landowners but should be a minimum of six feet (three feet along both sides of a row). As the trees grow, widths of vegetation-free zones should increase correspondingly up to about 15 feet (7.5 feet on both sides of a row). Roundup, applied as a mixture with Princep 4L in late March/early April has provided excellent control in our program. Three-to-four pints of Roundup plus seven pints of Princep per 25 gallons of solution have been applied per row-acre of trees with a tractor-mounted sprayer. A second application of Roundup has been spot applied as needed during June to control difficult-to-kill species. Because of the potential for buildup and damage from Princep over time, if Princep is used the landowner is cautioned to watch for abnormal leaf development. Leaf curling and necrotic zones along leaflet margins have been observed in our program following eight-to-ten years of chemical weed control and have been attributed to Princep. Because of the damage to walnut observed in our program, an evaluation of Surflan as a preemergent substitute is currently underway.

Fertilization

Perhaps the greatest weakness in managing eastern black walnut as a component of an agroforestry regime is found in the lack of understanding of fertility needs. Insufficient research has been performed to permit the development of sound fertilization prescriptions especially relative to nut production. Ponder (1976) demonstrated that fertilization benefits nut production in pole-size trees in Missouri but precise prescriptions for varying site conditions are unavailable. While trials are currently underway in our program that suggest the need for regular fertilization throughout the early years of plantation development, application over the first 13 years has been primarily for the benefit of the intercrop. When soybeans were used as an intercrop, the trees benefitted from the application of 0-60-60 pounds of actual NPK per acre applied in May. With wheat, 40-50-50 pounds of actual NPK were applied in October and an additional 30 to 40 pounds of actual N were added in May. Fertilizer was applied equally to trees and intercrops. Generally, nitrogen is the element needed most by the trees and it is often the one that is most lacking. Due to the loss of nitrogen from the site as a result of harvesting intercrops and removing tree prunings, N supplements must be made to maintain favorable growth rates of trees. If trees are to be fertilized independent of an intercrop, a good rule of thumb is to apply, within the dripline, one pound of triple twelve (12-12-12 NPK) per inch of stem diameter.

Pruning Recommendations

Contrary to the conventional approach of maximizing the clear length of a walnut log, agroforestry management advocates shorter boles with larger crowns. Numerous analyses (Garrett and Kurtz 1983a and 1987, Garrett *et al.* 1986) have demonstrated that internal rate of return and present net worth are maximized through the sacrifice of clear log length in favor of greater crown area for nut production. Therefore, on most upland sites (SI 55-70) the recommendation is to prune to a height providing a clear 8-to 10-foot log. On bottomland, bench and higher quality upland sites (SI > 70), an attempt should be made to produce 12- to 20-foot logs. Pruning cuts should be to the outside of the branch collar and conducted during late winter but prior to sap movement. Furthermore, an emphasis should be placed on eliminating weak branches coming off the central stem well above the current years pruning height. It is not enough to concentrate only on the stem scheduled for clear-pruning in the current year. A conscientious effort must be made to guard against 'problem branches' higher up on the stem. This is especially true in agroforestry management where increased light is available for branch development as a result of the wide spacings between trees. Trees grown under these open conditions demonstrate less apical dominance and artificial pruning is necessary to maintain a straight, single stem through the crown.

The cost of pruning and removing pruned branches from the site must be considered if a landowner plans to have extensive plantings of walnut. In a study conducted on 10-year-old trees (average height 23.5', diameter 5.0") in our program, cost of removing prunings from the site was found to be greater (\$0.20/tree) than the cost of pruning (\$0.14/tree). Total cost per tree (pruning + removal) was \$0.34 or \$36.72/acre (108 trees). Based upon our observations, a pruning tower and chipping equipment are desirable if the size of planting exceeds 50 acres. A pruning tower is needed by age 10 on a good site and a chipper, for disposing of pruned branches and small diameter trees removed early in the rotation, is needed by age eight.

