Farmers harvest crops from their fields, and loggers harvest trees from their forests, but what do forest farmers harvest? The answer is an eclectic collection of non-timber forest crops like maple syrup, medicinal herbs, fruits, gourmet mushrooms, and nuts.

Forest farming is an approach to forest management that combines some of the management practices of conventional forestry with those of farming or gardening to achieve an environmentally and economically sustainable land-use system. It is one of several related practices that fall under the domain of agroforestry—a multidisciplinary approach to agricultural production that achieves diverse, profitable, sustainable land use by integrating trees with non-timber forest crops.

While some other agroforestry practices begin with planting young trees that take years to mature, forest farming involves planting non-timber forest crops beneath the canopy of an established forest. In other words, other agroforestry practices bring the forest to the crops, whereas forest farming brings the crops to the forest. In this regard it is helpful to consider the role of forest farming in overall forest man-

Many sections of the Northeast have been reforested over the past century. Extensive forest cover is seen in this view from Wachusett Mountain in central Massachusetts.
agement. A forest farm should be designed to emulate as much as possible a natural forest. This includes characteristics of a healthy forest ecosystem such as species diversity, resilience to disturbance, soil health, and a relatively wide tree age distribution.

Forest Farming Through the Ages
Although this article will focus on modern temperate region forest farming, similar practices have been used in tropical regions by indigenous peoples for hundreds of years. In a classic paper from the agroforestry literature, Fernandez et al. (1984) described an agroforestry practice called home gardens, used by the Chagga people who live on the slopes of Mt Kilimanjaro. Home gardens are highly integrated, multistory collections of overstory forest trees valued for timber, an intermediate layer of small trees including coffee and banana, and a diverse array of understory herbs and vines used for food and medicine. In North America, during and prior to the seventeenth century, native peoples are known to have planted and managed various food bearing trees including walnuts and peaches, but there is no evidence of deliberate cultivation of useful crops beneath the canopy of established forest.

Although some types of forest farming and other agroforestry practices have been going on for centuries, the terms “agroforestry” and “forest farming” are of relatively recent origin. Agroforestry—as a concept that recognized the integration of trees, crops, and people—was introduced in 1973 by John Bene, and led to the establishment of the International Council for Research in Agroforestry (ICRAF) in Nairobi, Kenya which is now the World Agroforestry Center. It was not until 2000 that the term forest farming was introduced by Hill and Buck (2000) to describe the cultivation of non-timber forest crops beneath an existing tree canopy. One factor contributing to the growing popularity of forest farming in northeastern North America is the gradual increase in the extent of privately owned forest. Using the state of New York as an example, forest cover was at a minimum of about 15% in 1880 because of extensive conversion of forest to farmland.

Farming or Wildcrafting?
Although there is no anthropological or archeological evidence that Native Americans practiced forest farming per se, unquestionably they were highly skilled at gathering and utilizing wild forest products, including food, medicines, and ceremonial plants. Prospective forest farmers today frequently ask if the collection of wild forest products like edible mushrooms, wild leeks (ramps), ginseng and other medicinals, and decoratives like pine cones for wreaths and vines for basketry can be considered forest farming. These practices, known collectively as wildcrafting, are certainly compatible with forest farming, particularly when done on a sustainable basis, but don’t qualify as forest farming (i.e. cultivation) unless they are practiced in combination with deliberate cultivation of non-timber forest crops.

Wild-collected morel mushrooms.
Reforestation since then has gradually increased forest cover to 65%, and about 60% of that is privately owned. At the same time average parcel size has decreased, making timber extraction a less economically feasible option. This transition from "industrial" forestry to "investment" forestry by owners who consider forestry a part-time activity or even a hobby makes forest farming an attractive management alternative. Those interested in forest farming include conventional farmers, many of whom have woodlots on their farm, but also private forest owners with non-farm day jobs who want to use their forest productively while preserving or restoring the natural ecosystem. In either case, supplemental income associated with sale of non-timber forest crops can be the deciding factor, although many forest owners pursue forest farming as a source of non-timber forest products for the family, or simply as a source of personal satisfaction.

