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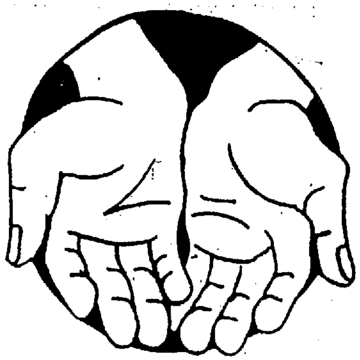
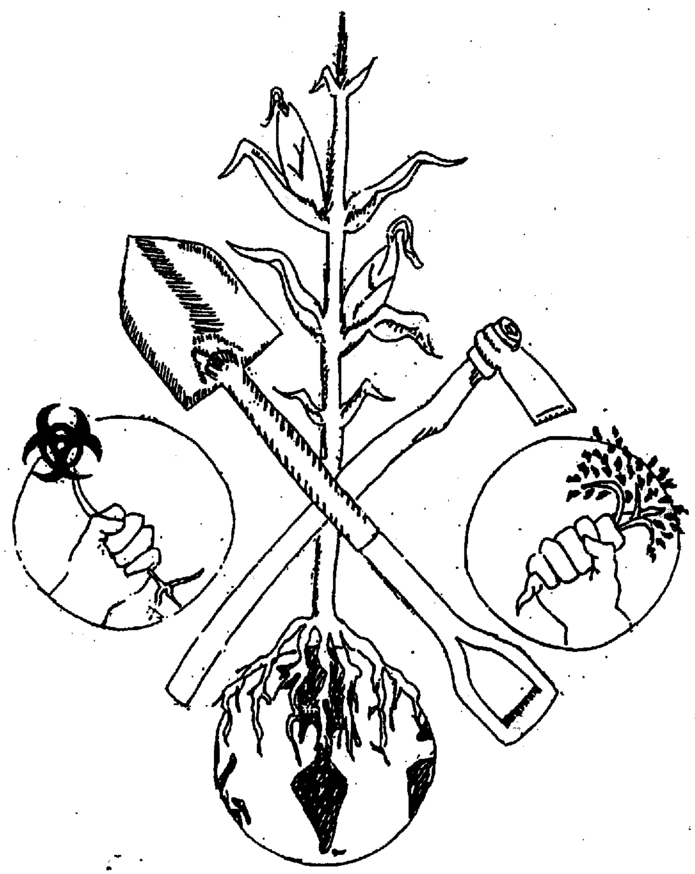


GUERRILLA GARDENING

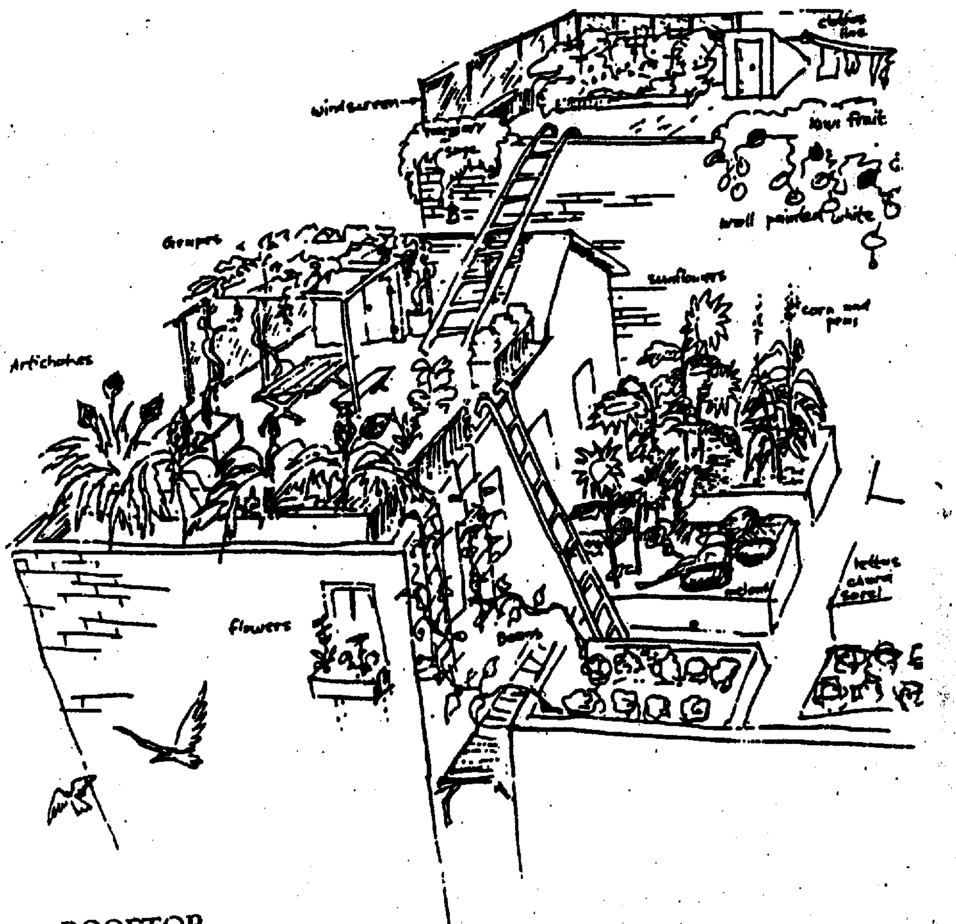


URBAN PERMACULTURE

A Reader Compiled for the DIY Skillshare

CUT + PASTED BY CLEA + SASCHA

MAY 2000, OAKLAND, CA.



ROOFTOP
GARDENS

Blackberry	Lupin
Black currant	Mesquites
Apricot	Mints
Black locust	Borage
Leatherwood	Cherry plum
Clover	Comfrey
Peach	Dandelion
Pear	Tagasaste
Raspberry	Gooseberry
Rosemary	Citrus spp.
Sage	Hawthorn
Sloe	Hyssop
Sour cherry	Laurelberry
Pride of Madeira	Some Eucalypts
Osier willow (& other willows)	

Table 16. Species for Very Dry Sites

Almond	Mesquites
Black locust	Mulberry
Burr oak	Olive
Carob	New Zealand spinach
Cork oak	Pampas grass
Tagasaste	Prickly pear
Many *Acacia* spp.	*Pistachio
Pomegranate	Jujube
Fig	Quandong
Holm oak	Rosemary
Honey locust	Stone pine
Lavender	Taupata
Most aromatic herbs	

Table 17. Legumes & Other Nitrogen-fixing Plants
The trees can be coppiced for green manuring and animal fodder. * denotes non-legume nitrogen-fixer.

<u>A. Temperate</u>
<u>Trees</u>

Tagasaste	Black locust
Autumn olive	Russian olive
*Alder	Siberian pea shrub
Albizia	*Ceanothus
Tree medic	

<u>Small species</u>

Azolla (aquatic)	Fenugreek
Clover	Lucerne
Beans & peas	Vetch
Lupin	Lespedeza

<u>B. Warm/dry climates</u>
<u>Trees</u>

Mesquite	Acacias
Tagasaste	Albizia
Casuarina	

C. Tropics/Subtropics
Trees

Acacias	Albizia
Gliricidia	Calliandra
Leucaena	Sesbania
Pongamia	Tamarind
Cassia	Ice cream bean tree
Tipuana tipu	

Small species

Pigeon pea	Lab lab bean
Winged bean	Peanut
Beans & peas	Clover
Lucerne	

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URBAN PERMACULTURE TABLE OF CONTENTS

Can't Hang with the Monocult - Lessons in the Forest
Kickin it on the Farm - Month Seven

I'm sitting under a huge cedar tree on a thick cushion of moss and needles and decomposing wood, it's early Saturday afternoon, and I'm in the middle of the forest across the lake from the farm. I've been working clearing trails in the park here for the past bunch of hours, cutting back sollal roots and pulling up ferns; now I'm watching the squirrels run across the upper story of the trees and resting my sore arms in the shade, feeling sweat beading down my neck, listening to the sound of my breath and the birds chirping and the wind blowing across the lake. I'm about at fern level, looking straight up into the crisscrossing network of spirals and whirls of tree branches, light flickering through the patterns of needles and swirls. The soil under the cedar needles I'm resting on is thick and black, held together with decomposing organic matter - constantly in flux and full of life. It's all mulched under a carpet of the tree's energy - breaking down and building up and breaking back down again - slowly getting taller and deeper - holding the energy in and letting it go little by little over time. Life in this forest is an endless flow of producing, consuming, and decomposing. The tree I'm sitting under sheds it's weight and builds the soil it stands in. The old growth fir trees stumps everywhere that were hand-logged back in the 1920's have giant new hemlocks growing out of them - the new trees taking advantage of the old root systems carved through the soil and rock.

Here in the forest, everything is connected up and down and underground - from the smallest microbe fixing nitrogen in the soil to the cougar catching a deer for its dinner on the edge of the bluff. There are a lot of important lessons to learn out here.

The Backdrop:

So while most of my friends are back in the city somewhere cultivating their stress and balancing activism and computer temp jobs or scamming their way along the trainlines and supermarket dumpsters of America, this urban kid has been learning how to grow food and living at a farm near the edge of the forest on a tiny island in British Columbia for the past half a year.

Here's my routine: I wake up in the morning with the sun and write down my crazy dreams, slip out of the house and feed the pigs, water the greenhouse full of tomatoes and peppers, tend to my little broccoli transplants which are just starting to make heads for Fall, maybe jump in the lake if it's not to chilly. Usually after breakfast, me and the rest of the crew head out to the production garden and harvest corn and beans and squash and carrots and eggplants and leeks and beets and lettuce and tomatoes and zucchini and basil. We work on building compost or building fences or slowing down erosion in the creek that feeds into the lake by our house. A couple times a week we'll have a discussion group kind of class on soil chemistry or composting toilets or land trusting. A couple of us are building a seed bank and networking with a bunch of local farmers and seed companies and exchanges.

Hickories	Acacias
*Ice cream bean	*Leucaena
*Pigeon pea	Amaranth
Quinoa	*Sesbania
*Winged bean	Carob

B. Foliage

Bamboo	Lespedeza
Chicory	Lucerne
Comfrey	Lupin
Tagasaste	Pampas grass
Sunroot	*Vigna* spp.
*Lab-lab bean	*Leucaena
Tree medic	*Pigeon pea
*Sesbania	Taupata
Willow	Kurrajong
*Winged bean	Dandelion
Choko/chayote	

D. Roots, tubers, rhizomes

* Arracacha	*Yam beans
Sunroot	Chickory
*Yam	Choko
Comfrey	Sweet potato
Arrowhead, duck potato	
*Queensland arrowroot	

Table 7. Edible Flowers For Salads

Daylily	Borage
Calendula	Feijoa
Black locust	Nasturtium
*Sesbania	Dandelion
Salsify	Sweet violet
Zucchini	*Winged bean
Rose (*Rosa rugosa, R. canina*)	

Table 8. Hedge Plants

Taupata	Some clumping bamboos
Alder	Hawthorn
Hazel	Russian olive
Autumn olive	Elderberry
Laurelberry	Pampas grass
Coprosma	*Queensland arrowroot
Pomegranate (closely-spaced; clipped)	
Some *Prunus* spp. (Damson plum, sour cherry)	

Table 9. Animal Barrier Plants
(Spiny or unpalatable dense thickets)

Euphorbia spp.	Hawthorn
Gorse	Sloe
Honey locust	Natal plum
Prickly pear cactus & other cactus spp	

Table 10. Useful Perennial Vines

A. Deciduous

Grape	Wisteria
Kiwifruit	Scarlet runner bean
Scarlet trumpet vine	*Yam beans
Virginia creeper	

B. Evergreen

*Passionfruit	Choko/chayote
*Vanilla	*Lab-lab bean
Jasmine	Ivy

Table 11. Pest Control Plants

*Sunn hemp (nematodes)
Marigold (*Tagetes* spp.) nematodes
Pyrethrum daisy (broad spectrum insecticide)
White cedar and neem tree (insecticide)
Tobacco (insecticide)
Derris root (*Derris elliptica*)
Rhubarb (insecticide)

Table 12. Umbelliferous Plants

Celery	Angelica
Florence fennel	Parsley
Dill	Chervil
Lovage	Queen Anne's lace
Caraway	Coriander
Fennel	Cumin
Anise	Sweet cicely
Parsnip	Carrot

Table 13. Composite Plants

Tarragon	Southernwood
Tansy	Chamomile
Wormwood	Daisies
Artichoke	Salsify
Sunroot	Sunflower

Table 14. Water or Wetland Plants

Azolla	Rush (*Scirpus* spp.)
Watercress	Water chestnut
Mint	*Kang kong
Water lily	*Lotus
Wild rice	Rice
Duckweed	Duck potato (arrowhead)
Willows	Cranberry
Highbush cranberry	
Cumbungi or cattail	
Reed (*Phragmites* spp.)	

Table 15. Bee Forage

Almond	Lavender
Apple	Loganberry
Bergamot	Lucerne/alfalfa

Appendix B

SPECIES LISTS IN USEFUL CATEGORIES

The following are lists of useful permaculture categories, with no attempt to describe particular plants. Some of those listed can be found in Appendix; others are so common as to need no description. Asterisk (*) marks tropical/subtropical species.

Table 1: Plants with Food Products from Roots, Tubers, or Shoots

*Arracacha	Asparagus
Bamboos	Beet
*Cassava	Carrot
Celeriac	Chicory
Choko	Dandelion
*Yam beans	Onion
Parsnip	Radish
Sunroot	Potato
*Taro	Turnip
Salsify	*Queensland arrowroot
Peanut	Scarlet runner bean
Duck potato (USA)	

Table 2: Plants Giving Storable Food Products

A. Nuts

Almond	Black walnut
Walnut	*Bunya pine
Butternut	Chestnut
Filbert, hazel	*Macadamia
Ginkgo	Pecan
*Pistachio	Oaks
Stone pine & other pine nuts	

B. Fruits (suitable for local drying & storing)

Apple	Apricot
Fig	Jujube
Peach	Prune plum
Cherry	Pear
*Mango	*Pineapple
*Banana (some small varieties)	
Grape (some raisin varieties)	

C. Flours and meals

Carob	Honey locust
Sweet chestnut	White mulberry
Pigeon pea	
*Indian water chestnut	
*Queensland arrowroot	

D. Cooking and salad oils

Almond	Beech	
Hazel	Olive	
Live oak	Walnut	
Mustard	Grapeseed	
Safflower	Rape	Sunflower

Table 3: Fresh Fruits

A. Temperate

Alpine strawberry	Loquat
Apple	Medlar
Apricot	Mulberry
Blueberry	Nectarine
Cape gooseberry	Peach
Checker berry	Pear
Kiwifruit	Persimmon
Feijoa	Plum
Fig	Grape
Strawberry	Grapefruit
Strawberry guava	Jujube
Cherry	Tamarillo
Berries (black, logan, boysen, red)	
Banana passionfruit	Black, red currants

B. Subtropical/tropical

Mango	Jakfruit
Guava	Rambutan
Carambola	Mangosteen
Lychee	Naranjilla
Sapote	Jaboticaba
Mammey sapote	Pepino
Papaya	Custard apple
Prickly pear	Natal plum
Granadilla	Pineapple
Passionfruit	Citrus spp.

Table 4. Fruit Used in Cooking, Preserves, Wine

Cranberry	Elderberry
Quince	Huckleberry
Cornelian cherry	Barberry
Pomegranate	Cumquat

Table 5. Fruit High in Vitamin C

*Barbados cherry	Citrus
Rose (*Rosa rugosa*)	*Rosella
*Guava	

Table 6. Animal Forages and Feeds

A. Nuts, pods, seeds

Almond	Mesquites
Beech	Taupata
Oaks	Siberian pea shrub
Honey locust	Tagasaste
Hazel	Walnut

All my housemates are really busy with projects: canning tomatoes, cooking jam, drying plums, threshing amaranth and quinoa and beans, making pesto and tending to the berry wine. Our eight month sustainable agriculture program ends in six weeks and we're all planning our futures, heading off in different directions ready to take on the world with all this knowledge in our hands and arms and minds.

