# Experimental Design in Agroforestry

Proposal for the Student Farm Initiative
at Penn State University

By Lara Nagle, MSLA ’16 in LArch 510

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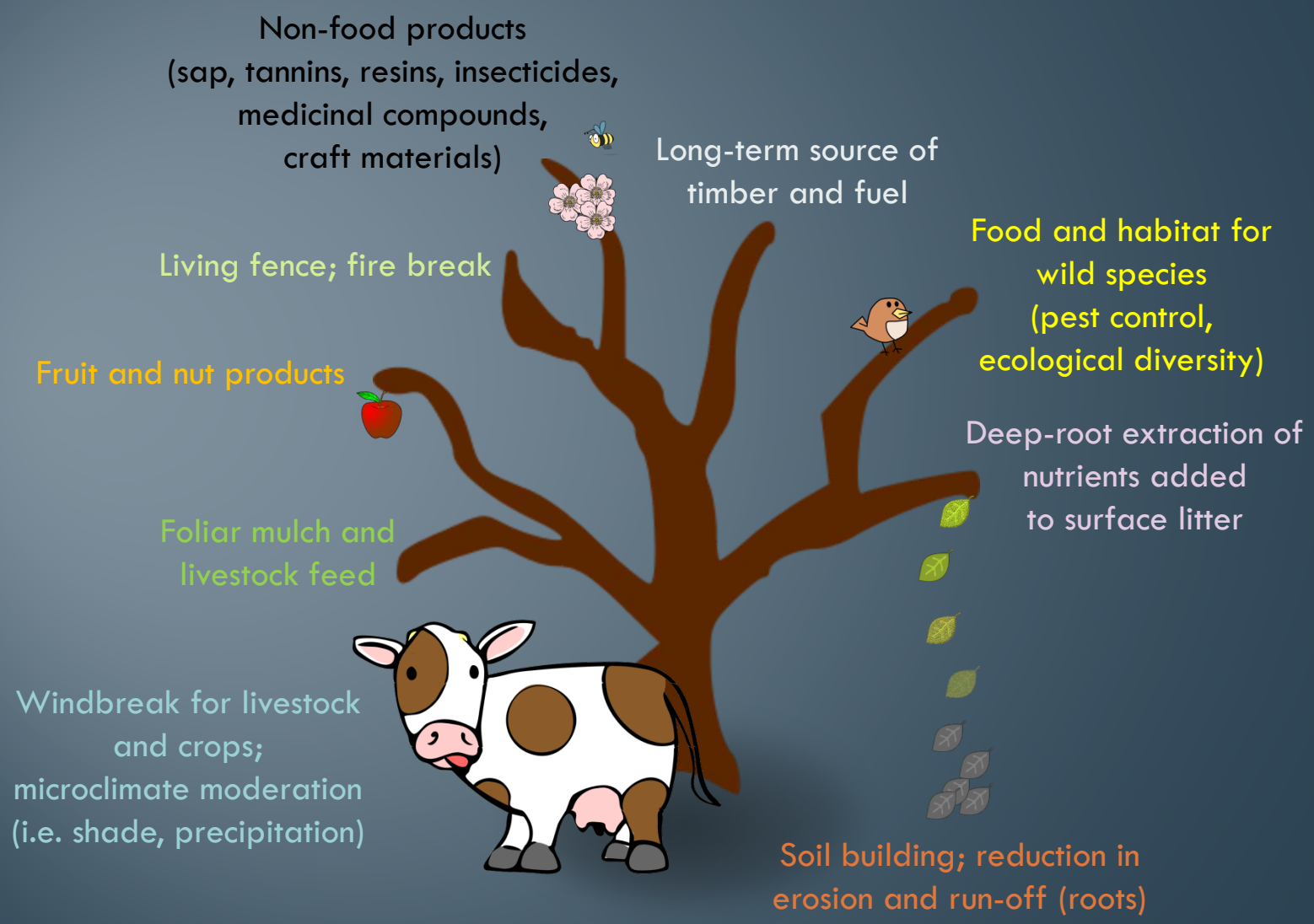
# What is agroforestry?

"The integration of trees, plants, and animals in conservative, long-term, productive systems…" (Martin et al. 1)

<u>A combination of tree crops, non-tree crops, and animals to:</u>

- Diversify production
- Use land more efficiently and holistically
- Create food/habitat for livestock and wild species
- Control run-off and stabilize slopes
- Improve microclimate and visual interest of the landscape
- Condition soils
- Boost productivity (with ideal plant pairings)
- Reduce the need for chemical applications
- Increase the value of a property into the future

# Role of a Tree in Agricultural Landscapes



## Issues

- Too much shade?
- Root competition?
- Extra work? More management?
- Less room for equipment?
- Initial cost too high?
- Livestock damage to trees?
- Need for nurse trees?
- Decreased acreage for cash crops?