Unique to agroforestry management is tip pruning (the removal of the growing tip of the branch) of lower branches. As trees develop, lower branches grow into the open areas on either side of a row and can become entangled in farm equipment operating between rows often causing irreparable damage to the trees. Tip pruning avoids this damage and enables the landowner to maintain greater live crown ratios early in the life of the stand thereby maximizing tree growth responses. While there are no set rules as to when tip prunings should begin or the amount of branch to be removed, both should be based on minimizing the danger of damage from equipment.

Thinning

Thinnings under agroforestry management can be delayed longer than under conventional management due to two sides of each tree being open from the wide spacings between rows. However, depending upon the site and initial spacings within a row (but assuming that spacing within a row will not exceed 20 feet), the first thinning will become necessary between years 10 and 15. Thinnings are designed to select trees for removal based upon stem quality (straightness,

diameter, height and apical dominance) and nut production characteristics (precociousness, bearing regularity, percentage crackability, quality and quantity of nuts produced). Thinnings are conducted on an ongoing basis with the final objective being to reduce the original planting number to 27 to 35 of the most valuable trees.

Row Intercrops

Operational plantings of soybeans, wheat and milo have been made with walnut in our program since 1974. Of the conventional row crops tried, winter wheat has proven to be the best. Winter wheat grows during the trees dormancy resulting in minimizing the competition for water, nutrients and light. During the early years (the first three years) of the planting, it can be grown to within three feet of a tree row removing only 13% of the land from wheat production. During subsequent years, however, spacing between the crop and trees must be increased to as much as seven feet or more to protect against possible root damage. Even at this spacing though, 45 rows of wheat spaced at 7-inch intervals can be placed within a 40-foot lane.

Soybean, milo or other warm season crops compete directly with walnut for water and nutrients although walnut does rely on a much deeper profile to meet its needs (Dey *et al.* 1987). In addition, various grasses and herbaceous types invade the tree rows necessitating weed control. Because of the need to operate weed-control equipment in close proximity to the trees, six-to-seven-foot crop-free zones must be maintained from the beginning along both sides of a row of trees when growing warm season crops. This permits the planting of ten, 30-inch or 20, 15-inch spaced, rows of soybeans. Thirty-eight percent of the land base is taken out of soybean production as compared with only 13% early in the rotation for wheat.

Field plantings of soybeans and winter wheat under agroforestry conditions in our studies have yielded an average of 24 and 41 bushels per acre of cropland, respectively, on an upland site (SI 62) and 32 and 41 bushels respectively, on a bottomland site (SI 80) over the first five years. During the second five-year period, soybean and wheat yields declined, but due to differences in growing seasons, losses were greater for soybeans than for wheat. On the best sites (bottomland), soybean yields were approximately 43% below the average of the first five years by the end of year 9. Wheat yields were 30% lower in year 10.

Specialty Intercrops

The landowner is not limited to traditional row crops during the early years of walnut establishment. Intercrops such as Christmas trees, red clover, vegetables, landscaping species and a host of other choices can be made limited only by the site requirements of the specialty crop, light needs and local markets. While little can be done to alter site conditions, available light can be regulated to some degree by changing the spacing between and within walnut rows. As an example, changing the within-row spacing from 10 to 20 feet increases the light within the 40-foot lanes and permits the alternating of walnut and Scotch pine, grown for Christmas trees, within the row. High-quality Christmas trees can be produced under these conditions in about eight years.

Intercropping with row and specialty crops is feasible as long as yields justify it. However, between years 9 and 15, depending upon site, spacing and intercrop species planted,

Table 1. Growth of young eastern black walnut stands planted at a 40 × 20-foot spacing on an upland (SI 60, age 15 years) and at a 40 × 10-foot spacing on a bottomland (SI 80+, age 13 years) under agroforestry management

Site	Height (feet)	Diameter (inches)	Crown diameter (feet)		
			N-S	E-W	Mean
Upland	24.7	6.2	17.2	17.3	17.3
Bottomland	37.8	6.9	16.6	25.5	21.0

light becomes limiting and conversion to cover crops or less light-demanding species becomes necessary.