**Becoming a Forest Farmer**

Before starting, the forest owner should consider site issues beyond just “Can I grow ginseng (and/or any other crop) at this site?” A successful forest farm should be seen as an integrated agro-ecosystem that satisfies the owners goals while sustaining ecosystem components including soil, water, trees, and wildlife.

A forest farm often begins with a more or less natural (unmanaged) stand of trees. To make it suitable for forest farming, some degree of management is necessary, including management of the forest light environment. For the medicinal herb ginseng (Panax quinquefolius), up to 70% shade is necessary, and for mushrooms like shiitake (Lentinula edodes), the more shade the better. On the other hand, fruit crops like blackberries (Rubus spp.) and pawpaw (Asimina triloba) perform best under moderate shade. Light management practices include pruning, selective tree removal, utilizing natural gaps in the forest canopy, and planting less shade-tolerant crops along the forest perimeter. Observing the natural distribution of wild relatives can inform decisions about appropriate placement of candidate non-timber forest crops. For example, wild brambles like black raspberry and blackberry typically occur along the ecotone (interface) between field and forest. Attempts to grow cultivated brambles beneath a dense forest canopy rather than along its perimeter generally have not been successful.

While light is an environmental factor that can be managed, others, including soil pH, fertility, slope, and water availability, cannot be modified in forests as easily as in field agriculture. Irrigation, fertilization, and modification of soil pH are not realistic management options in most forest situations. It makes more sense to select crops that are naturally well-suited to the site characteristics.

**Types of Non-Timber Forest Crops**

There are three major categories of non-timber forest crops used in forest farming: medicinal, food, and ornamental. Ginseng and mushrooms, in the medicinal and food categories respectively, have the greatest proven income potential but there are others in each category well worth considering (see Chamberlin et al. 2009). While cultivation of ornamentals in forest farming systems is less frequently practiced it does have considerable potential.

In traditional farming, crop diversification was considered insurance against the failure of any one crop. Species and temporal diversity are characteristics of a natural forest ecosystem which forest farms ideally should seek to emulate. For example, in a forest farm growing mushrooms, maple products, and ginseng, diversification makes good sense from a production standpoint; maple is tapped yearly, mushrooms yield a harvest for several years, while ginseng will take eight years to mature. In this
case, the maples also provide shade for both other crops and additional calcium (in fallen leaves) needed by the ginseng.

**Medicinals**

The forests of North America have been repositories for a wide range of herbs and other plants and mushrooms gathered for use in traditional medicine. The pallet of medicinal plants collected and used by Native Americans and others was and is extensive, but only a few of these species are cultivated as non-timber forest crops today. To a very great extent, this is due to economic factors, including lack of markets and concomitantly low potential for income generation. Ginseng and goldenseal (Hydrastis canadensis) are the two medicinals most often cultivated by forest farmers.

American ginseng (Panax quinquefolius) is a shade-loving perennial herb that produces a valuable below-ground storage root. It occurs in hardwood forests throughout most of eastern North America. Although wild populations have declined somewhat because of harvesting, it is still relatively common. American ginseng has been highly valued in traditional Chinese and Korean medicine since it was first exported from North America in the seventeenth century. Most commercial demand today is from China and Korea. Ginseng is valuable as a forest farming product, but potential growers should use Beyfuss's site assessment techniques (see listing under Additional Reading) before jumping in.

American ginseng is reputed to function in the human body as an “adaptogen,” increasing the body's resistance to stress. In traditional Chinese medicine, ginseng is said to promote yin energy and have a calming effect. This and other beneficial effects of ginseng have been claimed for centuries, but there is little modern scientific research to substantiate these claims. Nevertheless, ginseng is the most valuable of North American medicinal herbs.