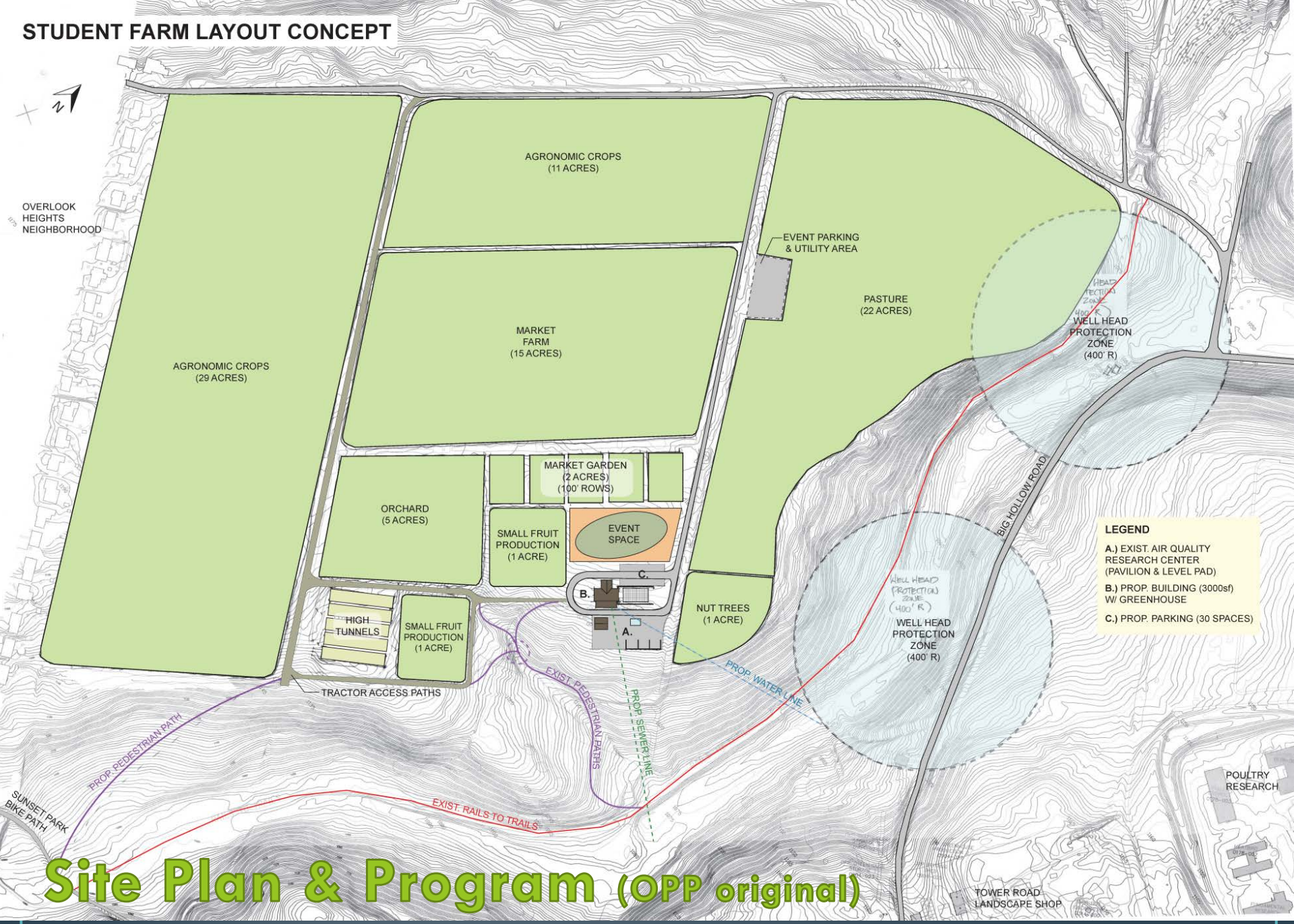
# SFI Opportunities

The student farm at Penn State could showcase sample plots of agroforestry concepts for:

- demonstration (education)
- monitoring (research)
- production (marketing)