Forage Cover Crops

Evidence strongly suggests that, at least for many cool season species, walnut shade enhances forage yield and quality. A study in Ohio led the investigator to conclude that many of that states pastures could be greatly improved by planting black walnut (Smith 1942). Dry weight forage yields of wild and cultivated grasses were 50% greater the first year and 33% greater the second under walnut than in the open. Moreover, the quality of shade-grown forage was superior to open-grown. Work in our program has demonstrated significant increases in yields of Kentucky 31 tall fescue (*Festuca arundinacea* Schreb.) orchardgrass (*Dactylis glomerata* L.) and Reed Canarygrass (*Phalaris arundinacea* L.) when grown under walnut as compared to in the open (Garrett and Kurtz 1983a, 1983b). Increases of as much as 33% in yields have been observed along with a 10% improvement in *in vitro* digestibility. Studies on warm season forages, however, have been less encouraging with most species showing significant decreases in yield.

Walnut Growth Responses Under Agroforestry Management

The practicality of walnut agroforestry management is in part determined by the quality of the site under management. The better the site, the better the overall growth and quality of the trees and the greater the potential for intercrop production. The greater the overall growth of the trees, the less time required to produce a high quality veneer or sawlog and the higher the return on the investment. Growth of 1,000 walnut trees has been evaluated under agroforestry management on both an upland (SI 60, 40' × 20' spacing) and bottomland (SI 80+, 40' × 10' spacing) site and comparisons are made in Table 1. While trees on the upland site are two years older (15 years) than those on the bottomland (13 years), they average only 24.7 feet in height compared with 37.8 for those on the bottomland. Diameter differences are less contrasting with representative means of 6.2 and 6.9 inches for the upland and bottomland sites, respectively. Crown size which is so critical in nut production is also sacrificed on an upland site (Table 1). Differences in crown diameters illustrate the value of placing walnut on the best sites.

Differences in crown symmetry found on the upland and bottomland sites are the result of different spacings and better growth (greater competition between trees within a row) on the bottomland site. Crowns of the bottomland trees yielded 53% greater diameter in the between-row orientation (east-west) than in the within-row orientation (north-south). The sacrifice in within-row crown development on tree growth and nut yields is unknown but is probably significant.

Table 2. Height and diameter growth responses of eastern black walnut four years after herbicidal release (released at age 9) from an intercrop of Kentucky 31 tall fescue

Herbicide application	1984		1987	
	Height (feet)	Diameter (inches)	Height (feet)	Diameter (inches)
Untreated	7.00	2.29	8.60	2.92
Herbicide	7.04	2.11	12.10	4.25

Effects of Weed Control on Growth of Walnut

Weed control is required to maximize the growth response of walnut irrespective of the site or management regime and is mandated to justify the economics of growing walnut. While competition varies with the weed species, most herbaceous weeds create some inhibition for walnut due to the increased competition for the limited water supply available. Walnut is intolerant of competition for moisture and shows strong growth inhibition when forced to compete. However, it is logical to assume that growth inhibition is less, under similar circumstances of competition, on a deep, high quality site than on a more shallow, lower quality site. In a study conducted by the authors on a poor to intermediate upland site (SI 55), four rows of walnut were established on a 12.5 × 35-foot spacing in the spring of 1975. Forty trees occupied a row and Kentucky 31 tall fescue was established between rows. Chemical control in three-foot diameter circles was maintained around each seedling through year three of the study. In 1984, six years after grass control was stopped, it was resumed around two of the four rows. Roundup was applied to the drip-line on both sides of a row. By the end of the 1987 growing season, the four-year changes in height and diameter in the untreated rows were only 23 and 28 percent, respectively, while in the herbicide rows they were 72 and 101 percent (Table 2). Foliage was a deeper green and was retained longer in the treated rows. Similar findings have been reported by others. Schlesinger and Van Sambeek (1986), demonstrated increases in walnut growth of up to 250% following the eradication of fescue.