The ginseng plant has an unusual growth habit and life cycle that contribute to the relative difficulty and long timeframe involved in cultivating it as a crop. A more typical plant has roots, stem(s) and multiple leaves, each associated with a bud that grows into new branches. Not ginseng. The mature plant consists of a single stalk that looks like a stem, but is in fact a sympodium consisting of the fused petioles (leaf stalks) of its 3 or 4 palmately compound leaves. Ginseng develops a narrow underground rhizome—about the thickness of a good sized-earthworm—with a bud at one end and one or more tuberous storage roots at the other end. A single flush of aboveground growth emerges from the rhizome bud in the spring while the storage root grows slowly during the summer. The plant's slow growth rate is an adaption to its low light environment and results in forest-cultivated ginseng taking about eight years to mature.

The storage root, which looks a little like a branched carrot, is what all the excitement is about. In Chinese the word for ginseng means “man root,” and the more it looks like a person (arms and legs) the more valuable it is to traditional Asian buyers. The root is the source of
the pharmacologically active compounds known as ginsenosides. When it comes time to harvest the crop, it can only be sold to a licensed dealer if it is intended for export, as is the case with most American ginseng.

The price structure for ginseng is a curious inversion of most other crops. The more intensively it is cultivated, the less it is worth. Large scale, high density ginseng grown in Wisconsin, Ontario, and British Colombia requires expensive artificial shade structures and considerable amounts of fertilizers and fungicides. The wholesale value of this ginseng is about $25 per pound dry weight as of 2009.

As a forest farming crop, ginseng is cultivated either by the “woods-cultivated” or the “wild-simulated” method. “Woods-cultivated” ginseng is grown in raised beds, often amended with organic matter. Its price is about $150 per pound dry weight. The less intensive wild-simulated method involves minimal management—little more than roughing up the ground with a rake, scattering the seed, and coming back to harvest eight years later. It wholesales for about $300 per pound dry weight. This inverse relationship between price and intensity of cultivation extends even to wild-collected (zero cultivation) ginseng which wholesales for $400 to $600 or more per pound dry weight.

Food
North American forests abound with edible plants. However, their use in forest farming is limited since few of these forest edibles can be grown in sufficient quantity, in a reasonable period of time, and be sold for a reasonable price. Food crops that are most likely to be found in a forest farm include gourmet mushrooms like shiitakes (Lentinula edodes), berries, other fruits such as pawpaw (Asimina triloba), ramps (Allium tricoccum), and tree nuts such as walnuts (Juglans spp.) and hickories (Carya spp.).

Forest-cultivated mushrooms deserve serious consideration for those starting a new forest farming venture. Most candidate crops like medicinals, fruits and nuts, or ornamentals require specific site conditions, but since mushrooms are grown on logs they are less dependent on factors like soil moisture, pH, and drainage. Mushrooms are not photosynthetic and therefore can tolerate nearly complete shade, and a shady site is essential to minimize excessive drying of the substrate logs. Aside from socioeconomic factors like access to markets, mushrooms can be cultivated almost anywhere as long as there is sufficient shade and a source of substrate logs.

Mushrooms are less valuable per pound than ginseng, they are more perishable, and their cultivation requires more labor than ginseng. On the other hand, $8 to $16 per pound fresh weight for shiitake mushrooms is not a bad price when you consider that you can start harvesting mushrooms in as little as one year after log inoculation, and continue harvesting from the same log for 3 to 5 years. By contrast, once a ginseng root is harvested, the plant is gone.

Other mushrooms including lion’s mane (Hericium spp.), oyster (Pleurotus spp.), and hen of the woods (or maitake) (Griffola frondosa) can be cultivated under forest farming conditions but cultivation strategies are not yet as well worked out as for shiitake. People curious about mushroom cultivation often ask about the ultra-valuable truffles (Tuber spp.), which can sell for nearly $1000 per pound, and valuable morels (Morchella spp.). It is probably best to discourage all but the bravest and most patient entrepreneurs from investing time or money in cultivating truffles—many have tried to grow them but very few have succeeded. Similarly, there are very few who have successfully grown morels, which are best left to wildcrafting.