My days are really full and completely revolve around food - sowing it, tending to it, talking about it, studying it, harvesting it, processing it, eating it. I've been t-bud grafting fruit trees and rooting semi-hardwood cuttings of shrubs and trees in tins of wet sand, saving tons of different kinds of vegetable and flower and herb seed, staying up late at night reading drip irrigation and biofertilizer and plant propagation textbooks. I swear it's so magical - like casting spells - getting the timing down and mixing up the right amounts of soil and seeds and water and sun and - poof! - it all starts growing.

Reclaiming Lost Knowledge

What's incredible is that people aren't learning these skills anymore - food cultivation and land stewardship are rapidly becoming lost arts. Not so many generations back most of our families were providing their own food in one way or another. Our grandmothers had fruit trees in their backyards, our grampas would catch their own fish, people would save their own seed and grow the same tomatoes their gramparents had grown. We lived in tighter communities with more localized economies and had a closer connection to the land we lived on and the people around us.

Now a couple multinational chemical companies own most of the crop seeds in the world and genetically alter our food to be dependent on their fertilizers and herbicides. We grow our food on huge tracks of monocropped land and transport it all over the place in monster trucks and buy it wrapped up in plastic from nightmarish superstores. We've sprawled out of our cities in strangleholds of highway and covered up our best agricultural soil with cancerous growths of suburban development and industrial parks. Our economy is based on an infinite growth model that doesn't factor in our limited natural resources or peoples' livelihoods and happiness. The rivers are full of toxic waste and there's a law against fruit trees in my home town because the fruit might fall on peoples' cars. Kids like me grow up in big apartment buildings totally alienated and clueless and never knowing where our food really comes from or how anything really works.

When I listen to the news on the radio full of war and catastrophe and stock market bullshit, I take comfort in the fact that the skills I'm learning will never become outdated. No matter what I end up doing I will never be downsized and replaced by a machine. I'm going to spend the rest of my life helping to clean up the mess the corporations have created in all their greed and shortsightedness. And just like the rest of the people I work with everyday, I'm just going to get better at all of this stuff as the years go on. Anyone can learn how to grow food and take care of themselves and the world around them. What follows are some rough notes about some of the stuff we've been learning out here.

Straight Up Permaculture

Everything we do on the farm is somehow mimicking things that happen out in nature. The principles and forces at play out in the forest are the same ones we use to design our fields and gardens and homes and lives. Where I've been living is like a big experiment in organic development and sustainability. Instead of acres of tractor tilled monocrops full of pesticides and herbicides and fungicides and factory buildings pumping out mutated cows and chickens, we have an organic vegetable gardens and happy animals and what we call little patches of permaculture scattered throughout the farm.

Energy Cycling

In the forest water falls from the sky, soaks into the soil, moves through the soil and across the land, rises up in the stems of trees, and returns to the atmosphere. The same way the trees in the forest hold onto water, use it, then let it back out - we try to turn flows of nutrients and energy (sun, water, wind, organic wastes) through our farm into cycles.

We have a pipe which runs from our water source (a spring) up in the hills and intercepts the flow before it runs down the creek and into our lake. Our pipe connects down to a big ferrocement tank at the top of a bluff which connects to a number of other pipes which carry water down to our houses and fields. The idea is to catch, store, and use all of our resources before they run off the property. Recycling kitchen waste into compost, channeling household greywater into the garden, raking leaves up around trees as mulch - those are all different ways of energy cycling. Rather than using expensive, complex machinery which need petroleum and random parts from the other side of the world, we use hand tools like scythes, wheelbarrows, forks, and spades. The energy we expend out in the fields goes into our food cultivation, then we eat the food and the cycle starts all over again.

The idea is to create a closed circle where we feed ourselves and don't have to be dependent on the global market for our survival. The idea of localized economy is based on the same principle - supporting your friends and regional community and keeping the trade flowing in a circle. Buying from the neighborhood family market rather than the megamall - supporting local businesses rather than giving it to people who already have plenty of money and live really far away from you in fancy houses somewhere.

Accelerated succession - pioneers and climax species.

The forest develops and changes over time, always giving rise to a new succession of different species. Each stage creates the right conditions for the next stage. When the trees get cut down on this land, the first thing that happens is the alders grow. There are patches of alder all over this forest from where the old trees have been clearcut. Alder is a pioneer species. Their roots fix nitrogen in the ground and build up the soil for the next generation to come along. As the rest of the flora and fauna develop around them in layers of vines and shrubs and ground cover, the cedar and fir slowly begin growing again. Eventually the alder fall and break back down into soil, shaded out by the climax species cedar and fir.

water-loving. Mostly temperate climate. Easily propagated from stem cuttings. May become naturalised or rampant, especially along streams.

USES: *Salix viminalis* (osier willow) and other species used for basketry. Long 1-2 year old shoots are cut from pollarded willow stumps, or from thickets of willow stems (trunk cut at ground level). *S. matsudana* is used in New Zealand for erosion control. Weeping and pussy willows (*S. discolor*), among others, are excellent bee forages. Willows are fire retardants (steam rather than burn). *S. matsudana* var. *Tortuosa* has lush foliage for emergency sheep and deer fodder during drought; one hectare of willows can maintain 1000 sheep for 6 days (data from *Agroforestry in Australia and New Zealand*).

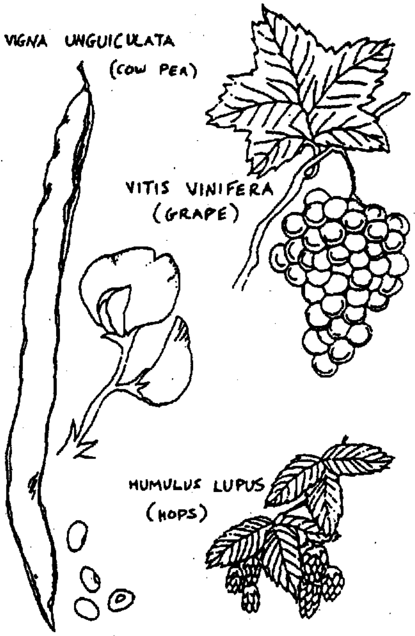
WINGED BEAN (*Psophocarpus tetragonolobus*)
Leguminous, twining vine, growing to over 3m when supported. Valuable, nutritious tropical garden bean.

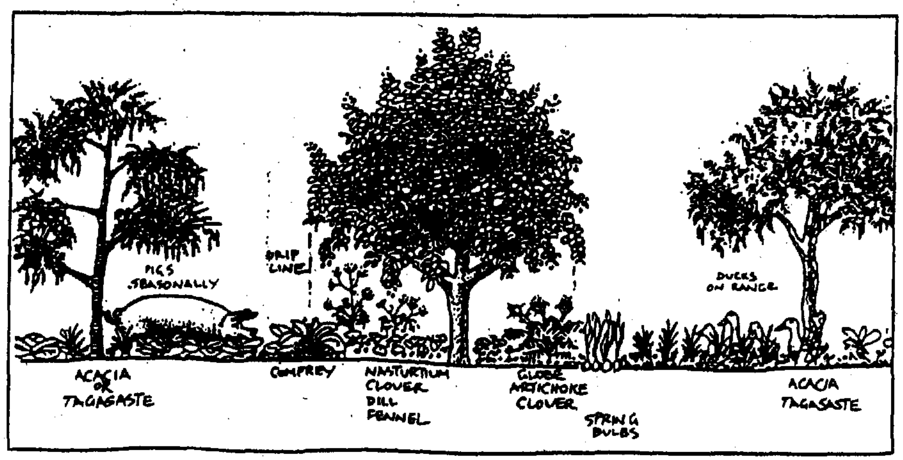
USES: Edible pods, young leaves, shoots, flowers as vegetables; immature tuberous roots eaten raw or cooked. Very high protein content. Can be used as for soy beans for processing to bean cake. Seeds contain oil for cooking, soap, and lighting. Dry flowers eaten like mushrooms. Excellent nitrogen-fixer (heavy nodulation), soil conditioner and cover crop for the tropics.

YAM BEANS (*Pachyrrhizus erosus*, *P. tuberosus*)
Herbaceous, twining plant 2-6m tall. Warm-climate, dry-land perennial beans with crisp, edible tubers; harvested after 4-8 months. Mature seeds and leaves toxic.

USES: Tubers widely eaten in Mexico, Philippines, SE Asia, raw or cooked. Called jicama (*P. erosus*) in Mexico and eaten in salads or sliced thinly and sprinkled with salt, lemon juice and chilli sauce. Young pods of *P. erosus* sometimes eaten like French beans. Old starchy tubers are fed to cattle.

YARROW (*Achillea millefolium*)
Herbaceous perennial to 1 m, with white flower heads. Drought-resistant; naturalises along roadsides and disturbed soils. Bee forage. Insectary plant (a member of the composite family which attracts beneficial insects). Flowering tops and foliage of medicinal use for stock, especially sheep.





poor soils, drought. Like sunflowers, sunroots release a root exudate which is toxic to some plants.

USES: Human food; tubers eaten as vegetable. Animal forage: dry stalks and leaves eaten by goats; tubers by pigs. Fast garden windbreak; also useful to break up hard soils. Leaves used for mulch in gardens after tubers harvested.

SWEET POTATO (*Ipomoea batatas*)
Perennial twining plant, often treated as an annual. Temperate to tropical tubers usually planted on ridges or mounds (cannot stand waterlogging). Propagated by stem cuttings in tropics; tuber sprouts in temperate climates. Needs frost-free growing period of 4-6 months.

USES: Important food source, eaten boiled or baked. Used for canning, drying, flour manufacture, and as a source of starch, glucose, syrup and alcohol. Also fed to livestock. Vines are widely used as fodder for stock. Grown in subtropics as a groundcover for orchards, but must occasionally be slashed from tree trunks. Die back in frost.

TARO (*Colocasia esculentus*)
Tropical wet culture plants with over 1000 cultivars. Grown either in wetland terraces with *Azolla* fern (for nitrogen fixation) or on mulched and irrigated plots. Staple food of the tropics. Large root is eaten, although some taros are grown for their leaves. The leaves of many taros are poisonous.

TAUPATA (*Coprosma repens*)
Also called New Zealand mirror plant. Large, evergreen shrub 2-3m with shiny leaves; dioecious (separate male and female plants). Easily grown from cuttings. Temperate climates; windhardy and resistant to salt spray, drought, and fire. Common ornamental seaside plant in New Zealand and Tasmania.

USES: Hedgerow plant and fire retardant. Fruit and seeds are excellent poultry forage. Leaves are eagerly eaten by sheep, horses, cows. Pruned clippings make a good mulch or compost.

TAGASASTE (*Chamaecytisus palmensis*)
NOTE: Previously named tree lucerne (*Cytisus proliferus*). Nitrogen-fixing legume tree 6-10m, living for more than 30 years. Easy to grow from seed (scarify or pour boiling water over seeds and soak). Tolerant of poor soils, drought, wind; originated in dry, Mediterranean-type climate, but does well in cool temperate areas, withstanding light frosts. Tagasaste recovers after pruning or defoliation by animals.

For best results fertilise with trace elements and lop branches regularly (either by hand or browsing) to give a more bushy foliage. Seed can be direct drilled into pasture, but plants should be protected from stock for up to 3 years (or stock let in for brief periods to graze). If sheep ringbark trees, cut to the ground to encourage new growth; this will form thickets more resistant to sheep damage.

USES: Foliage an important protein-rich fodder for stock during drought and at the end of summer. Bee forage; many small white flowers. Chickens eat seeds. Windbreak hedge. Nurse plant surrounding frost-sensitive trees in early years. Excellent cut mulch; tree can be lopped 3-4 times in summer.

TAMARILLO or TREE TOMATO (*Cyphomandra betacea*)
Short-lived shrub to 3-6m, of the tomato family. Sown from seed or propagated by cuttings from 1 or 2 year old wood. Yields in two years. Subtropical, marginally suited to cool areas (place in a sheltered, sunny position—will tolerate mild frost). Well-drained soil. USES: Fruit high in vitamin C; used fresh, stewed, conserves. Commercially grown in New Zealand; high-value crop.

TRAPA NUT (*Trapa natans, T. incisa*)
Also called Indian water chestnut. Several species, temperate to tropical regions. Aquatic perennial, floats in water 2-3 feet deep. Needs high nutrients. USES: Important starchy food plant, rich in iron; flour like arrowroot.

WALNUT (*Juglans regia, J. nigra*)
Spreading, deciduous trees to 30m; long-lived. Temperate climate, cold areas. Yields best on deep, well-drained rich soils. Release root exudate which inhibits some understorey plants, although pasture does well. USES: Both species are important for nut production, timber, specialty woods. Husks produce a dye. Black walnut (*J. nigra*) rootstock is resistant to *Armillaria* root rot; all commercial English walnut stands are grafted. Black walnut is a particularly sought-after wood, with very high prices paid for good, straight timber (yields in 40-50 years).

WHITE CEDAR (*Melia azedarach*)
Short-lived (20 years), deciduous tree 9-12m tall. Suited to a wide range of warm climates (tropics to Mediterranean climates, e.g. South and West Australia).

USES: Fast-growing shade tree; good for afforestation. Valuable timber; resistant to termite attack (does not need to be treated) and used for poles, furniture, and roofing material. Fuelwood. Coppices well; trees lopped for green manure. Leaves, bark, and fruits are credited with insect-repellent qualities. Extracts of the leaves are used as a spray against grasshoppers, and leaves placed in books and wool clothing to protect against moths. Caution: fruits are very poisonous.