Walnut Nut Production Under Agroforestry Management

Eastern black walnut nuts must be viewed as an agricultural commodity similar to pecans if the walnut nut industry is to grow and prosper. Agroforestry management can serve as the catalyst to elevate black walnut from its current position as an important timber species to the more deserving and financially rewarding position of an agricultural commodity. To do so, however, means that an increased emphasis must be placed by landowners on managing walnut for nut production.

Nut Production Potential

There are few reports available on walnut nut production under managed conditions (Garrett and Kurtz 1987, Van Sambeek and Rink 1982). Those that are available, for the most part, are projections rather than documented yield accounts. Because of this, it is difficult to realistically project nut production potential under agroforestry management. However, one can secure a reasonable estimate for nut production by observing the yields of open-grown, mature walnut found growing on good sites. Nut production on six, open-grown trees ranging in age from 70 to 100 years

Table 3. Pounds of hulled nuts produced by six, open-grown, mature, eastern black walnut trees

Tree	Harvest year								
	1972	1973	1974	1975	1976	1977	1978	1980	1981
Pounds of nuts									
1	211	0	162	0	358	0	164	329	0
2	20	0	0	73	0	70	0	0	75
3	116	0	80	0	148	0	21	119	120
4	23	80	0	0	55	34	43	50	212
5	139	250	92	106	110	100	98	28	342
6	103	230	0	524	0	72	460	292	219
Average	102	93	56	117	112	46	131	136	161

Tree	avg./tree					
	1982	1983	1984	1985	1988	
1	35	306	92	325	17	143
2	0	23	97	0	35	28
3	14	100	62	89	154	73
4	0	106	0	128	17	47
5	0	240	22	156	0	120
6	0	100	108	199	125	174
Average	8	146	64	150	58	96

(28-36 inches DBH) and growing on a deep, well-drained, silty-clay loam, has been monitored for 14 out of the past 17 years (Slusher 1985, Table 3). High year-to-year and tree-to-tree variation has been observed. The average number of pounds of nuts produced per year over the 14 years by all six trees is 96. If one assumes 30 trees per acre (this would approximate a 40 × 40-foot spacing), and each tree produced 96 pounds of hulled nuts, the total yield per acre would equal 2880 pounds. If those nuts were sold for \$0.07/pound (1988 price was \$0.08/pound), each acre would return \$202.00 before removal of harvesting cost. If, through selection, one were so fortunate as to have grafts of only the best tree (tree #6), yields per acre would equal 174 times 30 trees per acre or 5220 pounds. Again assuming a price of only \$0.07/pound, those 5220 pounds of nuts would have a value of \$365.00 minus the cost of harvesting. Assuming as much as 50% of the value of the nut crop was charged for harvesting, a reasonable return on one's investment would still be realized even at the typical price paid by Hammon's Products Co. of Stockton, Missouri, the number one processor of eastern black walnut nut meat. Furthermore, it is noted that Hammon's Products has contracted plantation-grown nuts for as much as \$0.20/pound because of their better quality and guaranteed availability.

Moreover, the yields reported here do not necessarily represent the maximum potential that might be possible through genetic selection. By selecting trees that are more regular in bearing characteristics than those studied here, it might be possible to increase yields even further. To illustrate this point, Table 4 compares the nut production of a select tree in our program with the average for the plantation in which it is growing. Over a six-year period the select tree produced 5.9 times greater weight of nuts than the average tree. In excess of 13,000 trees are currently being monitored for nut production characteristics as part of our tree improvement selection program.

Mechanical Nut Harvesting

Nut harvesting equipment for eastern black walnut is still in its infancy. However, there is no reason to believe that

Table 4. Nut production of a select genotype compared with the average of a plantation in southwest Missouri¹

Tree age	Plantation averages		Select tree	
	Nuts per tree	Lbs per acre ²	Nuts per tree	Lbs per acre ²
12	14	28	370	740
13	131	262	882	1764
14	20	40	75	150
15	60	120	147	294
16 ³	56	112	368	736
17	379	759	2047	4094
Total = 1320 lbs		Total = 7778 lbs		

¹Site index = 60; average number of green nuts per lb. (husk removed) = 27;

²Pounds per acre with 54 trees per acre.