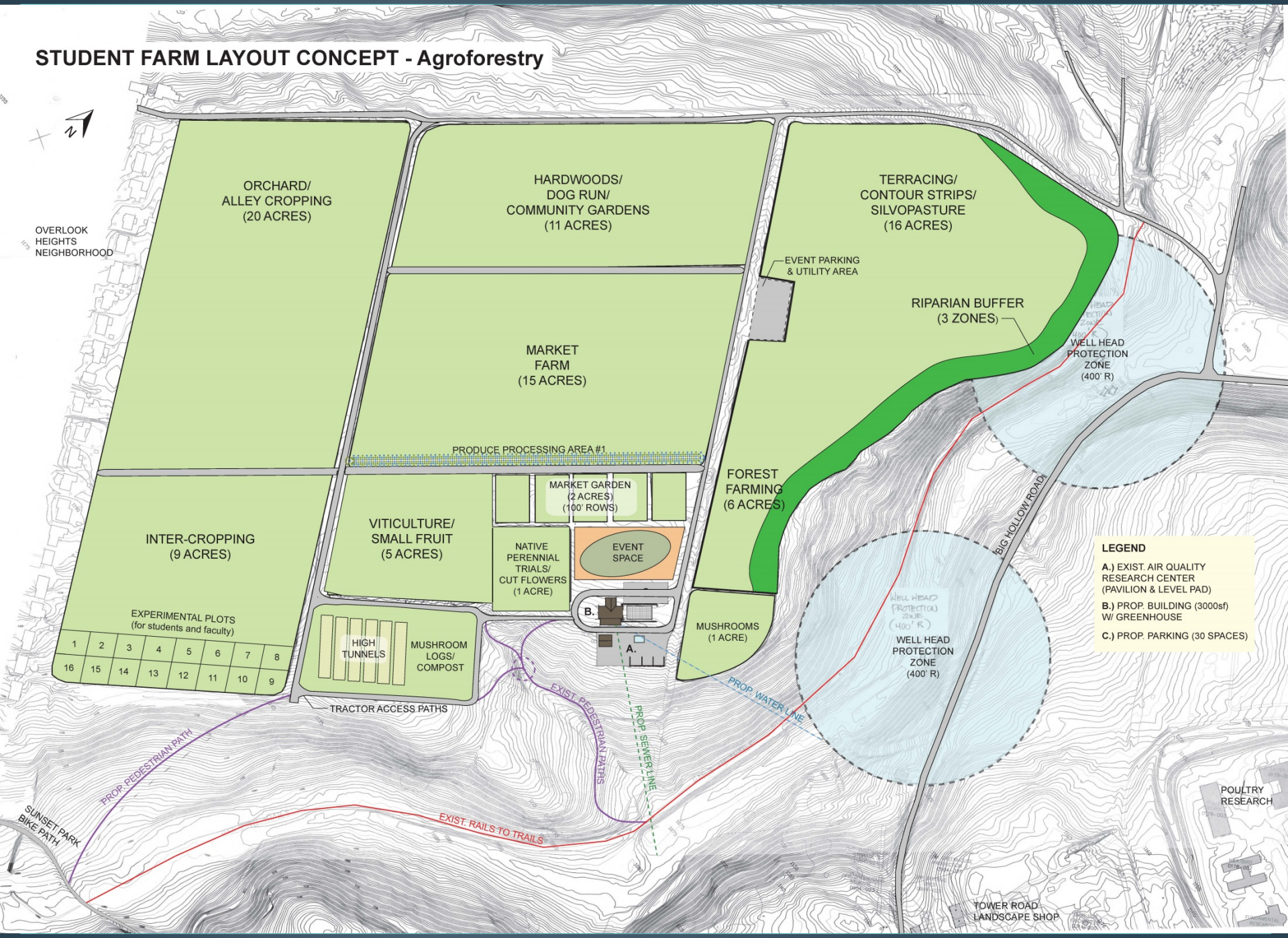
*Example Proposal*

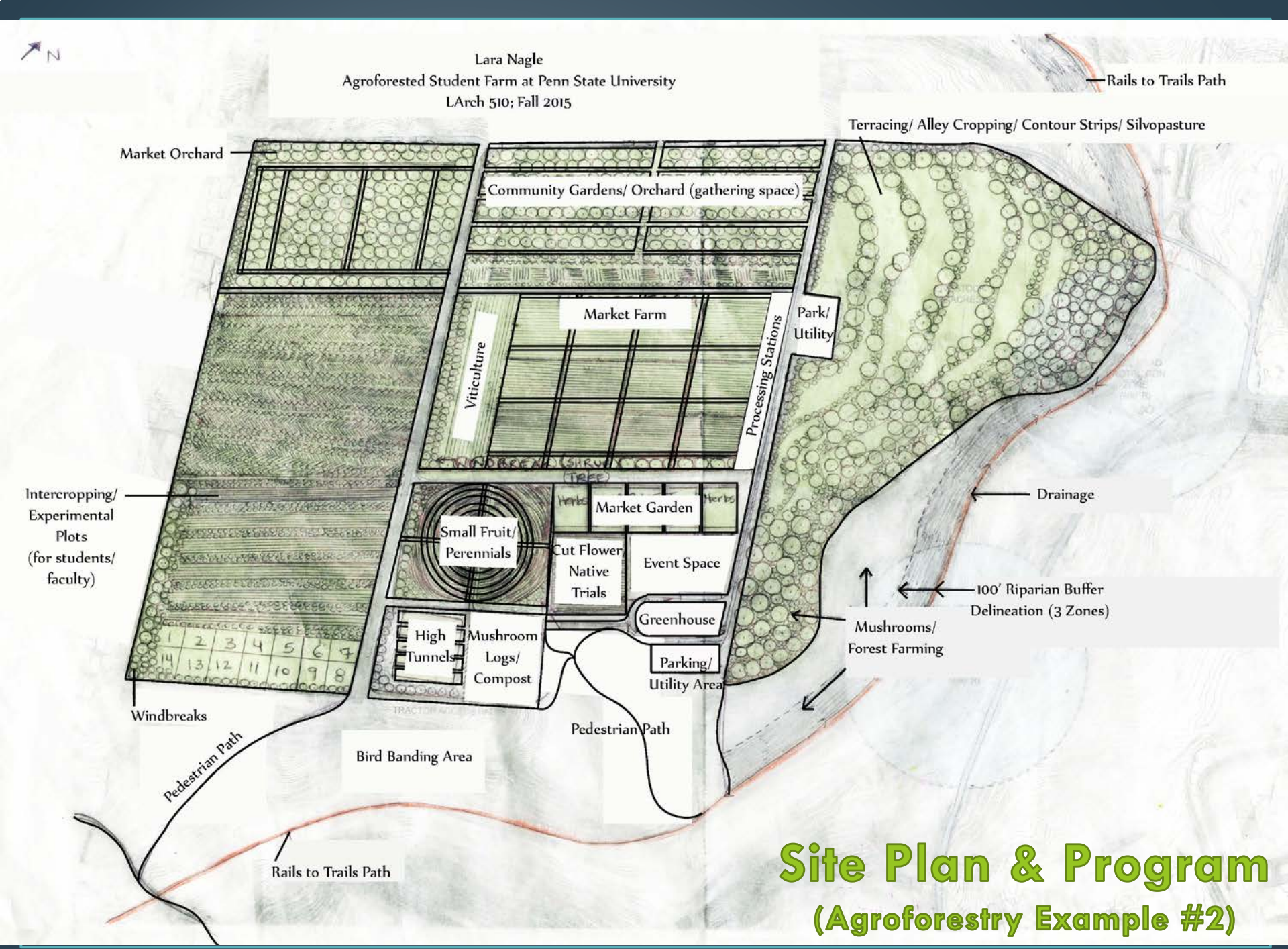
- Site Plan & Program
- Concept Definitions
- Installation & Maintenance by Agroforestry Concept




# Site Plan & Program (OPP original)

# STUDENT FARM LAYOUT CONCEPT - Agroforestry






# Site Plan & Program

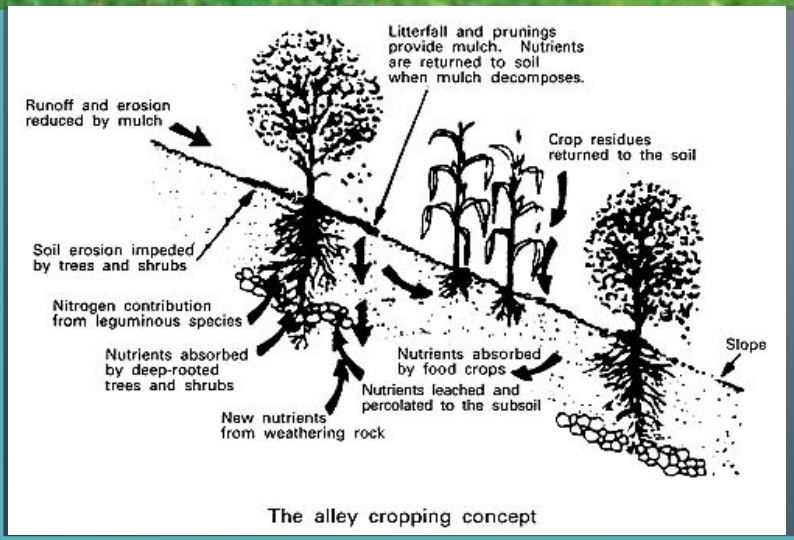
## (Agroforestry Example #2)

# Agroforestry Design Principles

- Alley Cropping
- Inter-Cropping
- Silvopasture
- Riparian & Upland Forest Buffers
- Contour Strips
- Wind Breaks
- Terracing
- Forest Farming

# Alley Cropping

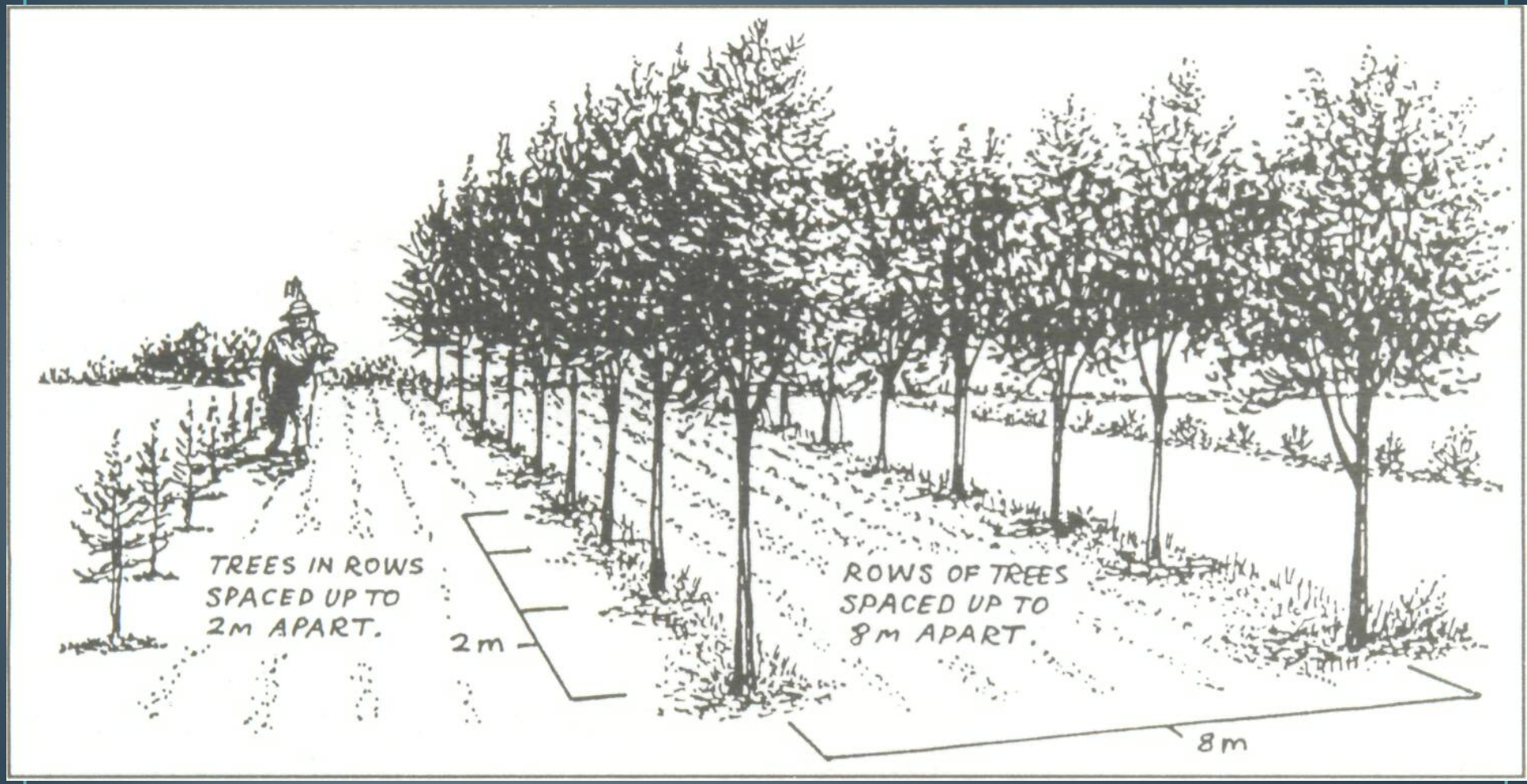
Trees may benefit from nitrogen-fixing crops; some forage crops prefer shade. Provides habitat to break up pest cycles and support local biodiversity.