WILLOWS (*Salix* spp.)
Around 300 species. Mainly spreading, deciduous trees;

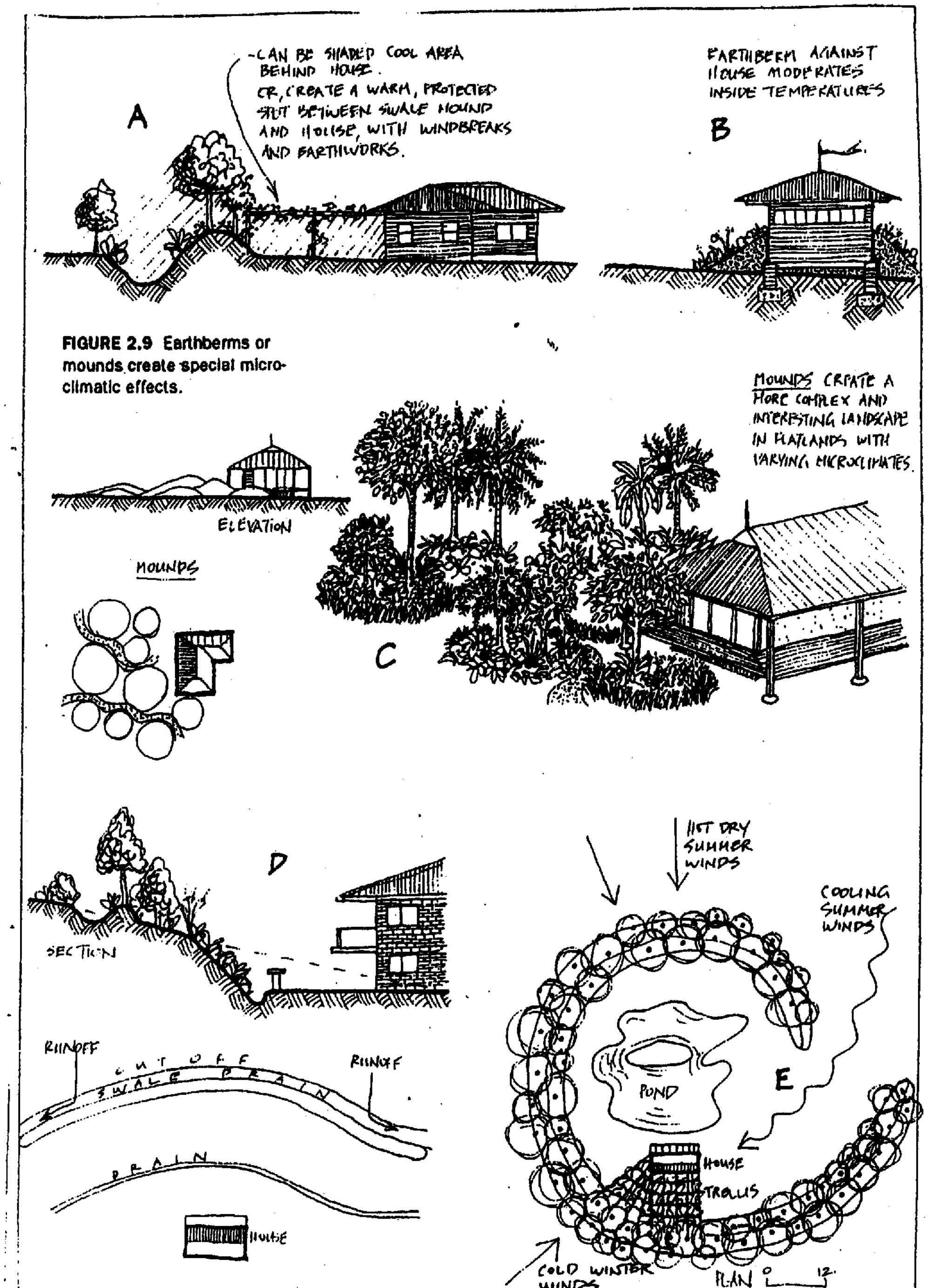


FIGURE 2.9 Earthberms or mounds create special microclimatic effects.

The same thing happens in abandoned rubble lots and pastures and anywhere else where the land has been disturbed. Areas will be colonized by a new weed and herb layer which might hold the soil against erosion, bring water to the topsoil with their roots, break up compaction, fix nitrogen, reduce salts, or bring up nutrients from the subsoil which will end up in the topsoil as they die back and decompose. Blackberry bushes with big old thorns will invade an area and keep everything else away while the land heals itself. Eventually, just like with the alder, trees will grow up through the blackberry vines and shade them out.

We can do the same thing by building up the soil and substituting our own herb, pioneer, and climax species. Depending upon the type of soil you start with (which might be eroded, salted, swampy, worn out, acid, alkaline, clayey, or sandy) - it's possible to introduce plants that will easily survive and might by more useful than the existing vegetation. We can grow cover crops of clover or alfalfa or peas or beans which fix nitrogen in the soil and then turn them in to build up the fertility. We can grow buckwheat which is a phosphorus accumulator or winter rye which suppresses weed growth. We can introduce animals into a system and have them do our work for us while they happily live their lives. If we play our cards right, in 20 years we can end up with forests of hazelnuts and peaches and blueberries. That's the plan - a permanent agriculture.

Sheet Mulching

There's all these subtle little sheet mulching projects all over the farm - it's a really basic, cool idea. The grass is full of nutrients cause it's so good at pulling minerals up from down in the subsoil. It becomes obvious pretty quick that it's a waste of time and resources to try and pull it out of the ground and clear beds for growing stuff. It's much easier to just throw a thick layer of wet cardboard or an old carpet over an area - wait a year - and when the top layer of weeds is dead and rotted back into the soil from all the heat and lack of air, then it's time to sow the vegetables. Periodically I stumble upon one of Brent's mulch spots - sets of bamboo poles or alder branches with nitrogen fixing beans trellising up from the cardboard, getting the soil ready for next year.

Pigs and Junkus

The pigs I feed everyday are fenced off in an area full of this thick weed called junkus that's scattered throughout the pasture land. It's really hard to get rid of with farm machinery, but pigs love to dig with their snouts and root up whatever they can. The longer they hang out there, the clearer that soil gets and eventually the farm crew is going to plant another fruit and nut orchard. We get to feed them our garbage, they get to play around all day and be really cute, and a bunch of people (not me) are going to be eating a lot of meat in the Wintertime.

Cows and Bamboo

The cow barn is close the lake. There's a huge clump of bamboo that's been planted at the edge of the barn which absorbs the excess nitrogen from the cow manure which would otherwise run down into the lake. The clump gets periodically harvested for poles. Everything works out.

after frost. Nutritious grain food, tasty greens. Grind seeds into flour or remove bitterness of whole grains by soaking; use boiled or in soup. Chicken fodder.

Other useful *Chenopodium* spp. for human food and chicken fodder are fat hen or lamb's quarters (*C. album*) with calcium-rich leaves for salads, seeds relished by poultry and birds; and good king henry (*C. bonus-henricus*), young plant eaten like asparagus and spinach.

ROSELLA (*Hibiscus sabdariffa*)
Fast-growing annual shrub of subtropics and tropics. Grows 1.5-2m tall. Tolerates most soils; must be well-drained. Needs long summer growing period.

USES: Fruits stewed or used in desserts and drinks; conserves. Tender leaves and young stems used as a salad or steamed; leaves are chopped as a savoury herb (for curries). Another useful plant of the *Hibiscus* family is okra (*H. esculentus*) with the tender pods boiled or sliced and fried. Used in soups and gumbos.

SALSIFY (*Tragopogon porrifolius*)
Temperate, biennial clumping plant to 0.6m, often planted as an annual. Cultivated for its oyster-flavoured edible tap-root (harvested autumn, winter, spring). Young leaves and flowers edible in spring and summer.

SCARLET RUNNER BEAN (*Phaseolus coccineus, P. multiflorus*)
Herbaceous perennial (grown as an annual in cold climates) with thick root stock. Tolerates some frost; grown in mild coastal or island climates. Needs cool periods to fruit heavily.

USES: Edible young pods, beans fresh or dried. Good trellis plant for shade; bright red ornamental flowers. Tubers are boiled as a vegetable in Central American highlands. Other useful *Phaseolus* are tepary bean (*P. acutifolius*), a high-value dryland species; and lima bean (*P. lunulatus*), a tropical low hedge plant on fences.

SESBANIA (*Sesbania bispinosa, S. aculeata, S. grandiflora*)
Fast-growing (4-6 m/year), short-lived subtropical and tropical legume tree 6-9m high. Drought-resistant. Easily propagated by seed.

USES: Seeds used for poultry fodder and leaves for forage. *S. aculeata* used in Asia as traditional green manure crop and border plant (nitrogen-fixer) planted together with rice. *S. grandiflora* grown in the Mekong delta in home gardens for its leaves and flowers used for human food and livestock & poultry. Planted along rice paddies, yield up to 55 tons of green material per hectare. Used as temporary shade trees in nurseries. Windbreak in citrus and coffee, banana. Living fence and firewood source. Used for large-scale reafforestation of bare land outside forests in Indonesia.

SIBERIAN PEA SHRUB (*Caragana* spp.)
Tall, leguminous shrubs 1-5m, forms thickets. *Caragana arborescens* is the only species that grows into a tree. Very cold and wind hardy, growing from arctic circle to warm, dry climates. Seeds burst out of 6cm-long pods and should be collected in bags before completely ripe if needed for seed.

USES: Windbreak and hedge shrub for very cold climates. Seeds are excellent poultry forage food, and pods can be left on the shrubs to burst open. Wildlife habitat, sheltering small animals in the thickets. *C. arborescens* leaves produce a blue dye. Nitrogen-fixer.

STONE PINE (*Pinus pinea* & other spp.)
Conifer up to 10-30m tall; slow-growing and long-lived. Suits cool areas and can grow on exposed, dry, rocky sites.

USES: Pine nuts or kernels are rich in oil, have a very good flavour. Cones are collected when mature but unopened; opened in summer sun or dryer and nuts are shaken free. Many species have excellent edible nuts, including pinyon pine (*P. edulis*), Coulters pine (*P. coulteri*), *P. cembra* (Europe), *P. gerardiana* (Afghanistan).

SUNFLOWER (*Helianthus annus*)
Annual plants 0.7-3.5m tall; temperate to tropical climates (not suited to the wet tropics, however). Drought-resistant, but do best when watered at intervals. Grow on a wide range of good draining soils. Release root exudate; some crops do not grow next to them.

USES: High-value protein seed for human and livestock, especially poultry, pigeons. Whole heads may be given to stock. Salad and cooking oil made from seeds; with seedcake residue fed to stock. Also used in blends with linseed for paints and varnishes. Lubricant and lighting. Stalks and hulls are mulch, bedding for livestock.

SUNN HEMP (*Crotalaria juncea*)
Tall shrubby annual 1-3m subtropics and tropics; frost-sensitive. Quick-growing, large leaved legume. Hardy and drought-resistant.

USES: Cultivated for fibres used as twine, paper, nets, sacking (better than jute). Root exudate said to control nematodes in the soil. Easily grown in gardens, with leaves used for mulch. *Crotalaria brevidens* used as annual fodder in tropical Africa. Green manure crop, often grown in rotation with rice, maize, cotton; and interplanted with coffee, pineapple. When thickly-sown, will smother all weeds, even vigorous grass weeds.

SUNROOT (*Helianthus tuberosus*)
Also called Jerusalem artichoke. Tall perennial which dies back to roots; 1-3m tall. Propagated by tubers. Yields are often 4-5 times that of potatoes. Hardy, wide climatic range from temperate regions to tropics. Will tolerate

crops; wood taken in 6-12 years (pruning and shaping necessary to maintain good log growth). Leaves contain nutrients, nitrogen; can be used as stock fodder and mulch.

PERSIMMON (*Diospryros kaki, D. virginiana*)
Many varieties, especially in Japan. Deciduous tree to 15m, yielding fruit in winter. Temperate to subtropical climates. Fairly frost-hardy; does well in most well-drained soils. Japanese persimmon (*D. kaki*) does best in full sun, while American persimmon (*D. virginiana*) can tolerate partial shade.

USES: Fruit, eaten when over-ripe (harvested when hard and ripened indoors). Fallen fruit is an excellent pig and stock food. Ornamental plant, with autumn colour (spectacular red fruits on leafless tree). A good front yard plant, along with other such ornamental edibles as nasturtium, kale, almond, peach, currant, etc.

PIGEON PEA (*Cajanus cajan*)
Leguminous woody shrub of dry subtropics and tropics; frost sensitive. Quick-growing, short-lived perennial; sometimes grown as an annual. 1-4m tall.

USES: Major tropical food grain, green seeds and pods used as vegetables. Ripe seeds for flour, dhal, sprouts (22% protein, 10% calcium). Important forage plant eaten green or made into hay or silage. Sometimes planted in pastures as a browse plant. Ideal windbreak and shade for vegetables; leaves cut for mulch on garden beds. Shade tree plantations (coffee, cacao) and vanilla production in India. Useful windbreak hedge species.

Used in Asian medicine as a treatment of skin irritations, cuts. Leaves used for silkworm culture in Malagasy. Green manure and cover crop. Used in erosion control. Dried stalks for firewood, thatching and baskets in India.

PRICKLY PEAR (*Opuntia* spp.)
Spiny cacti with flat, fleshy pads grown in dry subtropics/tropics. Like full sun; grow to 2m. Propagated by planting pads into the ground. Will grow in poor soils; drought-resistant. Caution: can be invasive; birds carry seeds.

USES: Fruit, eaten fresh or stewed (numerous hard seeds); use gloves to harvest, then scrub off fine spines and peel. Seeds are nutritious and are sometimes ground for animal feed. Young *Opuntia* pads are de-spined and sold in Mexican, Indian markets for human food; pads also fed to stock (spines are burnt off). Good barrier hedges. Some varieties are: mission prickly pear (*O. mega-cantha*); common prickly pear (*O. ficus-indica*); *O. undulata, O. streptacantha.*

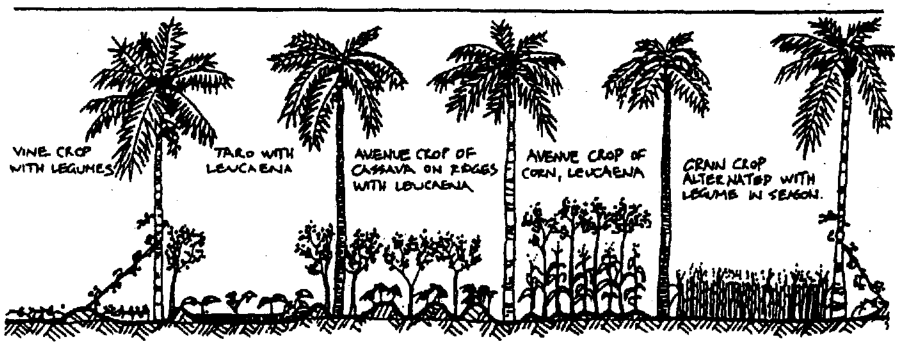
PRUNUS SPP.
These deciduous species contains some of the most important temperate fruits: apricot, plum, almond, peach, nectarine, cherry. Many cultivars, some miniature varieties. Most are small trees and shrubs 1-10m tall. Mediterranean climates, warm dry summers best. Semi-tolerant of drought.

USES: Mainly for fruit, usually eaten fresh or in conserves, juice. Almonds are a storable product. Some species such as damson plum (*P. insitia*), sour cherry (*P. cerasus*), and common plum (*P. domestica*) will form thickets, making an excellent hedge for windbreak, wildlife habitat. All species good bee forage.

QUEENSLAND ARROWROOT (*Canna edulis*)
A clump-forming perennial of the subtropics and tropics (originally from the Americas). One of the hardiest arrowroot plants, can grow in temperate areas where there is little frost (needs warm, sunny position).

USES: Tubers cooked for a sweetish taste, though inferior to sweet potato due to fibre. Arrowroot flour. Animal forage, especially pigs. Also used as a garden windbreak and weed barrier with comfrey and lemongrass; and can be chopped occasionally for garden mulch.