³This year's data were not available. Values representing the average of the preceding four years were used.

existing equipment for English walnuts and pecans could not be adapted for black walnut. In fact, pecan harvesting equipment was used on a test basis in our program in 1987. It would appear that acceptable results could be obtained with proper site maintenance and some equipment modifications.

Harvesting consists of two basic components: removing the nuts from the trees and retrieving them. This can be accomplished by either shaking and catching or shaking and sweeping. There are two basic types of shakers: those which attach to the tree about 3 feet above the ground, and those which extend and attach at some point above the butt log. Inherent risks of tree damage are associated with both and with any device that clamps hydraulically to a tree and delivers a high-frequency shaking. These risks, and methods to minimize them, should be studied with black walnut. However, the shaking system that attaches above the high-quality butt log has obvious appeal as it would seem to be the least damaging.

Nut harvesting equipment is expensive. The cost of the least expensive pecan harvester starts at approximately \$11,000 without a power source. A new pto-driven shaker costs about \$4,500, and the more sophisticated equipment is substantially more expensive. As is so often the case, one needs large acreage to justify the investment. However, through the formation of a growers' cooperative, custom hire, or share harvest arrangements, it would appear that such an investment could be justified.

Walnut Agroforestry Economics

Agroforestry provides the black walnut grower the opportunity to develop a portfolio of short- and long-term investments thus allowing for some risk spreading through diversification. In addition, for some farmers with cropland in production that is particularly unsuitable for cropping due to high soil erosion, agroforestry provides an avenue for the erodible land to be removed from crop production over an extended period as the trees mature.

Timber Only Option

In our program, Kincaid (1982), followed by Kincaid *et al.* (1982) and Kurtz *et al.* (1984) reporting on the same data, have examined several black walnut investment alternatives. Diameter growth projections of 1/3 inch (SI 65 and 80) and 1/2 (SI 80) were used for tree growth estimates from which thinning, harvest and volume estimates were derived for two

Table 5. Present net worth (PNW) @ 7.5% and internal rate of return (IRR) of alternative black walnut management regimes, site index 65 and 80, 60-year rotation

Management regime	Site index 65		Site index 80	
	PNW	IRR	PNW	IRR
	\$/ac	%	\$/ac	%
Timber	-1199	4.3	-575	6.7
Timber and nuts	-559	5.9	134	7.7
Timber, nuts and wheat	65	7.8	822	9.4
Timber, nuts, wheat soybeans, fescue hay and grazing	261	8.7	1290	10.9

rotation lengths — 60 and 70 years (Kincaid 1982). All of the typical silvicultural operations were included along with landholding costs, taxes and management charges. Land costs were differentiated by \$200 per acre to account for the two site indexes. Two clear-length prunings were applied to produce a clear bole of 15 feet while minimizing the impact from epicormic branching. From an initial density of 300 trees per acre, thinnings reduced the final stand to 27 trees. Log volume (bf Doyle Rule) was distributed according to tree size at time of thinning or final harvest. Stumpage prices were reflective of local markets and were appreciated at a real rate of 1.5% annually. Computed PNWs (7.5%) ranged from \$-575 per acre with an IRR of 6.7% for a 60-year rotation, SI 80, 1/2 inch diameter growth rate, to \$-1,199 per acre with an IRR of 4.3% for a 60-year rotation, SI 65, 1/3 inch diameter growth rate (Table 5).

Timber and Nuts Option

Management of a black walnut plantation for both timber and nut production requires a different strategy than management for timber production alone. For nut production, in general, fewer trees need to be planted because more room is required for crown development. Clear-length pruning heights will necessarily be lower; consequently, thinning schedules also will be somewhat different. Nut production, generally, is economically advantageous because it offers near-term and annual financial returns from an otherwise long-term investment, and some hedge against risk through product diversity.