The alley cropping concept

"Alley cropping is broadly defined as the planting of two or more sets of single or multiple rows of trees or shrubs at wide spacings, creating alleys within which agricultural, horticultural, or forage crops are cultivated. The trees or shrubs may include valuable hardwood species, such as nut trees, or trees desirable for wood products. Shrubs can provide nuts, fruit or other products." (Training Manual for Applied Agroforestry Practices – 2013 Edition)

# ALLEY CROPPING



# Inter-Cropping

Similar to alley cropping, inter-cropping more often involves three or more species in close proximity, creating synergies in performance;

it does not always include tree/shrub species.

Inter-cropping combines companion crops for:

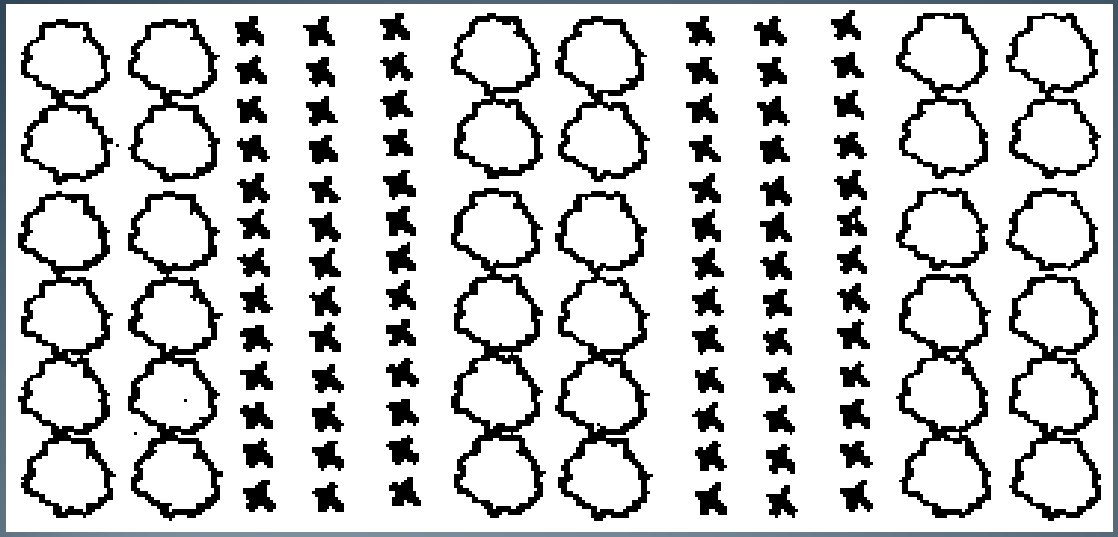
- Soil amendment
- Shade
- Support
- Pest control
- Efficient use of resources, like water and space (shallow-rooted plants with deep-rooted plants can grow in the same place)

<u>EXAMPLE:</u> *Corn* (support for beans), *squash* (shallow-rooted, moisture, mulch, and weed control, prickly texture deters insects) , and *beans* (nitrogen-fixing, stability for the corn).

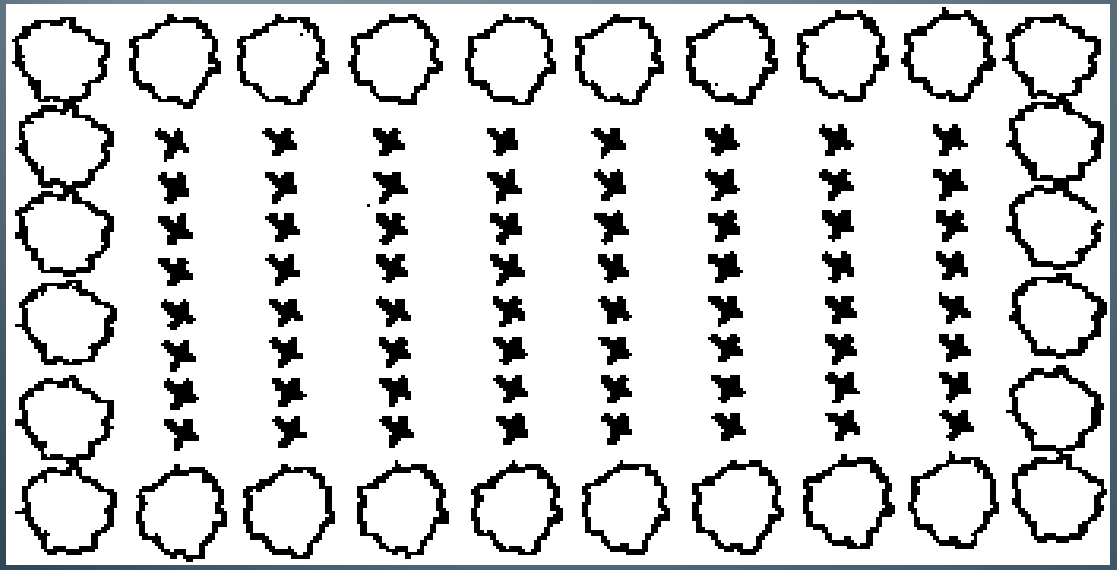
Nutritionally, the three make up a balanced diet as well!