QUINOA (*Chenopodium quinoa*)
Hardy annual to 1-2m, grown in South American Andes; cold temperate, dryland. Drought-tolerant. Sow in spring



Classical Palm Intercrop

52

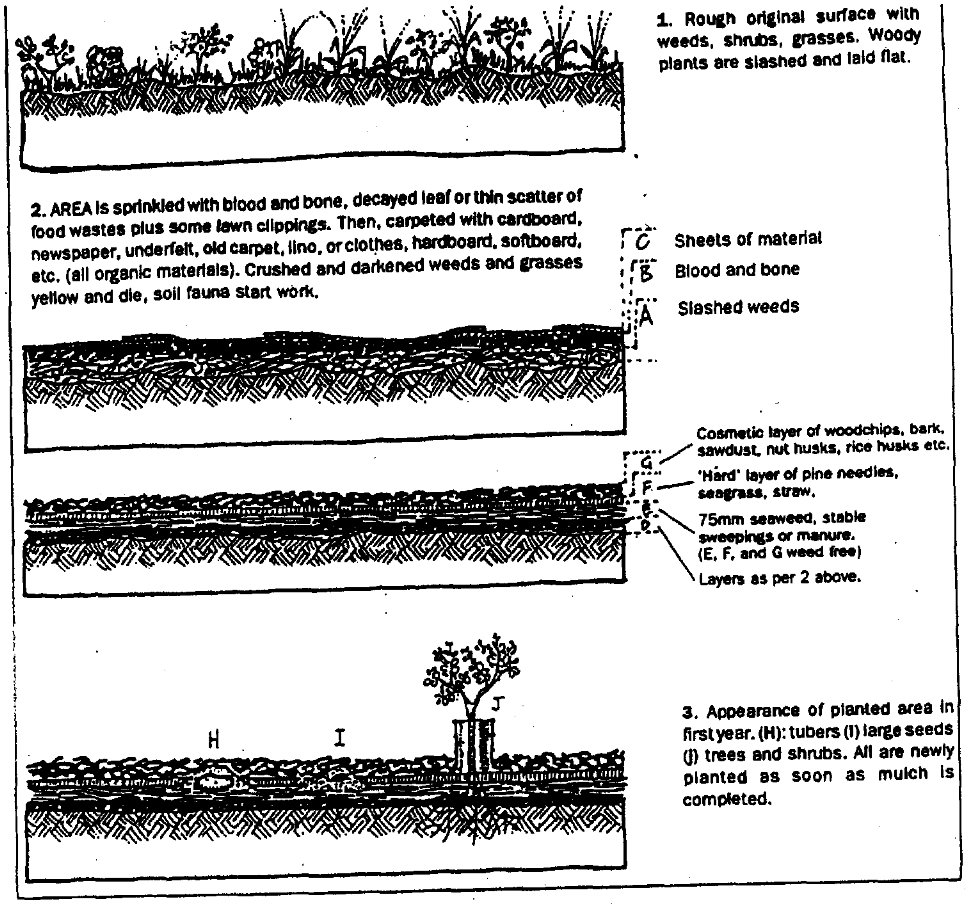


FIGURE 5.12 Steps in sheet mulching.

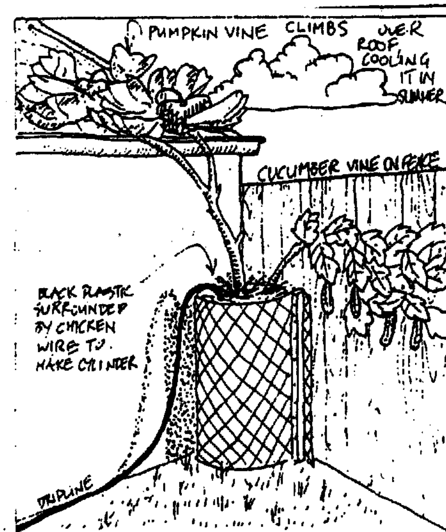


FIGURE 5.17b Circle garden with plastic tent.

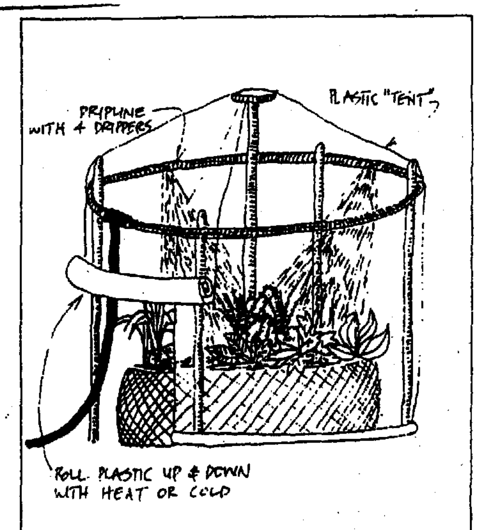


FIGURE 5.17c Chicken-wire column for rooftop vegetables.

9

Plant Stacking and Time Stacking and Swales

In the forest there are a series of interconnected levels - from the understorey of ferns and bushes to the upper canopy of the mature trees. Instead of planting a flat field of one crop which needs tons of attention and water, the idea is to intercrop taller and shorter species, climbing plants and herbs and different kinds of trees - everything placed according to their shade tolerance, heights, and water requirements.

In one of the permaculture sites there is a sequence of swales connected to a small dugout pond which carry nutrients down to the bottom of the slope. At the bottom of the slope there's a bunch of raised beds made of sticks and mud where all the garlic is planted. Swales are just these long level excavations that are dug to store water in the underlying soils or sediments. They're different than ditches because instead of just diverting water so it can drain somewhere else, swales work to intercept the water flow, hold it for a few hours or days, and let it slowly infiltrate the ground water, recharging soils and tree root systems. The site was a big swamp full of alder trees a couple years ago and slowly the permaculture crew has been rerouting the water to make the wet areas nicer and the surrounding areas more fertile for growing ground crops, carefully removing the alders and replacing them with fruit and nut trees. Trees are totally important parts of swale planting systems. Our teacher Brent shows us how he cuts the alder trees to harvest their wood but does it in such a way that the younger trees can take advantage of the old root systems and exposed sunlight from removing the canopies. Just like everything else around here, the idea is to set up the system so that it doesn't need any inputs from the outside and can totally function as a self-contained ecosystem.

Guilds

The fir trees in the forest have like 26 different types of fungi and scrubs and insects that somehow pay a role in their growth and life. In the forest, the trees, bugs, birds, fungi, ferns, and huckleberry bushes all work together to create an interconnected web. Sometimes, rather than thinking about organisms individually, it's useful to think of them in clusters or groups. When the individuals are clustered around a central element we call these groups guilds. In the forest we can talk about the fir tree guild.

There are a couple of fruit orchards spread around the farm, mostly apple and plum trees. There are also a small heard of sheep which keep the grass down in the orchards by grazing. They also eat up any fruit which falls and rots on the ground, preventing diseases in the trees. Every week or so the sheep are moved from one orchard to another so that they don't graze the grass too low. To keep the trees healthy and not competing with invasive grasses, we grow yarrow and clover and borage and nettles and comfry around the them. The sheep also eat these and like them too. We can say that the sheep and herbs we grow in the orchard and the trees are all part of the fruit tree guild.

OLIVE (*Olea europaea*)
Small, evergreen tree to 8m; long-lived (up to 700 years). Dryland plant of Mediterranean region, not suited to maritime or cold regions (although fairly frost-hardy, fruit needs hot summers to ripen). Propagation by cuttings; olives bear in 4-6 years. Can grow on thin, rocky soils but yield is best on fertile soils.

USES: Fruit is eaten green or ripe; green olives must be soaked in a lye solution before pickling to remove bitterness. Excellent oil crop: fruit picked when fully ripe (but not soft), then crushed to a mash and placed in cloth bags. These are pressed and the oil collected. Good olive varieties yield as much as 30% oil. The remaining pulp after pressing can be fed to stock. Olive trees are a good shelter and occasional forage for stock.

PALMS
Woody perennials with many uses, from human food, oils, sugar, animal fodder, structural material, thatch, and fibre. Most useful palms grow in dry or wet tropics. Have deep tap roots, and many are successfully used in agroforestry (crops and pasture) as they do not compete for water.

Date palm (*Phoenix dactylifera, P. sylvestris, P. canariensis*): Dioecious, need one male to 60-80 females. Staple food yielding dates; old trees are tapped for toddy (sugar). Inferior species of dates can be used for animal fodder or possible fuel crop.

Borassus palms (*Borassus* spp.): Palmyra (*B. flabellifer*) tapped for sugar in India (produces 170 pounds of nectar per acre, or 40,000 litres of alcohol fuel). Timber is hard and durable. Others are *B. aethiopican*, *B. sundaicus*.

Doum or gingerbread palm (*Hyphaene thebaicus*): Multi-stemmed, branched palm to 15m, bearing heavy crops of edible hard-shelled fruits. Staple food and fodder crop of arid lands, mainly Egypt.

Coconut (*Cocos nucifera*): Essential plant of many tropical island cultures. Yields coir for rope, thatch, oil, drinking "water", nut meats, and sugar from flower stalks.

Chilean wine palm (*Jubaea spectabilis*): Temperate-zone palm yielding 410 litres of sweet sap annually. Cold hardy. Fruits with edible nut, useful for fodder.

Peach palm or Pejibaye (*Bactris (guilielma) gasipaes*): A spiny-trunked plant; staple plant of Central & South America exceeding maize in protein and carbohydrate yields per acre. Fruits chestnut-like, boiled and dried as food. Also for poultry and pig forage. Hardy only in frost-free areas.

PASSIONFRIUTS (*Passiflora* spp.)
Evergreen perennials; vigorous growers (sometimes rampant as they will naturalise and climb in forest trees). USES: Edible fruit, poultry and pig fodder, sun deflector to shade walls, used to cover (and keep cool) water tanks and sheds. Ornamental, with showy flowers.

Black passionfruit (*Passiflora edulis*) is a vigorous climber of subtropical to tropical areas. Cultivated on fixed fence trellis, cropping for 4-8 years (some varieties last longer). Frost tender in early growth.

Banana passionfruit (*P. mollisima*) is grown in temperate maritime climates; will withstand moderate frost once established. Yields from late autumn to early summer, and is a valuable poultry fodder (fruit seeds). An under-used fruit for winter fresh fruit, more easily peeled than *P. edulis*.

Lillikoi (*P. alata*) is a hardy, vigorous grower of the subtropics and tropics; plant two or more for best cross-fertilisation. Delicious fruit.

Other edible passionfruits of the tropics are granadilla (*P. quadrangularis*), sweet granadilla (*P. ligularis*), and water-lemon (*P. laurifolia*).

PAULOWNIA (*Paulownia tomentosa, P. fargesii*)
Quick-growing, drought-resistant deciduous trees to 15m. Mild temperate to subtropical range, with *P. fargesii* in the cooler climates. Grown extensively in China. Has deep taproot and will not compete with pasture, crops. Has large leaves, but with some pruning and wide spacing allows light through.

USES: Timber crop for fine furniture, boxes, chests. Used in agroforestry to shelter cereal, soybean, and cotton

SUB DOMINANT: COFFEE, CACAO, VANILLA, PIGEON PEA....
DOMINANT SPECIES: AVOCADO, COCONUT, JAKFRUIT, CASHEW, PECAN .... Coconut Circle

HEDERA HELIX (ENGLISH IVY)

PHASEOLUS COCCINEUS (SCARLET RUNNER BEAN)

OAKS (*Quercus* spp.)

Mostly large, spreading, deciduous trees up to 40m, although some are smaller or even prostrate. Long-lived; many are fast growing and bear acorns early. Large habitat range from dryland soils to acid swamps; temperate to subtropical climates (most species are well-suited to cold areas). Good germination, although acorns sometimes lose viability in a year. Yield is variable, usually yielding in alternate years.

USES: Acorns as animal forage, high carbohydrate. Most valuable for pigs, although crushed acorns and leaf mould are fed to poultry. Species used are "sweet", or low in tannin. Excellent hardwood timber and firewood. Some species used for wine vats to aid maturation process. Oaks offer shelter for stock and are good fire sector species (poor burners when "green"). Leaves are used for animal bedding. Following are a list of some species suited to particular uses:

Human food: Acorns contain tannin which can be removed from ground acorn meal by leaching in streams and cooking. Some sweeter acorns are: *Q. ilex* var. *ballota* (a cultivar of the holm oak) which is the best old world eating acorn used in Portugal and Spain. *Q. alba* (white oak) a common North American tree with acorns boiled like chestnuts by Native Americans.

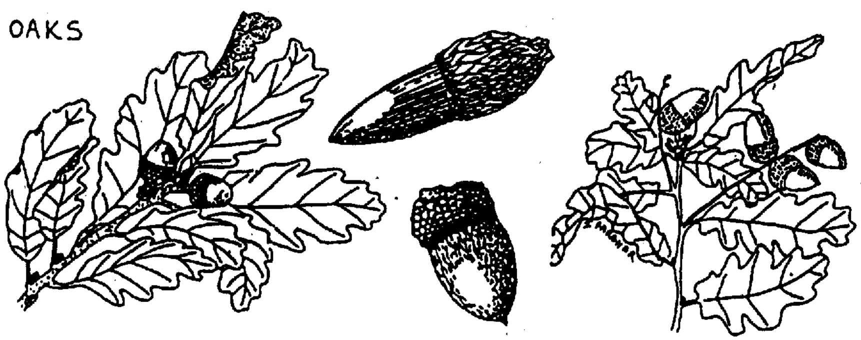
Fodder: Best is *Q. ilex* (holm oak) and *Q. suber* (cork oak); mixed stands are grown in Portugal for pig forage, with very high yields on alternate years. Such mixed oak forests yield 68kg/ha per year over a ten year period. Other fodder species are *Q. prinoides* (chinquapin oak), *Q. alba* (white oak), and *Q. minor* (post oak).

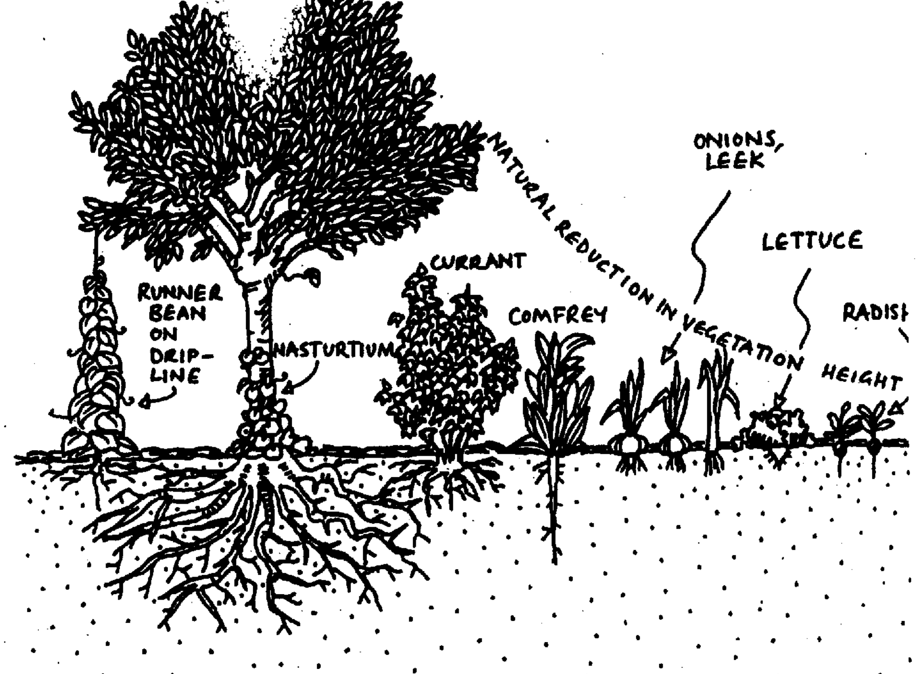
Timber: Most oak trees produce superior quality timber. Some important species are *Q. robur* (English oak) used for centuries in buildings and ships; *Q. petraea* (durmast oak); *Q. alba* (white oak), also used for barrel making; and *Q. rubra* (red oak), used extensively for furniture.

Cork: *Quercus suber*, the cork oak, is cultivated in Spain and Portugal for wine/champagne bottle stoppers, insulation, flooring, etc. Once mature, cork can be harvested every 8-10 years without harming the tree. A hectare of cork oak will yield an average of 240 kg/year.