By far the most reliable mushroom for forest cultivation, and for which there is the greatest commercial demand, is shiitake. While log-
grown shiitake can be a reliable non-timber forest crop for forest farming, it is worth pointing out that most shiitake mushrooms available to the public are grown indoors on artificial (sawdust) logs, in expensive climate-controlled rooms. The quality of these artificially cultivated shiitake is generally considered inferior to log-grown shiitake mushrooms.

Shiitake is a primary saprophytic fungus that derives its nourishment from dead organic matter; in forest farming, freshly cut logs provide the substrate. The goal of shiitake cultivation is to facilitate the decay of the log through a process by which the fungal mycelium (aggregated fungal strands, or hyphae) enzymatically digests the wood by degrading lignin and cellulose, producing carbon dioxide, water (products of respiration), and the energy necessary for the fungus to assimilate the remaining carbon into new mycelium and reproductive structures, that is, the mushrooms.

Since shiitake competes poorly with other fungi, the substrate logs for production must be freshly cut and lack competing decay organisms. Freshly cut logs also provide the high moisture content necessary for fungal colonization after inoculation. A number of deciduous hardwood tree species make good shiitake substrate. Oaks (Quercus spp.) are considered the gold standard in the Northeast but sugar maple (Acer saccharum) also rates highly. Tulip poplar (Liriodendron tulipifera) is particularly desirable further south. Conventional wisdom says that species with tight bark that helps maintain a high moisture content make the best shiitake bolts, yet our research has shown that aspen, which maintains a higher moisture content than oak, beech, or red maple, is the poorest with respect to shiitake production. Interestingly, in our tests ironwood, or American hornbeam (Carpinus caroliniana) outperformed red oak.

Cut logs are then inoculated with spawn, a pure culture of shiitake fungal mycelium (not spores) grown on sawdust or other substrate which is introduced into holes drilled in the logs. Production of uncontaminated spawn must be done under sterile laboratory conditions, so most growers purchase their spawn from commercial producers. An approximately $20 bag of spawn inoculates about 20–30 logs. Once inoculated, the logs are transferred to the

Lion’s mane (Hericium spp.) and oyster mushrooms (Pleurotus spp.) can be cultivated in forest farms, though not as reliably as shiitake.

Forest-farmed shiitake mushrooms ready for harvest.
The MacDaniels Nut Grove: A Unique Educational Site

Practicum in Forest Farming is a multidisciplinary course taught at Cornell University. What makes the course unique is not only the subject matter but also the MacDaniels Nut Grove, the outdoor classroom where the course is taught.

Both are an outgrowth of the rediscovery, in 2000, of a more than 70-year-old temperate nut tree variety trial established in the 1920s by Professor Lawrence MacDaniels. Not long after Dr. Mac (as he was known) retired in 1956, the site was abandoned. Soon, it was all but forgotten as it reverted to secondary forest including oak, hickory, maple, cherry, and invasive honeysuckle. Fifty or more years later, the only obvious sign that the seven acre site was once a repository for hickory and walnut clonal varieties was an abundance of graft unions on over 100 of the older trees. When Dr. Mac was acquiring and grafting scions (upper portion of a grafted plant) onto understocks (lower portion), little was known about the limits of genetic compatibility between different hickory (Carya) species. Graft unions between genetically compatible scion/stock combinations like C. x dunbarii (C. laciniosa x C. ovata) grafted onto a shagbark hickory (C. ovata) understock are barely evident today. Other combinations like shagbark hickory grafted onto red pignut hickory (C. ovalis) showed extreme bulging and cracking at the graft union, signs of delayed incompatibility.