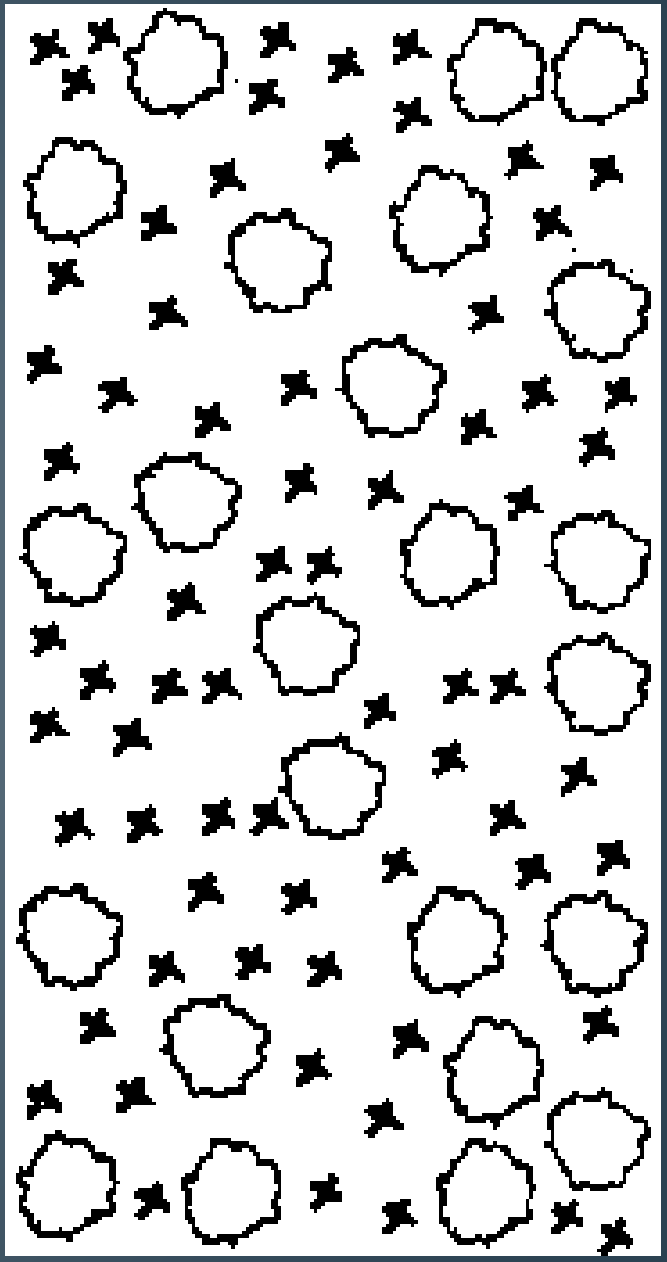
# INTERCROPPING/EXPERIMENTAL PLOTS

| PLANTS | TEACHING & RESEARCH |
| --- | --- |
| A wide variety of plants can be combined in two's, three's, and upwards in number, interspersed among shrubs also commonly found in orchards; or focusing solely on annuals, shade-tolerant plants include: lettuces, chives, carrots, beets, chard, leeks, radishes, and turnips.<br>Sun-loving crops: peppers, tomatoes, corn, beans. Vining crops: squash, cucumbers, peas. Legumes a plus.<br>Companion planting also encourages predator populations that prey on crop pests, and structural support among plants. Example pairings include: tomato, cabbage, and hawthorn; corn, sweet potatoes, and goldenrod; cauliflower and white clover, sorghum and peas; barley and wheat with soybean; rye, alder, sorghum, nasturtium, and wheat with fruit trees; borage and dill with tomato; strawberry and garlic. | • Companion crops<br>• Maximized production with efficient planting patterns<br>• Ecological research frameworks applied to agronomical research<br>• Variations in growing conditions as the sensitive variable with plant mutualisms<br>• Sustainability and efficient resource use<br>• Investigate and reduce impediments to making these practices ubiquitous in American agriculture |



# CROPPING PATTERNS





# Silvopasture

Silvopasture is managed grazing of livestock with intentionally-planted forage and trees.

Benefits include:

- Wind break from trees improves animal health and productivity (moderates extreme weather, like heat and high winds, which stress animals)
- Odor control
- Animal manure fertilizes soil
- Animal feeding reduces weed pressure and root competition
- Habitat connectivity for wildlife

# ORCHARD

| PLANTS | DESIGN | MAINTENANCE SCHEDULE | MARKETING | RESEARCH |
|---|---|---|---|---|
| Apple, pear, plum, peach, berries (raspberries, currants, gooseberries, blackberries, blueberries, strawberries, elderberry, aronia), persimmon, grapes, cherries, pumpkins, winter squash, hops, rhubarb, asparagus; nut trees (hazelnut/filbert, dwarf pines, almonds, Allegheny chinquapin, gingko if regularly pruned, pawpaw, serviceberry). | Clumping or rows of trees interspersed with vining fruits and squashes.<br>Rows should be crown-width wide, plant spacing 5-8' apart.<br>Nut trees need more space.<br>Combine several varieties as separate plants grouped together or several branches grafted to one rootstock. Plant most desired plants first due to establishment lag time. | *Trees:* Annual pruning and training. Adolescent trees may need fencing or protection from wild and domestic grazing pressure.<br>*Crops:* Mechanical or manual removal annually or several times per season. Perennial crops may need periodic pruning, grafting, suckering, or transplanting. Plants may take a few years to establish.<br>Practice IPM. Animals can be used for initial brush clearing (goats), pest management (poultry), and consumption of residual wastes (pigs.) | 1. Calculate value of yield based on seasonal pricing x scale of plot per crop.<br>2. What is the establishment time?<br>3. Are there processing fees?<br>4. What is the cost of labor?<br>5. Where is the market? Will these products sell locally, regionally, or nationally?<br>6. Will this supply support its own market? Can a niche market be created? | • Cultivar selection; hybrids<br>• Stormwater and water filtration capacity<br>• Aboveground and belowground interactions<br>• Measuring levels of biodiversity<br>• IPM and BMPs<br>• Novel plant pairings<br>• Updates in technology (precision canopy, irrigation, etc.)<br>• Variations in design and how this affects productivity<br>• Climate effects |

# ORCHARD YIELDS & SCHEDULE

Approximate crop harvest times and yields for which data was available is shown in Figure 16. Use this information plants to inform decisions on which crops to grow. Harvest labor may be reduced by grouping crops with similar harvest times.

| Form | Common Name | Genus / Species | Hardiness Zones | Crops | Crop Yield Pounds / Plant | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vine | Grape, Fox | Vitis labrusca | 5-8 | Fruit | 12.5 | | | | | | | | | |
| Tree | Apple, Dwarf | Malus spp. | 4-8 | Fruit | 48.0 | | | | | | | | | |
| Tree | Cherry, Sour Dwarf | Prunus cerasus | 4-8 | Fruit | 22.0 | | | | | | | | | |
| Tree | Cherry, Sweet Dwarf | Prunus avium | 5-8 | Fruit | 22.0 | | | | | | | | | |
| Tree | Chestnut, Chinese | Castanea mollissima | 4-8 | Nuts | 30.0 | | | | | | | | | |
| Tree | Crabapple, Siberian | Malus baccata | 3 | Fruit | | | | | | | | | | |
| Tree | Mulberry | Morus spp. | 5-9 | Berries | 17.5 | | | | | | | | | |
| Tree | Pawpaw | Asimina triloba | 4-8 | Fruit | 12.5 | | | | | | | | | |
| Tree | Peach, Dwarf | Prunus persica | 4-8 | Fruit | 57.0 | | | | | | | | | |
| Tree | Pear, Asian | Pyrus pyrifolia | 4-9 | Fruit | | | | | | | | | | |
| Tree | Pear, European Dwarf | Pyrus communis | 4-9 | Fruit | | | | | | | | | | |
| Tree | Persimmon, American | Diospyros virginiana | 5-9 | Fruit | 27.5 | | | | | | | | | |
| Tree | Plum, American Standard | Prunus americana | 3-8 | Fruit | 122.5 | | | | | | | | | |
| Tree | Plum, European Dwarf | Prunus domestica | 4-8 | Fruit | 8.8 | | | | | | | | | |
| Tree | Plum, Japanese | Prunus salicina | 6-10 | Fruit | | | | | | | | | | |
| Tree | Walnut, Black | Juglans nigra | 4-7 | Nuts | 120.0 | | | | | | | | | |
| Shrub | Aronia Berry, Black | Aronia melanocarpa | 3-9 | Berries | | | | | | | | | | |
| Shrub | Beach Plum | Prunus maritima Ecos | 3-6 | Fruit | | | | | | | | | | |
| Shrub | Blueberry, Half-High | Vaccinium spp. | 3-7 | Berries | | | | | | | | | | |
| Shrub | Blueberry, Highbush | Vaccinium corymbosum | 3-7 | Berries | 7.5 | | | | | | | | | |
| Shrub | Blueberry, Lowbush | Vaccinium angustifolium | 2-6 | Berries | 1.9 | | | | | | | | | |
| Shrub | Cherry, Bush | Prunus japonica | 4-8 | Fruit | | | | | | | | | | |
| Shrub | Current, Black | Ribes nigrum | 3-7 | Berries | 10.0 | | | | | | | | | |
| Shrub | Current, Red | Ribes silvestre | 3-7 | Berries | 6.5 | | | | | | | | | |
| Shrub | Elderberry | Sambucus canadensis | 3-10 | Berries | 15.0 | | | | | | | | | |
| Shrub | Gooseberry | Ribes uva-crispa | 3-8 | Berries | 9.0 | | | | | | | | | |
| Shrub | Hazelnut | Corylus americana | 4-9 | Nuts | 22.5 | | | | | | | | | |
| Shrub | Nanking Cherry | Prunus tomentosa | 3-7 | Fruit | | | | | | | | | | |
| Shrub | Raspberry | Rubus ideaus | 4-8 | Berries | | | | | | | | | | |
| Shrub | Saskatoon | Amelanchier alnifolia | 2-7 | Berries | 5.7 | | | | | | | | | |
| Herb | Asparagus | Asparagus officinalis | 2-9 | Shoots | 0.4 | | | | | | | | | |
| Herb | Blackberry, Thornless | Rubus fruticosus | 5-8 | Berries | | | | | | | | | | |
| Herb | Rhubarb | Rheum x cultorum | 1-9 | Stalk | 3.5 | | | | | | | | | |
| Herb | Strawberry, Garden | Fragaria ananassa | 4-9 | Berries | 1.0 | | | | | | | | | |