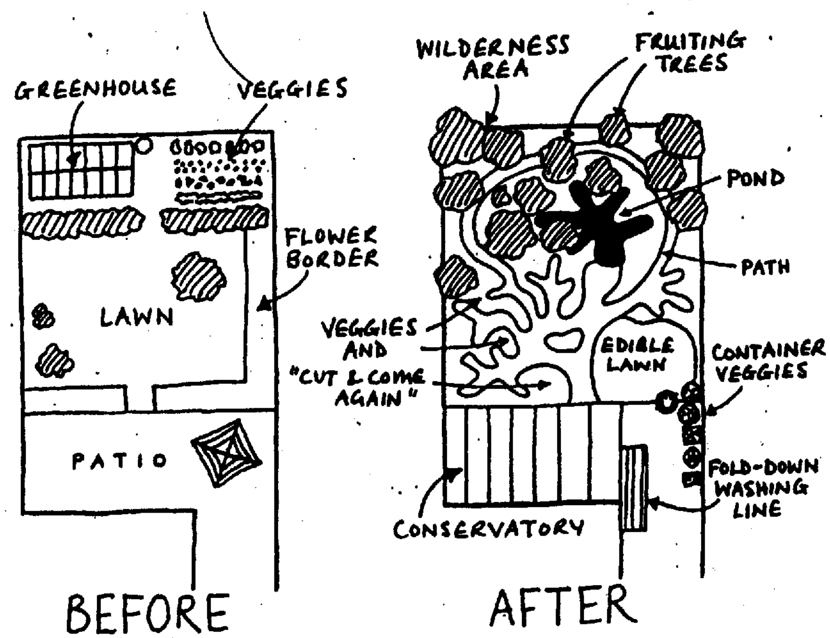
Other Uses: *Q. mongolica* is the host plant for the tusser silkworm of China and Japan; these are semi-domesticated and produce a high-quality silk. *Quercus velutina* (black or quercitrin oak) yields a permanent yellow dye from its inner bark. *Q. ilex* and *Q. alba* are used for high-quality charcoal production.

OAKS





Here the fruit tree forms the centre of a small 'guild' of related plants, using every vertical layer of the garden as space for yield. The careful choice of speci makes the plants mutually beneficial.



Starting with an 'all-square' garden design, a more adventurous and high-yielding plot is evolved.

The quintessential crop guild is the traditional Native American planting of corn, beans, and squash. As the runner beans trellis their way up the corn stalks, they fix the nitrogen that's being lost to the soil from the corn which needs a lot of nutrients to grow. As the squash plant provides an understorey which keeps away weeds and helps to keep the soil moist, their big spiny leaves also keep the animals from trying to climb up and steal the corn ears as they ripen.

Edge

At the edge between the forest and the lake there's always a mix of both ecologies and whole other set of species that doesn't exist in either of the two. Ecological productivity always increases at the boundary between two ecologies because the resources from both systems can be used. This is true for land/water, forest/grassland, estuary/ocean, sidewalk/street, wherever.) Energies and materials always accumulate at the edges - soil and debris are blown by the wind against fences or walls. Increased edge makes for a more productive landscape - creates more surface area, more patches of microclimates. People always want to live on the edges.

When we build our garden beds or ponds, we take edge into account and don't just always make them normal rectangles or circles. We built an herb spiral next to our house out of smashed up concrete from an old building foundation. The raised spirals condenses space, creates a bunch of little microclimates for shade and sun tolerant herbs, increases the surface area, and looks really cool. Edges define areas and break them into manageable sections - look around and see what I'm talking about.

Relative Location

Out in the forest the individual plants and animals and soil organisms aren't nearly as important as how they all relate to each other. When the birds eat berries from the trees, they fly to the other side of the forest and plant new trees by shitting out the seeds. Bark beetles carry the spores of fungi into fallen trees and the fungi help break down the wood of the trees back into soil which provide the materials for new trees to grow. If we separate out each organism it's hard to appreciate what's actually going on. If you haven't already figured it out, this is a reoccurring theme here. Rather than viewing everything on our farm as separate entities, we try to figure out how as many of the elements in our system can work together as possible.

In our production garden we have a five year crop rotation. The idea is that we keep up the soil fertility by growing a succession of crops that complement each other: after corn we grow beans and then tomatoes and then squash. To throw off the pests and diseases, the same crop is never grown a bed two years in a row. We also factor a slew of chickens into the whole thing. We keep the chickens fenced off in a nice big area and as they hang out they scratch up the ground and eat the pests and shit all over the place to get the soil ready to plant in. They have a nice life on the farm, rub themselves in the dust and have sex and all that, they eat bugs and food scraps and corn scratch, we eat their eggs, everyone's happy. At the beginning of the next

to stabilise slopes. Mostly grown in the USA for hay, cut before flowers bloom. *L. stipulacea* and *L. striata* are annuals.

LEUCAENA (*Leucaena leucocephela*)
A fast-growing, leguminous tropical tree to 10-20m (although can be kept to a manageable size if coppiced or grazed by cattle). Does best on well-drained soils. Contains a mimosine that may cause toxicity in stock if overfed; a low mimosine variety is *L. leucocephela* var. *Cunninghamii*. Also, CSIRO scientists have isolated a microbial culture which cattle can use to break down the toxic substance in their stomaches. As long a leucaena is kept to 30%-40% of diet, there are no adverse effects even from normal leucaena varieties.

USES: Excellent high-quality forage (both leaves and pods) for cattle, sheep, goats; palatable and nutritious. Can be cut-and-fed, or stock let in to browse. Also useful in revegetating tropical hillslopes prone to erosion. Excellent coppicing for firewood, good timber. Rich in organic fertiliser; used as mulch in alley cropping. Fixes nitrogen in the soil. Used extensively as living fence/hedge species in West Africa and India.

LOQUAT (*Eriobotrya japonica*)
A small evergreen tree to 7m. Slow to develop from seed; use proven cultivars grafted onto loquat, pear, or quince stock. Yields by 6th year, peaks in 15-20 years. Suited to temperate areas; needs sheltered, sunny position. Frost-hardy but needs warmth for fruiting. Suits most soils, but is a gross feeder (plant near leachline outfall). USES: Fresh fruit in spring; medium understorey tree. Poultry and pig fodder (fruits).

LUCERNE/ALFALFA (*Medicago sativa*)
Perennial, leguminous herb with life expectancy of 10 years. USES: Human food: foliage as alfalfa tea; alfalfa sprouts for salads. Major temperate animal fodder plant. Excellent bee forage, blooming just after sweet clover. Soil improver, drawing up subsoil nutrients; useful ground cover/living mulch under trees.
Also TREE MEDIC (*Medicago arborea*): Perennial leguminous shrub to 4m; grows in temperate zones. Important fodder shrub with foliage equivalent to lucerne. Can be netted and sheep allowed to browse.

MACADAMIA (*Macadamia tetraphylla, M. integrifolia*)
Slow-growing, evergreen nut tree to 20 m; subtropical to tropical climates. Need windbreak protection. Grafted varieties bear in 6-7 years. Native to Australia, grown extensively in Hawaii and California.

USES: High-value nuts, difficult to crack by hand. Nut shells make excellent mulch. As with many trees, can be grown in pasture, with sheep let in after trees are mature enough to withstand grazing animals.

MAPLE (*Acer saccharum, A. macrophyllum*)
Deciduous cold area tree to 30m. Long-lived to over 200 years. Tolerates partial shade. Sends out growth inhibitor to nearby plants through roots. USES: Maple sugar, tapped in winter. Ornamental: red and yellow autumn leaves. Good carving wood. Bee forage.

MESQUITES (*Prosopis juliflora, P. tamarugo*)
Leguminous spreading shrubs and small trees 10-15m. Arid climates; totally drought-resistant and extremely salt tolerant. Grown from saline desert to semi-desert zones. *P. juliflora* (honey mesquite) yields 50 tons of pods per hectare, with 3-5 years to production. Caution: Easily becomes rampant.

USES: Major fodder trees of drylands for stock and poultry; 14cm-long pods are high in sugar, some protein. Pods made into a syrup (in Peru). Bee forage. Coppices easily for firewood. Also *P. alba, P. nigra, P. pallida* and *P. chilensis*.

MORINGA (*Moringa oleifera*)
Also called the horseradish or drumstick tree. Small tree to 10m; propagated by cuttings. Tropical, fast-growing. Tender pods as vegetables; flowers and young leaves eaten. Fried seeds. Roots as condiment (like horseradish). Twigs and leaves lopped for stock fodder.

MULBERRY (*Morus* spp.)
Deciduous dome-shaped trees to 20m, grow from temperate to subtropical climates. Main species are black mulberry (*M. nigra*), red mulberry (*M. rubra*) and white mulberry (*M. alba*). Can be grown in full sun but is also shade tolerant. Easily grown from seed or cuttings.

USES: Edible berries, *M. nigra* and *M. rubra* have superior fruit. *M. alba* is fast-growing, with short fruiting season; leaves are used as silk-worm food in China. Excellent trees for poultry and pig forage as fruits are numerous and fall easily to the ground. Leaves can also be fed to cattle. Useful wood for fenceposts and barrels.

NASTURTIUM (*Tropaeolum majus*)
A creeping or climbing perennial, usually grown as an annual; frost-sensitive. Prolific in moist gardens, but will also grow in most soils and sites. USES: Good ground cover and companion plant around fruit trees. Seeds can be pickled as a substitute for capers; they are also used medicinally as an antiseptic. Leaves and flowers edible in salads.

NATAL PLUM (*Carissa grandiflora*)
Thorny, evergreen shrub to 2m; grows in dry subtropics/tropics. Ripe fruits eaten raw; preferably made to conserves. Substitute for cranberry sauce. Attractive ornamental shrub; valued as a hedge in South Africa.

fodder for cattle, pigs; also fish food. "In Malaya it is widely grown in fish ponds by the Chinese who feed it to their pigs; the pig manure is used to fertilise the fish ponds; thus fish, pork and spinach are provided." (*Tropical Crops - Dicotyledons*, J.W. Purseglove, 1968).

KIWIFRUIT (*Actinidia chinensis*)
Also called Chinese gooseberry. Large, woody, deciduous climber, trellised at 2.5m, forming a bramble. Dioecious (male and female plants), although male and female may be grafted on one vine. Needs a strong trellis system. Tolerates frost; grown from temperate climates to subtropics. Needs shelter from wind. *Actinidia arguta* tolerates heavy frost; has smaller, astringent fruits, but hybridised with kiwifruit will produce sweeter yields.

USES: Delicious fruits; for eating, wine, conserves. May be fed to pigs and chickens if fruit set is abundant; also a high-value commercial crop. Useful deciduous shade vine for pergolas, patios.

KURRAJONG and BOTTLE TREE (*Brachychiton populneum* and *B. rupestre*)
Hot, dry climate fodder trees suited to agroforestry. Large trees. Have deep tap-roots; do not compete with crops or pastures. Can be easily coppiced. USES: Leaf fodder, especially as drought rations for sheep and cattle. Leaves lack phosphorus, which must be provided by stock licks. Bottle trees (*B. repestre*) are often cut down completely to feed soft inner pith to cattle in extreme drought; these must be replanted.

LAB-LAB BEAN (*Lab-Lab purpureus*—Syn. *Dolichos lab-lab*)
Herbaceous perennial legume, often grown as an annual; 1.5-6m tall. Subtropical to tropical evergreen or summer herbaceous climber. May become rampant, but managed by slashing 3-4 times a year or grazing by sheep, goats or cows. In subtropics dies back in light frost and can therefore be interplanted with grains. Tropics: remains green in dry season.

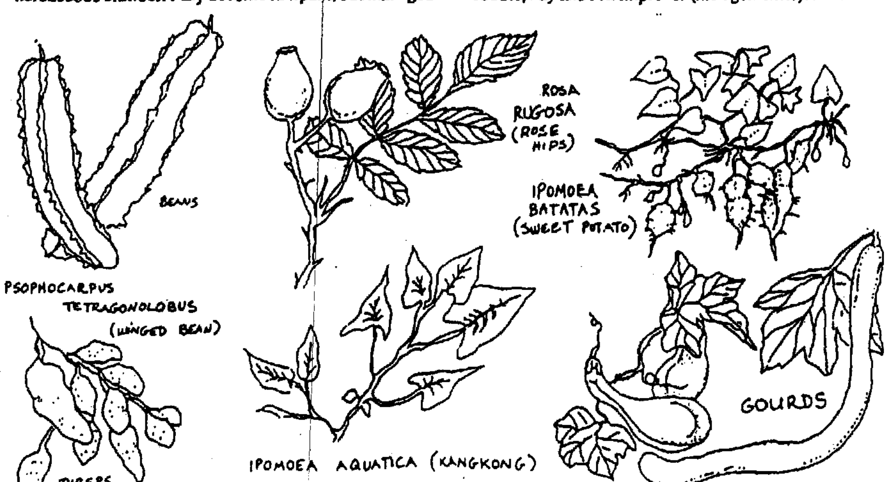
USES: Young leaves eaten raw or cooked, ripe seeds as split peas, or sprouted, boiled and mashed to a paste, then fried. High biomass forage crop (either green or as hay or silage) A useful dryland trellis crop for a sun shield (must be watered). Excellent green manure plant and cover crop; cut and use as mulch. Often grown in rotation with commercial crop to provide nitrogen.

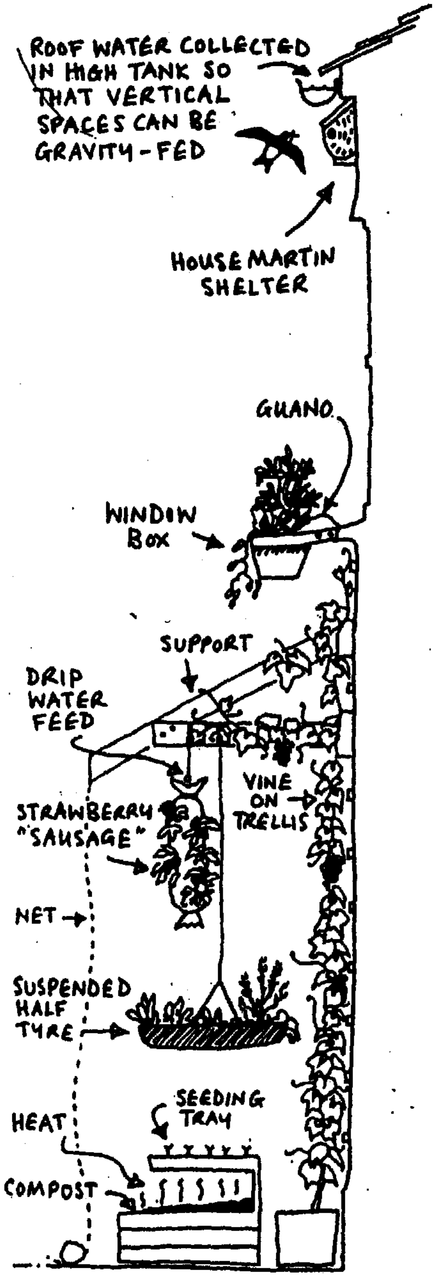
LAVENDER (*Lavandula vera, L. dentata*)
Small, woody shrub easily grown from cuttings. Suited to cool areas and is drought-resistant (originally a Mediterranean mountain plant). Well-drained, alkaline soil is best.

USES: Ornamental hedge plant, creating an "edge" in gardens; excellent bee forage. Flowers and leaves used medicinally. Lavender oil is a powerful germicide and insect repellant; dried flowers keep moths out of stored linen and clothes. Place sachets of lavender flowers in clothes drawers.