When the site was rediscovered it was easy to recognize it as a nut tree variety trial, but it didn’t take long to envision it as an outdoor forest farming classroom for Cornell students and members of the community. The course is structured around experiential learning, combining a wide range of outdoor activities with related reading and writing assignments. A field trip to Cornell’s Arnot Teaching and Research Forest lets students learn about ongoing mushroom and ginseng research, including hands-on inoculation of freshly cut logs with shiitake mushroom spawn and digging young ginseng seedlings from a wild-simulated (not wild) ginseng patch. Both the logs and the ginseng are brought back to the MacDaniels Nut Grove for further learning activities. Additional activities include soil analysis, vegetation inventory, site indexing to gauge suitability for a given tree species, and forest stand improvement. Data collected in each of these categories contribute to an ongoing GPS database of the MacDaniels Nut Grove. As an integrator of all these hands-on activities, student groups work on a final project involving a systematic permaculture-inspired approach to site assessment and design using an explicit set of “forest owner” goals developed by each group in order to synthesize a final design.
laying yard where they will incubate while the fungal mycelium colonizes the log. The laying yard must be well shaded (about 80%) year round to minimize moisture loss from the logs. Production of mushrooms for harvest typically occurs about a year after inoculation.

Ornamentals

The North American public spends a considerable amount of money on plants used as ornamentals, either in gardens or for decorative purposes around the home (e.g. cut flowers). Ornamental plants like roses or lilacs that thrive in full sun are not well suited for forest farming, but there is plenty of demand for shade-tolerant garden perennials including hostas, daylilies, ferns, heucheras, trilliums, astilbes, and hellebores. Note that some of these are forest wildflowers, but in forest farming the emphasis is on deliberate cultivation and conservation of wild plants so plants are grown, not wild collected.

Two basic nursery production systems are adaptable to forest farming—field (in the ground) and container. Field production can have lower costs but harvest and sale of plants is seasonally limited. Container production makes it easier to harvest, move, and sell plants, but has drawbacks such as wind throw, low and high temperature stress to root systems, and higher water needs from restricted rooting volume.

A newer method, pot-in-pot production, solves many of these container problems and may be well suited for forest farming. This method uses an empty socket pot buried in the ground so that its rim is about even with the soil surface. A second pot containing the crop plant slides down into the socket pot, so its soil line is at about the natural ground line. This prevents wind throw, allows for easy, multi-season harvest, moderates soil temperature within the crop pot, and reduces water use. The latter is particularly useful in most forest farming systems where irrigation is usually not readily available.

Another category of ornamentals for forest farm production includes cut stems, flowers, cones, and vines that are harvested from intact plants that remain alive, ready to produce subsequent crops. Although collection of cones, boughs, bark, etc., is more closely allied with wildcrafting than forest farming, the distinction becomes blurred if a wild plant is deliberately managed to produce a continuous supply of cut products. Woody florals—ornamental stems of woody shrubs such as red-twig dogwood or
Red-twig (or red osier) dogwood (*Cornus sericea*) can be grown as a woody floral for its colorful winter stems.
corkscrew willow used in floral design—are another potential crop, though most woody species in this category would be best suited for planting along the perimeter of a forest farming site. Woody floral shrubs are generally coppiced [cut back to ground level annually] to generate multiple new shoots for harvest each year.

The Future of Forest Farming

Forest farming is not yet a widespread approach to, or component of, forest management, but it has great potential for wider adoption as forest owners look for alternatives to either management of the forest for timber extraction or no management at all. Development of a successful forest farming design should include an integration of the explicit goals of the forest owner with a systematic assessment of both biophysical and anthropogenic characteristics of the site. Ginseng, maple syrup, and forest-cultivated mushrooms have the most reliable track record, and are potentially more profitable than other non-timber forest crops. Others like minor fruits and ornamentals have considerable potential for exploration and development.

Additional Reading


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