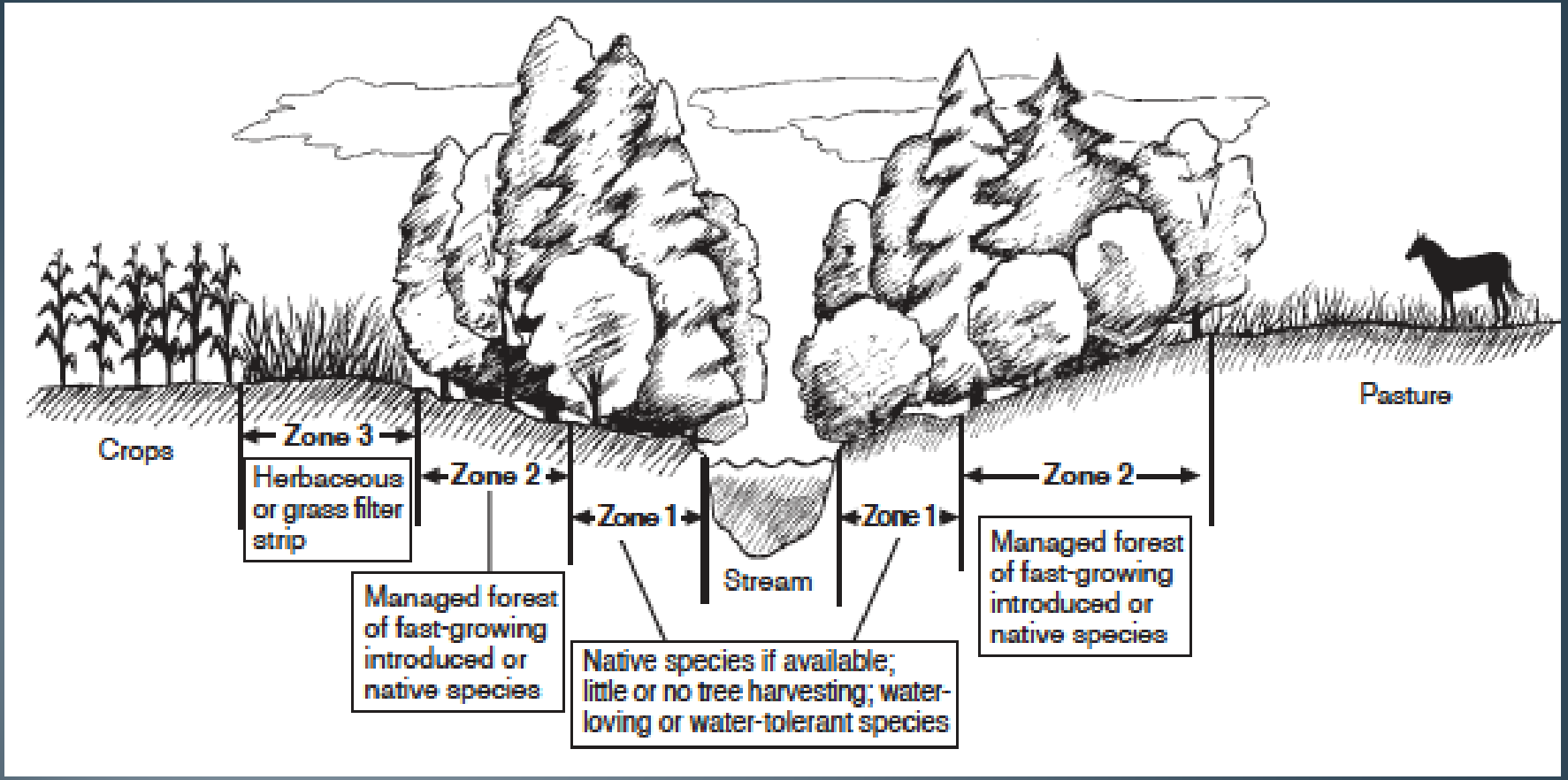
Figure 17. Approximate Crop Yields and Harvest Times

Yields and harvest times may vary greatly based upon site conditions. Estimates are provided from several sources.[19,20,21]

# Riparian and Upland Forest Buffers


## Contour Strips

Plantings along contours and beside waterways help reduce erosion, maximize run-off/water capture, diversify and increase harvest potential, improve riparian and aquatic habitat, and create visual interest and variety.