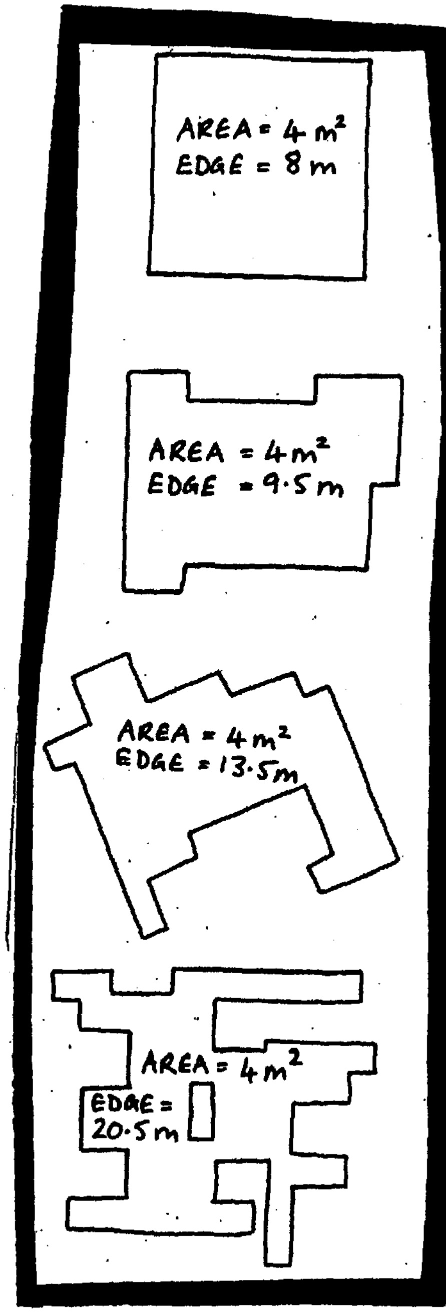
LEMONGRASS (*Cymbopogon citratus*)
Perennial medium-sized "grass" of subtropics and tropics. USES: Lemongrass tea, and flavouring used in Asian cooking. Excellent border plant in gardens and orchards to create edge; cut and use for mulch. Erosion control on slopes when planted in rows along the contour; will catch and hold silt.

LESPEDEZA (*Lespedeza* spp.)
Sericea (*L. cuneata*) is a perennial legume (similar to clover) common in temperate zones. High-value animal fodder, hay and soil improver (nitrogen-fixer). Also used





Creative vertical space usage.



Getting the most edge out of one size of pond.

growing season, we move the chickens to the where the corn was growing the year before and keep rebuilding the fertility. Just like in the forest, we're in the process of creating a long term self-sustaining cycle filled with different interconnected elements.

Diversity

By growing tons of different kinds of things, we're guaranteed to be eating well year round. When onion season is over, leek season is just beginning. When the kale is starting to all go to seed, the first heads of lettuce are ready to harvest. In our orchard there are early, mid, and late season apples trees all right next to each other. With all our canning and drying and freezing, there's no problem eating jam and pesto sauce all sorts of other goodies all year round. No one ever goes hungry around here. If this was an industrial monocrop farm, we'd have to ship in tons of food or things would get really boring. Diversity is all about stability and living large - the important stuff.

Urban Guerrilla Gardening - Growing Food in the City

We need to start growing food where we live and reclaiming all this knowledge for ourselves and future generations. We can't keep importing and trucking all of our food all over the globe and let big corporations control the most basic aspect of our lives for us. There is so much potential for growing food in the cities and suburbs. Taking over abandoned rubble lots and roof tops and lawns and starting community gardens. Building compost with all the organic wastes from supermarkets and restaurants and our kitchens. Catching water before it runs off into the sewers - building ponds and attracting birds and insects. Creating urban woodlots of fire and timber wood grown around industrial zones can filter pollution from the air, produce oxygen, create habitat for birds and small animals, and not make all the buildings so damn oppressive. Locals parks could be full of fruit trees and berries. We could graft scion wood of good fruit trees to crab apples in alleyways or non-fruiting cherries and peaches and plums in parks, come back later for the harvest. We can dumpster tons of bathtubs and tires and milk crates and refrigerators and other good stuff to grow things out of. There's more edge and vertical growing space than you can shake a stick at in the city. The possibilities are rich. It's all like sculpture and art - dealing with living systems that change over time. It's so important to bring this stuff into the city, bridge connections between people of different generations and cultures, teach the kids that there's more to life than concrete and hate and fear.

Everyone around here knows me as the aggro city kid, the one who's sometimes too impatient and loud and talks faster than everyone else and goes out smashing up concrete slabs with a sledgehammer and builds raised vegetable beds out of sticks and blackberries just to prove we can grow food even in really crappy soil. As I've lived on this farm for almost an entire growing season, I've learned a little bit of patience and calm and a whole bunch of skills that I'm looking foward to bringing home.

ics; reaching to 90cm. Easily propagated by rhizomes. Often grown commercially as an intercrop with coconut, coffee, citrus, and turmeric (which provides partial shade to young ginger). Rhizomes eaten fresh or preserved for flavouring (candied, dried and powdered).

GRAPE (*Vitis vinifera* & spp.)
Long-lived, deciduous perennial vine, preferring some chill factor for fruiting, but many varieties and cultivars are adapted to a wide climatic and soil range. Planted on trellis, although in ancient times allowed to scramble on mulberry and fig trees.

USES: Fresh fruit; also dried (raisins), wine, juice. Young leaves are used as a food wrapping in cooking (Greek dolmas). Seeds are an excellent cooking oil. Deciduous vines to block summer sun from houses.

HAWTHORNS (*Crataegus* spp.)
Tough, thorny, deciduous shrubs/trees 2-7m high; slow-growing but long-lived (100-300 years). Tolerate partial shade, poor soils.

USES: Edible berries for jellies, conserves. Hedge and windbreak plant for temperate climates, grown extensively as hedgerows in England. Habitat for birds: shelter, nesting and food; useful for poultry. Good bee forage. Coppice wood. Black hawthorn (*C. douglasii*) produces best fruits for human consumption. English hawthorn (*C. monogyna*) makes a narrow, dense hedge. Popular southern European variety is Mediterranean medlar (*C. azarolus*).

HICKORY (*Carya ovata, C. laciniosa, C. ovata*)
Large, deciduous trees (18-45m) yielding nuts through winter to spring; form upright, cylindrical crowns. Yields often irregular, need cross-pollination. PECAN (*C. illinoensis*) most important nut tree of the genus. It needs 150-200 frost-free days, without extremes of cold or heat; suitable for subtropics but grown even in New Zealand.

USES: Nuts as human food; inferior nuts as forage for pigs (also for chickens if cracked and soaked). Excellent wood for tool handles (very tough) and charcoal (imparts flavour to hams in smoking process).

HONEY LOCUST (*Gleditsia triacanthos*)
Deciduous tree 6-40m; very thorny when young, although thornless cultivars have been developed (*G. triacanthos inermis*). Trees have open canopy which allows clovers and pasture to be grown underneath. Frost- and drought-hardy; likes temperate regime of hot summers, cold winters. Tolerates most soils. Although a legume tree, nitrogen-fixing nodules have not been observed in the roots.
Yields up to 110 kgs of pods per tree at years 8-9; at 86 trees/hectare, pod production equivalent to 10 tons/hectare of oat crop. Transplants easily, grows in full sun. Seed pods need to be gathered from trees as soon as they fall in mid-autumn and the seed scarified or boiling water poured over them (and soaked). Select high-yielding, thornless varieties.

USES: Pods are high in sugar (27-30%); pod and seeds 10% protein. Excellent stock fodder, ground or whole, especially during drought or at the end of summer pasture. Durable, quality timber. Excellent bee forage. High sugar content means potential for fuel production, molasses, wine.

HOPS (*Humulus lupus*)
Long-lived (80-100 years) herbaceous perennial climber. Propagate from root cuttings. Naturalises on swamp edges and river banks, scrambles in shrubs and trees or can be wound on hanging cords, wires.

USES: Mainly grown for beer flavouring, but also used as a pillow filling and mild narcotic (hops steeped in sherry to enhance calm and sleepiness). Shoots and tips used as steamed green. Browsed by sheep, geese when young, although sheep can be used in plantations from late spring to winter to browse the grass beneath the hops as commercial hop growers often cut vines to the roots.

HORSERADISH (*Armoracia rusticana*)
Herbaceous perennial 0.5-1m growing from large, edible root. Grows best in cool climates; likes full sun but can grow well in partial shade and useful as an understorey plant. Propagate by root division; all the pieces grow (like comfrey). Root eaten as a condiment. Medicinal uses are as a diuretic, for infections and lung problems.

ICE CREAM BEAN (*Inga edulis*)
Medium, leguminous tree to 12m; subtropical and tropical climates. White fruit pulp from pods used in desserts (said to taste like ice cream). Shade tree for coffee and tea plantations; mid-level understorey tree. Nitrogen-fixer.

JERUSALEM ARTICHOKE (see SUNROOT).

JUJUBE (*Ziziphus jujuba*)
Also called Chinese date. Deciduous tree to 12m; sometimes a large, spiny, dense shrub. Thrives in hot dry regions, alkaline soils, and can withstand severe heat, drought, and some frost. Propagation by stratified seed or root cuttings.

USES: Fruit can be eaten fresh, dried, pickled (resembles dates). Leaves and fruit useful fodder for stock, pigs. Trees coppice well and produce good firewood. Leaves used to feed the tasser silkworm.

KANG KONG (*Ipomoea aquatica*)
Aquatic floating herbaceous perennial found throughout the tropics. Young terminal shoots and leaves used as spinach; rich in minerals and vitamins. Vines are used as

forage; may have potential as chicken, pig food. Can be skimmed off ponds and used as high-nutrient mulch material. May take up heavy metals in polluted waters.

ELDERBERRY (*Sambucus nigra, S. canadensis*)
Deciduous shrub to 6m, temperate climate, tolerates full sun to partial shade. Easily propagated from cuttings.

USES: Hedgerow shrub; windbreak. Ripe berries make wine, dye, conserves (should not be eaten raw). Flowers fermented with lemon juice and peel as a beverage, or infused in hot water for respiratory inflammations. CAUTION: leaves, roots, stems and unripe fruit may be poisonous to humans and to stock.

FEIJOA (*Feijoa sellowiana*)
Also called pineapple guava, although not a true guava. Evergreen shrub 4-6m. Warm temperate areas to subtropics; grows in cool climates but fruits only in hot summers (place in sunny location). Needs shelter from wind. Grown commercially in New Zealand. If growing from seed, notice round tips on leaves in nursery beds; these indicate large-fruited forms and should be selected. Yields 3-4 years from cuttings (taken in summer).

USES: Fruit for dessert, conserves. Petals of flowers are very sweet and used in salads. Ornamental.

FENNEL (*Foeniculum vulgare, F. dulce*)
An upright self-seeding biennial or short-lived hardy perennial with umbel-shaped flowers in summer which attract beneficial insects (insectary plant). Grows in poor soils; naturalises along roadsides in temperate climates. Grows both in full sun or full shade.

USES: Seeds for culinary purposes; seeds and roots medicinally. Foliage as fresh herb, and root of Florence fennel (*F. dulce*) used in salads (crispy like celery, but with an anise flavour); prefers rich garden soil. Stock fodder in controlled quantities is medicinal. Suppresses grasses.

FIG (*Ficus carica*)
Deciduous shrub or tree to 8m; widespread in Mediterranean climates and marginal subtropics (not too wet). Likes full sun; will shade out anything planted underneath unless pruned. Propagated by cuttings. Important commercial crop, eaten fresh or dried. Useful chicken and pig forage. Mulch from dead leaves in autumn.

FILBERT, HAZEL (*C. maxima, Corylus avellana*)
Many varieties, most producing edible nuts (filberts and hazelnuts). Small, deciduous trees or thicket-forming shrubs to 6m; long-lived to 150 years. Grafted varieties start yielding in 5-6 years, with peak nut production at 15 years. Major commercial production in dry, Mediterranean countries, but also suited to cool temperate. Needs cross-pollination. Tolerates shade, but for nut production needs sun; yields best on an edge. Well-drained, fertile soil is best.

USES: Nuts for human food; also as animal forage (low-grade or small nuts). Good hedgerow tree which can be coppiced for poles, stakes, etc.; may need wind shelter in first years.

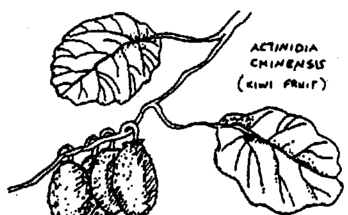
GLIRICIDIA (*Gliricidia sepium, G. maculata*)
Fast-growing, vigorous deciduous tree to 9m; out-competes most tropical grasses. Grows in tropical and subtropical climates. Legume tree.

USES: Widely-used shade tree for banana, coffee, young cocoa. Can be topped to produce material for green manuring. Tolerates repeated coppicing and is used in alley farming and for firewood. Also useful as a firebreak and tropical bee fodder. Durable wood for poles, fenceposts, and stakes. Legume tree.

GUAVA (*Psidium guajava* & other spp.)
Shallow-rooted shrub or small tree, 3-10m; can produce suckers. Adaptable to wide range of soils; susceptible to frost. Drought-tolerant. Sometimes become rampant as seeds are carried by birds.

USES: Fruit eaten fresh, although its numerous seeds make it best for conserves, jellies, paste, juice. Very high vitamin C (2-5 times that of oranges). Strawberry guava (*P. littorale*) hardier, marginally suited to cool areas; place in warm, sunny position.

GINGER (*Zingiber officinale*)
Herbaceous perennial of the humid tropics and subtrop-



NEED A HOME? DIVE A DUMPSTER!

by Brad Lancaster

Two years ago, while looking through other people's garbage for salvageable junk, I came across one heck of a find. There, on the corner of 9th and University, just north of downtown Tucson, stood a decaying adobe bungalow. Built in 1919, the 746-square-foot house cut the one-eighth acre lot in half leaving a good amount of yard space. Since the house was situated on an east-west axis, solar aspect was good. A separate one-car garage on the north edge of the property offered storage, and there were even a sour orange tree, a pomegranate, a white sapote, and three small chaste trees. It felt good, so I talked with my brother, Rodd. Together we made an offer on the house, and we bought it.

What we didn't get were water, electricity, sewer, heating or cooling, functional doors and windows, ceilings, a decent roof, floor, toilet, telephone, or fresh linen. This wasn't so much a house as a humdinger of a fixer-upper on the waiting list to be condemned. As it turns out, it was to become more than the largest salvage operation we'd ever undertaken, and also, an incredible classroom.

Shadecloth stretches over planting beds dug in caliche.

When we started our project, we lacked real experience and knowledge in such areas as roofing, electrical, plumbing, and carpentry. While friends read novels, we read how-to manuals. We also asked plenty of questions. Friends like carpenter John Andrews, network mama Barbara Rose, and others were indispensable. Rodd and I were to do 90% of the work on the house ourselves. We'd be saving money and learning the entire way.

The summer monsoons came and wreaked havoc around town. Streets were flooded and winds blew down over-irrigated ocotillos in landscaped gravel yards, along with the occasional telephone pole. Chaos? No, harvest! Rodd and I pounced on these free resources. We took down the chain link fence around our property and planted

55-gallon drums harvest water from the garage roof.

a living fence of ocotillo canes and agave flower stalks (see PDJ #22). On either side of the fence we started planting a 10-foot wide noise, pollution, light, and privacy buffer that doubled as wildlife habitat. The native plants used had medicinal, food, habitat, bee forage, and nitrogen-fixing value. The saguaros, barrels, and cholla cacti were salvaged from areas slated for clearing.

We traded the chain link fencing at the salvage yard for used 2 x 4's to extend the overhang on our gabled roof, which further protects our walls from rain and summer sun. To complete the job we replaced multiple layers of toxic asphalt with a corrugated steel roof for rain water harvesting.

Neighbors were starting to notice. Actually, they couldn't help but notice as we would wave enthusiastically at anyone who ventured by to show we were friendly and neighborly. We discovered we have great neighbors and have received physical help, security, advice, plants, hot meals, and beer as we plugged away. Gary from across the street came to inspect our progress and offered us his sagging carport/ramada if we'd be willing to dismantle it. The carport became a lumber rack, work bench, and bicycle ramada. There wasn't quite enough wood for the ramada roof; I rounded up a few plywood signs from the recent election and the roof was done, making for a great sleeping platform and rainwater catchment. An old pallet became the ladder and scavenged steel railing became the bike rack.