Kurtz *et al.* (1984) described management regimes developed by Kincaid (1982) for timber and nut production on two sites (SI 65 and SI 80). These management regimes closely parallel the actual management regimes established in our program at Stockton, Missouri, USA. Trees were assumed to be on a 40 × 10-foot spacing (108 trees per acre). Pruning was conducted only to a height of 11 feet. Commercial quantities of nuts were assumed to be produced beginning in year 20 — our research now indicates commercial production by age 15. Nut prices of \$9 per cwt were assumed and were not appreciated over time. For the lower quality site, PNW (7.5%) was -\$559 per acre and IRR was 5.9%; for higher quality site, PNW (7.5%) was \$134 per acre and IRR was 7.7% (Table 5).

Utilizing the same data, we examined the impact of nut production and nut price on economic returns from management for timber production and an agroforestry management regime of timber and winter wheat (Garrett and Kurtz 1982). Nut prices of \$5, \$9, \$15 and \$20 per cwt were utilized to

Table 6. Internal rate of return (IRR) and present net worth (PNW) @ 5% of alternative black walnut management regimes at nut prices of \$5, \$9, \$15 and \$20 per cwt

Management regime	\$5		\$9		\$15		\$20	
	IRR %	PNW \$/ac	IRR %	PNW \$/ac	IRR %	PNW \$/ac	IRR %	PNW \$/ac
Timber	6.7	2472	6.7	2472	6.7	2472	6.7	2472
Timber and nuts	7.3	2995	7.7	3614	8.3	4542	8.8	5316
Timber and wheat	8.2	3345	8.2	3345	8.2	3345	8.2	3345
Timber, nuts and wheat	8.7	3783	9.2	4359	9.9	5223	10.4	5942

gauge the effect of nut value on PNW and IRR. A site index 80 and rotation length of 60 years were held constant; land costs, taxes and management costs were not included in the analysis. Depending on nut price, PNW increased from \$443 per acre to \$2844 per acre and IRR increased by 0.5% to 1.3% from the addition of nut production (Table 6). The greatest differences were noticed for the timber only management regime because of the lack of any near-term returns from agricultural activities. Obviously, the addition of nut production increases all measures of financial profitability for a black walnut plantation.

Agroforestry Option

To provide a comparison to management for stumpage production only, two agroforestry management regimes — timber, nuts and winter wheat and timber, nuts, soybeans, winter wheat, fescue and grazing — were developed (Kurtz *et al.* 1984). The black walnut timber and nuts management regime identified earlier provided the basic timber component for both regimes. Crop and livestock costs and returns were based on budgets developed by the Department of Agricultural Economics, University of Missouri-Columbia. The timber, nuts, wheat, soybeans, fescue and grazing management regime provided the highest PNW (7.5%) (SI 80, 60-yrs.) at \$1,290 per acre and the highest IRR at 10.9% (Table 5). However, this particular regime incorporates a substantial degree of risk because of the ever present possibility of tree damage from livestock. Likewise, a substantial investment must be incurred early in the rotation for fence construction and maintenance (Garrett and Kurtz 1983). Obviously, the financial aspects of this regime are quite sensitive to movements in livestock prices.

Two salient, though general points emerge from this comparison. First, the greater financial returns will accrue to the agroforestry management regime that is the most complex. Second, the greater financial returns will be yielded by the higher quality site. The latter case is dependent on the increased productive capacity of the site more than offsetting the increased land costs.

Conclusion

In view of the past, present and projected values for walnut sawlogs and nuts, one can assume that increases in economic productivity per unit area of land will often result from management intensification and diversification with walnut agroforestry. Our 13-year study of planting eastern black walnut at wide spacings, intercropping with conventional and specialty agricultural crops and emphasizing nut production indicates that the integrated concept is not only a viable land use option but may be one of the best investment opportunities available in the profession of forestry. It now appears

that the added value from nut production may be even greater than our earlier estimates. Landowners, with plantation walnut on good sites, who do not want to intercrop, should manage for both nut production and veneer logs. However, landowners who wish to plant walnut and maximize their economic returns should consider integrated, forestry-farming.

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