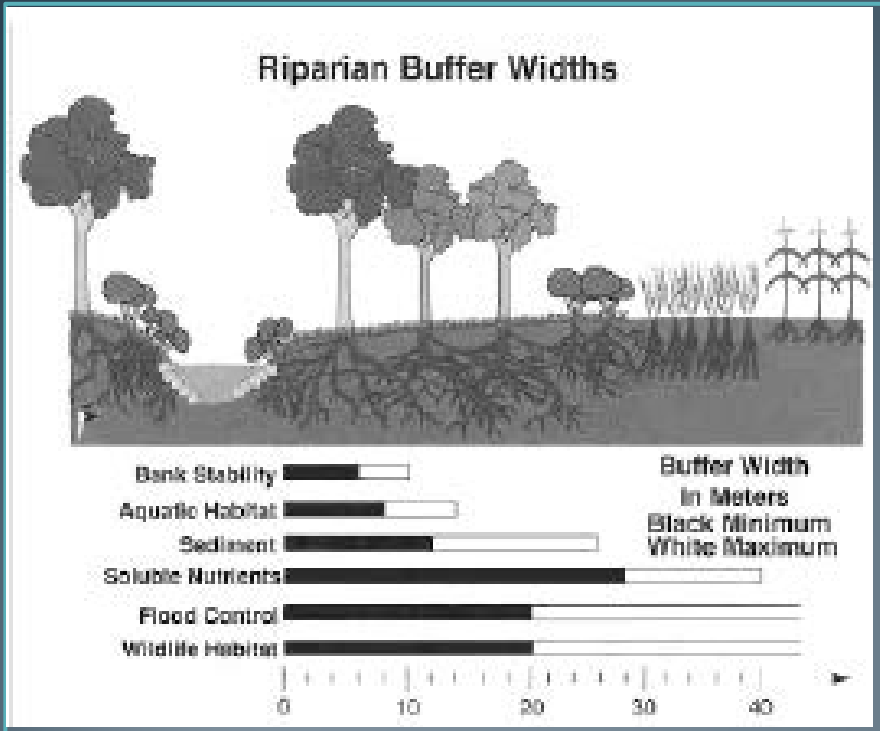



# Riparian Forest Buffer Zones

ZONE 1: Fast-growing woody species along edge of stream enhance aquatic habitat and control flood waters.

ZONE 2: Slower-growing woody species trap non-point source pollution, buffer flood velocity, and trap wastes and debris.

ZONE 3: Edge buffer zone of grasses and forbs slow run-off and capture first flush of chemicals and nutrients.



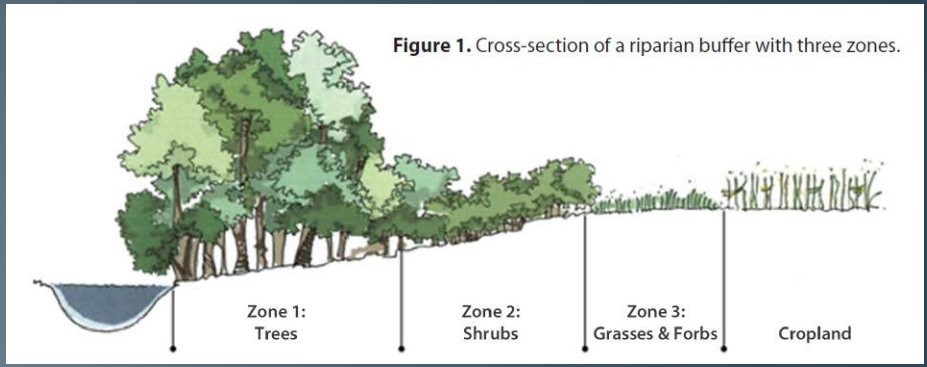




**Figure 1.** Cross-section of a riparian buffer with three zones.

**Table 2.** Vegetation effectiveness for select buffer benefits.

| Benefit | Vegetation Type: Trees | Vegetation Type: Shrubs | Vegetation Type: Grasses |
|---|---|---|---|
| Streambank stabilization | High | High | Low |
| Filtering sediment | Low | Low | High |
| Filtering nutrients, pesticides, pathogens | Moderate | Low | Moderate |
| Improving aquatic habitat | High | Moderate | Low |
| Improving forest habitat | High | Moderate | Low |
| Improving field (pasture) habitat | Low | Moderate | High |
| Flood protection | High | Moderate | Low |
| Visual diversity | High | Moderate | Low |

Low
Moderate
High

# RIPARIAN BUFFER ZONES

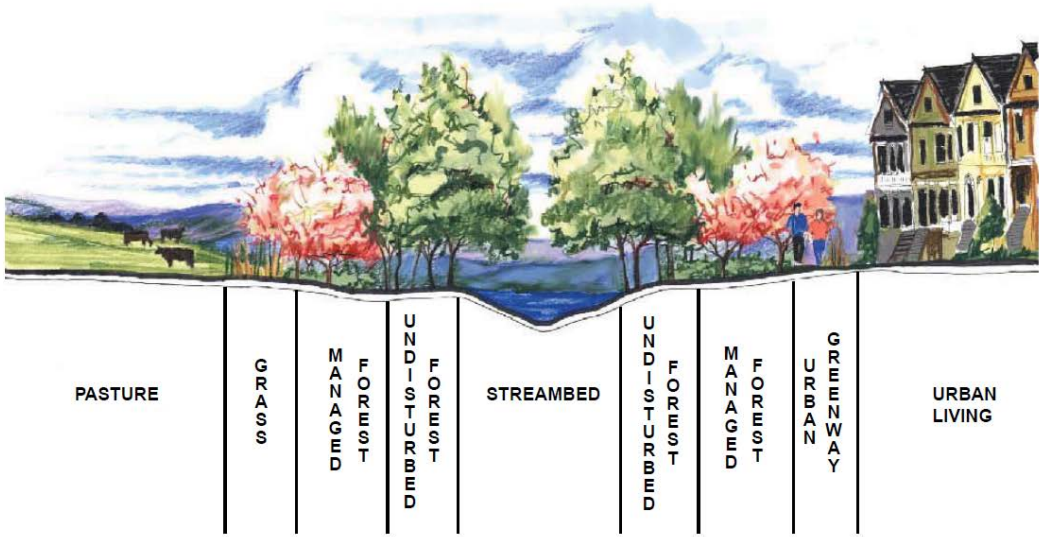



Figure 4. An example of an urban buffer.

| Program | Oversight |
|---|---|
| Conservation Reserve Enhancement Program (CREP) | USDA – Farm Service Agency (FSA) |
| Wetland Reserve Program (WRP) | USDA – Natural Resources Conservation Service (NRCS) |
| Conservation Reserve Program (CRP) | |
| Environmental Quality Incentives Program (EQIP) | USDA – Natural Resources Conservation Service (NRCS) |
| Wildlife Habitat Incentives Program (WHIP) | USDA – Natural Resources Conservation Service (NRCS) |

## Checklist for Riparian Buffer Success

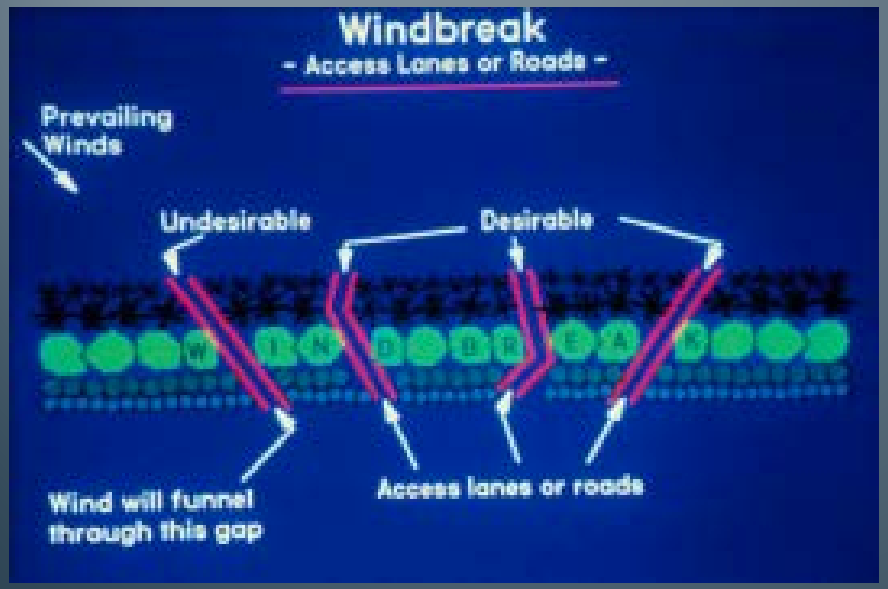
- ✓ *Establish objectives*
- ✓ *Site analysis*
- ✓ *Choose correct buffer type*
- ✓ *Select proper vegetation types*
- ✓ *Perform site preparation*
- ✓ *Quality planting job*
- ✓ *Post-establishment operations*
- ✓ *Evaluation and maintenance*