The temperature was dropping so we turned to our heater — the sun. Our gas water heater was removed and a pantry took its place. We called Tobin Schneider and Bill Cunningham who had designed a passive "bread box" water heater that needed testing. One-inch duct board insulation heat taped to a double thickness of 2 inches makes the box. Tempered double-glazed patio door glass set at a 45 degree angle (for maximum solar gain in the winter) seals the box. Inside is a stripped down gas water heater tank painted black. The black tank absorbs and stores the sun's heat. The box rests on a cradle of sheet metal stripped from the tank. City water pressure moves the water through the whole system. There are no moving parts. We have no backup source of heating water so the City required us to build two boxes to meet code.

When it comes to heating the house, we really get complex: we use our south-facing windows. Seventy-five percent of the windows were termite ridden and rotten. Most we replaced with double glazed windows. The old glass was saved for solar ovens and cold frames. To cut down on summer heat gain we got rid of all west facing glass except for the kitchen window (shaded by our neighbor's house three feet away, on which my other brother Mark painted us a view). All windows can be opened for maximum ventilation. Our extended roof overhang keeps direct sunlight from penetrating our south glass, yet in winter the sun is low enough on the horizon to enter and warm us —especially in the south-facing Arizona room.

In the Arizona Room, Rodd uncovered the only concrete slab in the house. It was an awful surface. Rather than refloor, he cleaned it and stained it with ferrous sulfate (available at any agricultural store). Improvement! The floor looked great and now the darker concrete mass was still exposed for better storage of the passive solar heat. *(The process is as follows: Mix two parts water to one part ferrous sulfate. Brush it on the floor, let it sit one week and then rinse it off. Oil the floor with one part boiled linseed oil to one part turpentine. Let it dry and wax it. That's it, although I hear red wine can be used instead of iron.)*

To further boost winter heat gain, we built a low, sloping retaining wall of local granite rocks facing the Arizona room (the house sits two and a half feet lower than the south half of the property). We collected the rocks for free when we visited our parents, as a developer had formed a rock pile when blading the desert nearby. We avoided using cement in the wall by sloping it and keying the rocks well into each other. The rock wall stops erosion, creates microclimates for a greater diversity of plantings and acts as a high mass heat bank for our home.

This is a great feature for winter, but not summer, so we put in a rounded rebar trellis (see article by Silvia Rayces and Laurence Cohen, PDJ, March 1994). To do this, 1/2-inch rebar is stuck 1-1/2 feet deep in the ground and bent into a curve before attaching it to the roof overhang. The 6-inch concrete mesh we bought for scrap is attached to the rebar, completing the trellis structure. There we grow edible annuals such as Magdelena Big Cheese Squash which cover the trellis in the warm months. The transpiring vegetation shades and cools the house while providing food. The season's first frost kills the squash, giving us mulch, and clearing the trellis to allow full solar heat gain in the winter.

The squash is watered by a 1200 gallon cistern which collects rain water off our roof. It's an oval, ferrocement septic tank elevated two feet above the highest point of our property with earth and rock. This allows us to water by gravity feed — no pumps, no maintenance, no moving parts. The cistern is located along the fence line where our neighbor has a rental cottage. In this location, the cistern acts as a fire break, a privacy screen, and a temperature moderator for our orange tree just to the north. The tree shades the cistern and drops leaves for mulch.

Organic droppings and prunings from around the yard and neighborhood were mixed with manure delivered to us free from an overflowing stable. All was composted and then spread as a one-foot deep mulch in all planting areas. This alone cut all watering needs by two-thirds.

Rodd replumbed the house and I rewired it. A low-flush toilet was installed to meet code and we could now read on porcelain of our own rather than that of the public library down the street. However, I still don't feel comfortable yellowing city drinking water via the toilet, so the yard plants usually receive my water. We are also researching composting toilet designs we can implement to give the trees and ornamentals a little humanure too.

Toilet aside, our bathtub was also being filled with water, and it pained us to watch it all go down the drain. That water had to be harvested! Problem was, the tub drain was lower than the rest of the property. So we ran a 1/2-inch vinyl tube through the window jam, with one end suction-cupped to the bottom of the tub and the other end lying under the winter-deciduous black mission fig which shades the bedroom in the summer. A simple hand pump gets the siphon going and that's it. If I want to use the tub water on the north side of the house, I hook the hose to an old half-inch irrigation line which deposits the water on a couple of Asian pears and a loquat.

Back inside the house we chipped off what remained of the crumbling plaster ceilings and walls. Rather than using dry wall we cleaned the existing wood lath and patched with new plaster by grooving mortar joints a quarter to a half inch — no chicken wire was needed! We then replastered with dual-purpose gypsum (it's easier to work with as it has a slower setting time than other gypsum), mixed at 3 parts mortar sand to one part gypsum. Once the plaster dried we put in baseboards, trim and shelves fabricated from wood salvaged from nearby dumpsters. The walls were primed eggshell white and then washed with paint we made on the advice of Barbara Rose. Paint recipe: equal parts boiled linseed oil and turpentine mixed with concrete pigments, and then washed on with rags or a sponge.

All that remained was the old Douglas fir floor. Layers of old carpet and linoleum had been peeled up to find lots of termite damage. As it turns out, the floor joists of our floor were resting on dirt. So we crawled under the floor and started digging. We excavated a 2-3 foot crawl space under the entire floor. This provided us with a cool storage for our

CHOKO
(SECHIUM EDULE)

the fruit, a large bland vegetable which can be baked, steamed, or fried with other vegetables. Used to smother less vigorous plants such as lantana, and is a good roof covering for summer. Pig and poultry food.

COMFREY (*Symphytum officinale*)
Herbaceous perennial to 1m high. Dies down in winter, except in mild climates. Easily propagated by root division; any part of the root crown will grow. Clumps of comfrey will stay in one place, but if dug or rototilled will spread quickly. High yields on fertile, watered country. 20-25% crude protein.

USES: Excellent bee forage. Stock fodder if fed in limited quantities (overfeeding has been shown to cause some liver damage in animals). Medicinal herb: roots dried, powdered and used in ointments for bruises, arthritis, broken bones. Vegetable source of vitamin B12, and can be used sparingly in salads, cooking. Rich source of mulch (high potash) and is combined with other leaves and manures for a nutrient-rich "manure tea".

CURRANTS and GOOSEBERRIES (*Ribes* spp.)
Small deciduous shrubs (0.5-1m) tolerating partial-shade; good hardy understorey bush tolerating neglect. Hardwood cuttings taken in autumn root easily. Bear 10-20 years if properly cared for. Mostly temperate plants.

USES: Tasty small fruits which can be eaten raw or made into juice, wine, jelly. Wildlife forage food, including birds and poultry (plants may need to be netted if used entirely for human food). Edible species: black currant (*R. nigrum*), golden currant (*R. aureum*), red currant (*R. rubrum*) Excellent bee forage. Also ornamental, especially golden currant and red-flowering currant (*R. sanguineum*). Gooseberries (*R. grossularia*) grow successfully in rock crevices; like well-drained positions.

CUMBUNGI or CATTAIL (*Typha latifolia, T. orientalis*)
Dense, herbaceous perennial to 4m; grows in full sun or shade around pond edges. Caution: Can be an invasive weed. Temperate to subtropical climates.

USES: Shoots edible, used like asparagus. Roots are peeled,cooked or grated raw. Seeds, roasted, have nutty flavour. Animal forage, mainly roots, especially for pigs. Weaving material, basketry. Duck and water fowl habitat. Seed head is of downy material; can be used as tinder. Extracts pollutants from water.

DANDELION (*Taraxacum officinale*)
Small perennial herb with yellow flowers early spring to late autumn. Grows in temperate to subtropical areas and is a common weed on lawns, pastures. Grows in full sun or shade.

USES: Leaves, roots, flowers eaten; roots are used as a coffee subsitute. Flowers can be used to make wine. Important bee forage with early and long flowering; high pollen yield. Forage crop, improves milk quality and quantity; good mix with lucerne.

DAYLILY (*Hemerocallis fulva*)
Herbaceous perennial to 0.6m, temperate to subtropical climates. Tolerates partial shade; useful understorey plant. USES: Edible shoots, flowerbuds, flowers, tubers. Low-maintenance plant; erosion control on hillsides. Ornamental. Grow under trees as part of guild with marigolds, dill, nasturtium, etc.

DUCKWEED (*Lemna minor*)
Perennial floating aquatic of ponds (likes quiet water); temperate climates. May completely cover a pond and exclude light. USES: Duck, goose, fish

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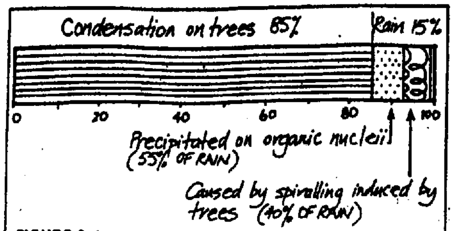


FIGURE 6.4
PERCENTAGES OF TOTAL PRECIPITATION
On a sea-facing hillside, trees as condensers, providers of bacterial ice nucleii, inducers of stream line compression, and re-humidifiers of the airstream create most of the conditions that create precipitation.

water-laden air flows inland. Where this humid air flows over the rapidly cooling surfaces of glass, metal, rocks, or the thin laminae of leaves, condensation occurs, and droplets of water form. On leaves, this may be greatly aided by the colonies of bacteria (*Pseudomonas*) which also serve as nucleii for frost crystals to settle on leaves.

These saturated airstreams produce seaward-facing mosses and lichens on the rocks of fresh basalt flows, but more importantly condense in trees to create a copious soft condensation which, in such conditions, may far exceed the precipitation caused by rainfall. Condensation drip can be as high as 80–86% of total precipitation of the upland slopes of islands or sea coasts, and eventually produces the dense rainforests of Tasmania, Chile, Hawaii, Washington/Oregon, and Scandinavia. It produced the redwood forests of California and the giant laurel forests of pre-conquest Canary Islands (now an arid area due to almost complete deforestation by the Spanish).

A single tree such as a giant Til (*Ocotea foetens*) may present 16 ha of laminate leaf surface to the sea air, and there can be 100 or so such trees per surface hectare, so that trees enormously magnify the available condensation surface. The taller the trees, as for example the giant redwoods and white pines, the larger the volume of moist air intercepted, and the greater the precipitation that follows.

All types of trees act as condensers; examples are Canary Island pines, laurels, holm oaks, redwoods, eucalypts, and Oregon pines. Evergreens work all year, but even deciduous trees catch moisture in winter. Who has not stood under a great tree which "rains" softly and continuously at night, on a clear and cloudless evening? Some gardens, created in these conditions, quietly catch their own water while neighbours suffer drought.

The effects of condensation of trees can be quickly destroyed. Felling of the forests causes rivers to dry up, swamps to evaporate, shallow water to dry out, and drought to grip the land. All this can occur in the lifetime of a person.

Precipitation from clear air is much less than that from fog, from which the precipitation by condensation often exceeds the local rainfall. Advection fogs are most noticeable where cold currents such as the Oya Shio off East Asia and the Labrador current off northeast America cause humid inland airstreams in spring and summer. Southfacing coasts near Newfound-land get 158 days of fog per year. Wherever mountains or their foothills face onshore night winds, fog condensation will probably exceed rainfall. On Table Mountain (South Africa) and on Lanai (Hawaii), fog drip has been measured at 130–330 cm, and in both cases condensation exceeds rainfall. Redwoods in California were once restricted to the fog belt, but will grow well in areas of higher rainfall without fogs

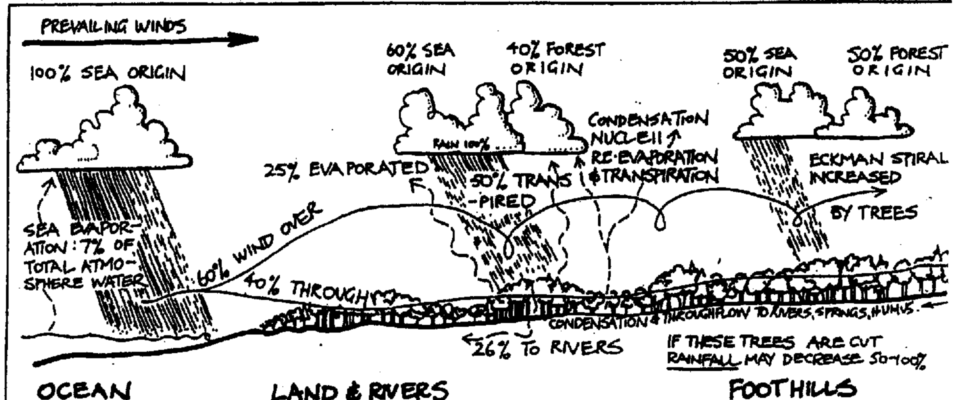


FIGURE 6.5
FOREST INTERACTIONS WITH CLIMATE. (Based on work in Brazil).
Forests inland produce most of the water for subsequent rainfall; recycled water is repeatedly transpired to the airstream.

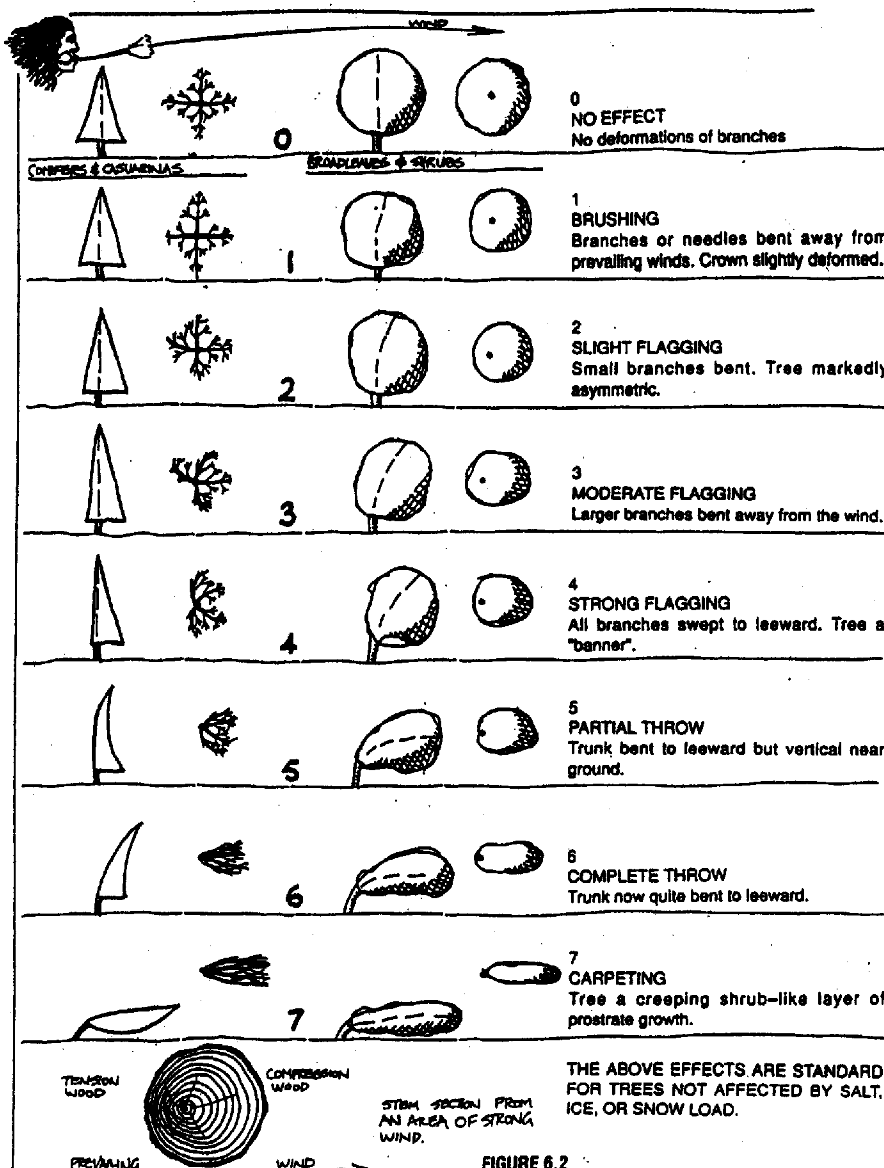


FIGURE 6.2
WIND EFFECTS ON TREES
As winds cross tree lines they are deflected in a new direction. Trees deform or "flag" permanently in prevailing strong winds and can be used to assess the effects of such winds; they form a site-record of wind history.

can place windbreak to reduce heat loss in homes, to avoid damage in catastrophic winds, and to steer the winds to well-placed wind machines.