# RIPARIAN BUFFER ZONES

| Zones 1&3 PLANTS | Zone 2 PLANTS | TEACHING & RESEARCH |
|---|---|---|
| **Zone 1:** Red osier dogwood (craft), mockorange/syringa (flower), *Cornus mas* (food), *Ribes* (food/medicinal), *Rosa palustris* (food, medicinal, flowers), *Salix discolor* (flower, craft), *Salix nigra* (medicinal, craft, nectar), *Cercis canadensis* (food, medicinal), *Cephalanthus occidentalis* (craft, nectar), *Liriodendron tulipifera* (wood products, nectar), *Lindera benzoin* (craft, aromatic).<br>**Zone 3:** Big and little bluestem, *Tripsacum dactyloides, Echinacea, Lobelia* (*siphilitica* and *cardinalis*), *Aster*, *Asclepias, Solidago, Ratibida pinnata*, *Eupatorium fistulosum, Panicum* sp. (if controlled for biofuel), *Chasmanthium latifolium*. | **Zone 2:** Chokecherry (food), sumac (craft, tea), willow (craft), *Sambucus* (food), *Sherpedia* canadensis (food), potentilla (animal feed/medicinal), *Populus tremuloides* (wood products), pawpaw (food), *Diospyros virginiana* (food), *Morus rubra* (food), *Amelanchier* (food), *Rubus* (food), *Prunus americana* (food), *Corylus americana* (food), *Callicarpa americana* (insect repellant/medicinal), *Calycanthus floridus* (flowers), *Viburnum prunifolium* (food, extract), *Cephalanthus occidentalis*. | • Demonstration riparian buffer plantings for residential and agricultural property owners and land managers.<br>• How does planting regime affect overall production, ease of maintenance, and financial return?<br>• Rates of sediment and run-off capture based on varying widths/types of plants in each zone, including how different cultivars perform.<br>• Establishment methods<br>• Biofuel production<br>• Wildlife studies<br>• Covering costs, grant programs, and requirements to install a riparian buffer. |

# Wind Breaks

- Particulate capture
- Sound, odor, & climate buffer
- Wildlife corridor
- Reduce water and soil erosion
- Increase crop yields
- Improve irrigation efficiency
- Visual screen
- Protect built structures




# Terracing

Grading earthen shelves and clumping vegetation to create ledges helps to:

- Control erosion and stormwater
- Increase the productivity and accessibility of steep slopes
- Stagger plantings by height, light, and water requirements
- Optimally trap nutrients in the planting beds
- Provide variation in habitat; good for wildlife diversity
- Fix nitrogen and build up soil, depending on planting choices

# TERRACING/ ALLEY CROPPING/SILVOPASTURE

| PLANTS | DESIGN | MAINTENANCE SCHEDULE | MARKETING | RESEARCH |
|---|---|---|---|---|
| *Trees:* Maple, oak, walnut, cherry, pecan, basswood, sassafras, sweetgum, hackberry, yellow birch, sycamore. *Crops:* Corn, soybeans, alfalfa, sugar beets, wheat and other grains, legumes, tubers, biofuels (switchgrass, alder, willow). | *Trees:* Planted on the contour or perpendicular to high winds; in clumps or rows with nurse trees. Row spacing determined by size of equipment, plant growth habits, and whether single/double rows. Interior species must grow taller and faster than exterior species. Nut trees need more space. *Crops:* Sun-loving crops can be grown 5-10 years in 60' wide alleys; up to 20 years in 80-120' alleys. | *Trees:* Annual pruning, training, lateral root ripping. Perennial harvest of tree parts once established. Heartwood harvest depends on age till maturity per species. Adolescent trees may need fencing or protection from wild and domestic grazing pressure. *Crops:* Mechanical or manual removal annually or several times per season. Perennial crops may need periodic burning, cutting, or re-seeding for enhanced growth. *Seasonal Techniques:* Crop rotation; tillage and aeration to prevent reduced productivity due to compaction; weeding, fertilizing, incorporating residuals, and other soil building methods. | 1. Calculate seasonal prices for lumber and wood products x scale of plot;<br>2. Calculate seasonal prices for ground crops x scale of plot.<br>3. Are there processing fees?<br>4. What is the cost of labor?<br>5. Where is the market? Will these products sell locally, regionally, or nationally?<br>6. Will this supply support its own market? Can a niche market be created? | • Cultivar selection; hybrids<br>• Stormwater and water filtration capacity<br>• Biomass options<br>• Aboveground interactions<br>• Belowground interactions<br>• Measuring levels of biodiversity<br>• Technology and socio-economic relationships<br>• Novel plant pairings<br>• Effects of various management practices on plant productivity<br>• Slope severity |

# Forest Farming

"Non-timber forest crops, like those covered in the practice of forest farming, are a potential incentive to support good forestry practices." (Gabriel)

Forest farming is the intentional cultivation of forest crops under existing forest canopy, whereas forest gardening is mimicking forest growth and function when gardening.

# FOREST FARMING/MUSHROOMS

| PLANTS | DESIGN | MARKETING | TEACHING/RESEARCH |
|---|---|---|---|
| Understory plants include Goldenseal, Ginseng, Ramps, Nettles, Fiddleheads, anise hyssop, purple coneflower, cohosh, false unicorn root, comfrey, rhubarb, Dutch white clover, garden strawberry, yarrow, milkweed; Possible mushrooms, whether natural or inoculated in organic material: shiitake, oyster. Higher risk: Lions Mane, Maitake, Morels, Truffles. (tie to Brodie Pomper's mushroom proposal) | Some forest herbs require unique fungal associations to grow. Mushroom compost options: hay/wheat straw with animal manure, conditioning agent (gypsum) plus nitrogen, fresh oak logs, oak woodchips, moistened or placed low on the ground in the shade. Inoculated holes should be sealed with wax to prevent contamination from other fungi, and to remain moist. | Mushrooms, particularly difficult-to-cultivate varieties, can be a lucrative investment, as well as ginseng, goldenseal, and other medicinal herbs that sell at high price/lb rates. More unusual plants, such as fiddleheads and yarrow, may sell in niche markets. Identifying a market prior to cultivating any of these plants is recommended. | • Consumer acceptance and use of forest herbs<br>• Expanding farmed varieties of mushroom<br>• BMP's and optimal growing conditions<br>• Mycorrhizal symbionts with forest herbs<br>• Efficacy and ease of use of different mushroom production methods and cultures<br>• Biological controls for forest herb and mushroom pests<br>• Re-use of agricultural bi-products<br>• Sustainability of forest herb production, certification programs (PCO verified) |

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