TABLE 6.1
RELATIONSHIP BETWEEN GRIGGS AND PUTNAM INDEX (G) AND ANNUAL MEAN WIND SPEED (V). IN m/sec.

G	V (m/sec.)	mph
0	<3.3	<7.5
1	3.3 - 4.2	7.5 - 9.5
2	4.3 - 5.1	9.6 - 11.5
3	5.2 - 6.2	11.6 - 14
4	6.3 - 7.5	14 - 17
5	7.6 - 8.5	17 - 19
6	8.6 - 11	19 - 24
7	>11	> 24

[From Wade, John E., and Wendell Hewson, 1979, *Trees as indicators of wind power potential*, Dept. of Atmospheric Sciences, Oregon State University.]

6.4
TEMPERATURE EFFECTS

EVAPORATION causes heat *loss* locally and CONDENSATION causes heat *gain* locally. Both effects may be used to heat or cool air or surfaces. The USDA's Yearbook of Agriculture on Trees (1949) has this to say about the evaporative effects of trees: "An ordinary elm, of medium size, will get rid of 15,000 pounds of water on a clear dry hot day" and "Evapotranspiration (in a 40 inch rainfall) is generally not less than 15 inches per year."

Thus, the evaporation by day off trees cools air in hot weather, while the night condensation of atmospheric water warms the surrounding air. Moisture will not condense unless it finds a surface to condense *on*. Leaves provide this surface, as well as contact cooling. Leaf surfaces are likely to be cooler than other objects at evening due to the evaporation from leaf stomata by day. As air is also rising over trees, some vertical lift cooling occurs, the two combining to condense moisture on the forest. We find that leaves are 86% water, thus having twice the specific heat of soil, remaining cooler than the soil by day and warmer at night. Plants generally may be 15°C or so warmer than the surrounding air temperature.

Small open water storages or tree clumps upwind of a house have a pleasant moderating effect. Air passing over open water is cooled in summer. It is warmed and has moisture added even in winter. Only water captured by trees, however, has a DEHUMIDIFYING effect in hot and humid tropical areas, as trees are capable of reducing humidity by direct absorption except in the most extreme conditions.

Reddish-coloured leaves, such as are developed in some vines and shrubs, reflect chiefly red light rays. Sharp decreases in temperature may result by interposing reddish foliage between a thermometer and the sun, up to 20°C (36°F) lower than with green pigmented plants (Daubenmire, 1974). Whitish plants such as wormwood and birch may reflect 85% of incoming light, whereas the dark leaves of shade plants may reflect as little as 2%. It follows that white or red-coloured roof vines over tiles may effectively lower summer temperatures within buildings or in trellis systems. Additional cooling is effected by fitting fine water sprays and damp mulch systems under trellis, thus creating a cool area of dense air by evaporation. This effect is of great use in moderating summer heat in buildings, and for providing cool air sources to draw from by induced cross-ventifilation.

6.5
TREES AND PRECIPITATION

Trees have helped to create both our soils and atmosphere. The first by mechanical (root pressure) and chemical (humic acid) breakdown of rock, adding life processes as humus and myriad decomposers. The second by gaseous exchange, establishing and maintaining an oxygenated atmosphere and an active water-vapour cycle essential to life.

The composition of the atmosphere is the result of reactive processes, and forests may be doing about 80% of the work, with the rest due to oceanic or aquatic exchange. Many cities, and most deforested areas such as Greece, no longer produce the oxygen they use.

The basic effects of trees on water vapour and windstreams are:

- Compression of streamlines, and induced turbulence in air flows;
- Condensation phenomena, especially at night; Rehumidification by the cycling of water to air;
- Snow and meltwater effects; and
- Provision of nuclei for rain.

We can deal with each of these in turn (realizing that they also interact).

COMPRESSION AND TURBULENCE EFFECTS

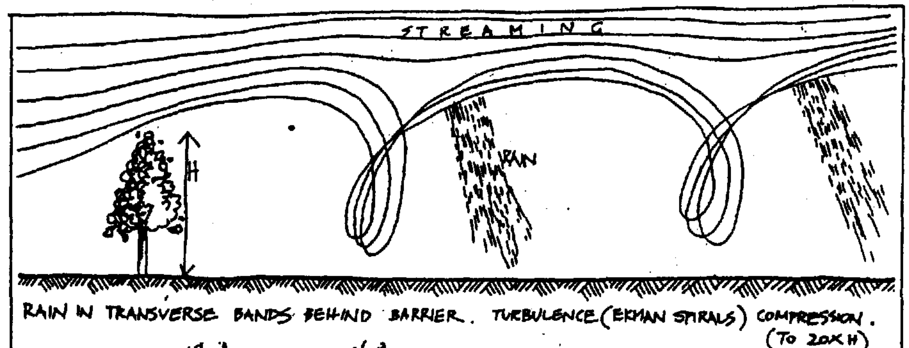
Windstreams flow across a forest. The streamlines that impinge on the forest edge are partly deflected over the forest (almost 60% of the air) and partly absorbed into the trees (about 40% of the air). Within 1000 m (3,300 feet) the air entering the forest, with its tonnages of water and dust, is brought to a standstill. The forest has swallowed these great energies, and the result is an almost imperceptible warming of the air within the forest, a generally increased humidity in the trees (averaging 15–18% higher than the ambient air), and air in which no dust is detectable.

Under the forest canopy, negative ions produced by life processes cause dust particles (++) to clump or adhere each to the other, and a fall-out of dispersed dust results. At the forest edge, thick-stemmed and specially wind-adapted trees buffer the front-line attack of the wind. If we cut a windward forest edge, and remove these defences, windburn by salt, dust abrasion, or just plain windforce may well kill or throw down the inner forest of weaker stems and less resistant species. This is a commonly observed phenomenon, which I have called "edge break". Conversely, we can set up a forest by planting tough, resistant trees as windbreak, and so protect subsequent downwind plantings. Forest edges are therefore to be regarded as essential and *permanent* protection and should never be cut or removed.

If dry hot air enters the forest, it is shaded, cooled, and humidified. If cold humid air enters the forest, it is warmed, dehumidified, and slowly released via the crown of the trees. We may see this warm humid air as misty spirals ascending from the forest. The trees modify extremes of heat and humidity to a life-enhancing and tolerable level.

The winds deflected over the forest cause compression in the streamlines of the wind, an effect extending to twenty times the tree height, so that a 12 m (40foot) high line of trees compresses the air to 244 m (800 feet) above, thus creating more water vapour per unit volume, and also cooling the ascending air stream. Both conditions are conducive to rain.

As these effects occur at the forest EDGE, a single hedgerow of 40% permeability will cause similar compression. In flat country, and especially in the path of onshore winds, fine grid placements of rain gauges in such countries as Holland and Sweden reveal that 40% of the rainfall measured down-wind of trees and mounds 12 m (40 feet) or more in height is caused by this compression phenomena. If wind speeds are higher (32 km/h or more), the streamlines may be preserved, and rain falls perpendicular to the windbreak. However, at lower wind speeds (the normal winds), turbulence and overturn occurs.



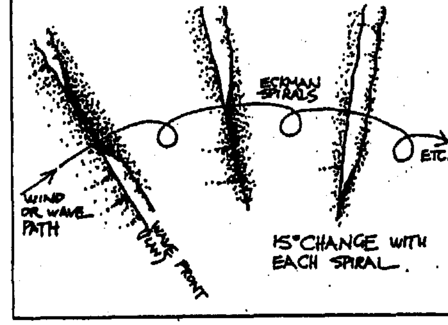


FIGURE 6.3
EKMAN SPIRALS
Wind overturn, repeated 4–5 times downwind causes compression of streamlines resulting (in the right conditions) in bands of rain.

Wind streaming over the hedgerow or forest edge describes a spiral section, repeated 58 times downwind, so that a series of compression fronts, this time parallel to the windbreak, are created in the atmosphere. This phenomena was first described by Ekman for the compression fronts created over waves at sea.

The Ekman spirals over trees or bluffs may result in a ranked series of clouds, often very regular in their rows. They are not perfectly in line ahead, but are deflected by drag and the Coriolus force to change the wind direction, so that the wind after the hedgerow may blow 5–15 degrees off the previous course. (One can imagine that ranks of hedgerows placed to take advantage of this effect would eventually bring the wind around in a great ground spiral.)

Winds at sea do in fact form great circuses, and bring cyclonic rains to the westerly oceanic coasts of all continents. These cyclones themselves create warm and cold fronts which ridge up air masses to create rain. In total, hedgerows across wind systems have a profound effect on the airstreams passing over them, and a subsequent effect on local climate and rainfall.

CONDENSATION PHENOMENA

On the sea-facing coasts of islands and continents, the relatively warmer land surface creates quiet inshore airflows towards evening, and in many areas cooler

(Chang, 1968). In Sweden "... wooded hills rising only 3050 m (9,500 feet) above the surrounding plains may cause precipitation (rain only) during cyclonic spells (fronts) to be increased by 50–80% compared with average falls over the lowland." In most countries, however, the rain gauge net is too coarse to detect such small variations (Chorley and Berry, 1971).

REHUMIDIFICATION OF AIRSTREAMS

If it rains again, and again, the clouds that move inland carry water mostly evaporated *from forests*, and less and less water evaporated from the sea. Forests are cloud-makers both from water vapour evaporated from the leaves by day, and water transpired as part of life processes. On high islands, standing clouds cap the forested peaks, but disappear if the forests are cut. The great bridging cloud that reached from the forests of Maui to the island of Kahoolawe, remembered by the fathers of the present Hawaiian settlers, has disappeared as cutting and cattle destroyed the upper forests on Maui and so lifted the cloud cap from Kahoolawe, leaving this lower island naked to the sun. With the cloud forests gone, and the rivers dry, Kahoolawe is a true desert island, now used as a bombing range for the U.S. Air Force.

A large evergreen tree such as *Eucalyptus globulus* may pump out 3,600–4,500 l of water a day, which is how Mussolini pumped dry the Pontine marshes of Italy. With sixty or so of these trees to the hectare, many tens of thousands of litres of water are returned to the air to become clouds.

A forest can return (unlike the sea) 75% of its water to air, "in large enough amounts to form new rain clouds." [Bayard Webster, "Forests' Role in Weather Documented in Amazon", *New York Times* (Science Section), 5 July '83]. Forested areas return ten times as much moisture as bare ground, and twice as much as grasslands. In fact, as far as the atmosphere itself is concerned, "the release of water from trees and other plants accounts for half, or even more, of all moisture returned to air." (Webster, *ibid.*) This is a critical finding that adds even more data to the relationship of desertification by deforestation.

It is data that no government can ignore. Drought in one area may relate *directly* to deforestation in an upwind direction. This study "clearly shows that natural vegetation must play an important role in the forming of weather patterns" (quote from Thomas E. Lovejoy, Vice-president of Science, World Wildlife Fund).

Clouds form above forests, and such clouds are now mixtures of oceanic and forest water vapour, clearly distinguishable by careful isotope analysis. The water vapour from forests contain more organic nuclei and plant nutrients than does the "pure" oceanic water. Oxygen isotopes are measured to determine the forests' contribution, which can be done for any cloud system.

Of the 75% of water returned by trees to air, 25% is evaporated from leaf surfaces, and 50% transpired. The remaining 25% of rainfall infiltrates the soil and eventually reaches the streams. The Amazon discharges 44% of all rain falling, thus the remainder is either locked into the forest tissue or returns to air. Moreover, over the forests, *twice as much rain falls than is available from the incoming air*, so that the forest is continually recycling water to air and rain, producing 50% of its own rain (Webster, *ibid.*). These findings forever put an end to the fallacy that trees and weather are unrelated.

Vogel (1981), applying the "principle of continuity" of fluids to a tree, calculates that sap may rise, in a young oak, fifty times as fast as the leaves transpire (needing only 7% of the total trunk area as conductive tissue, with an actual sap speed of 1 cm/sec). It is thus certain that only perhaps one-fiftieth of the xylem is conducting sap upwards at any one time, and that most xylem cells contain either air or sap at standstill. Perhaps too, the tree moves water up in pulsed stages rather than as a universal or continuous streamflow.

With such rapid sap flows, however, we can easily imagine the water recycled to atmosphere by a large tree, or a clump of smaller trees.

It is a wonder to me that we have any water available after we cut the forests, or any soil. There are dozens of case histories in modern and ancient times of such desiccation as we find on the Canary Islands following deforestation, where rivers once ran and springs flowed. Design strategies are obvious and urgent—save all forest that remains, and plant trees for increased condensation on the hills that face the sea.

EFFECTS ON SNOW AND MELTWATER

Although trees intercept some snow, the effect of shrubs and trees is to entrap snow at the edges of clumps, and hold 75–95% of snowfall in shade. Melting is delayed for 210 days compared with bare ground, so that release of snowmelt is a more gradual process. Of the trapped snow within trees, most is melted, while on open ground snow may sublime directly to air. Thus, the beneficial effects of trees on high slopes is not confined to humid coasts. On high cold uplands such as we find in the continental interiors of the U.S.A. or Turkey near Mt. Ararat, the thin skeins of winter snow either blow off the bald uplands, to disappear in warmer air, or else they sublime directly to water vapour in the bright sun of winter. In neither case does the snow melt to groundwater, but is gone without productive effect, and no streams result on the lower slopes.

Even a thin belt of trees entraps large quantities of driven snow in drifts. The result is a protracted release of meltwater to river sources in the highlands, and stream-flow at lower altitudes. When the forests were cleared for mine timber in 1846 at Pyramid Lake, Nevada, the streams ceased to flow, and the lake levels fell. Add to this effect that of river diversion and irrigation, and whole lakes rich with fish and waterfowl have become dustbowls, as has Lake Winnemucca. The Cuiuidika's Indians (Paiute) who live there lost their fish, waterfowl, and freshwater in less than 100 years.

80% as a result of divine forgetfulness), it acts as the agent of the oak. When the squirrel or wallaby digs up the columella of the fungal tree root associates, guided to these by a garlic-like smell, they swallow the spores, activate them enzymatically, and deposit them again to invest the roots of another tree or sapling with its energy translator.

The root fungi intercede with water, soil, and atmosphere to manufacture cell nutrients for the tree, while myriad insects carry out summer pruning, decompose the surplus leaves, and activate essential soil bacteria for the tree to use for nutrient flow. The rain of insect faeces may be crucial to forest and prairie health.

What part of this assembly is the tree? Which is the body or entity of the system, and which the part? An Australian Aborigine might give them all the same "skin name", so that a certain shrub, the fire that germinates the shrub, and the wallaby that feeds off it are all called *waru*, although each part also has its name. The Hawaiians name each part of the taro plant differently, from its child or shoot, to its nodes and "umbilicus".

It is a clever person indeed who can separate the total body of the tree into mineral, plant, animal, detritus, and life! This separation is for simple minds; the tree can be understood only as its total entity which, like ours, reaches out into all things. Animals are the messengers of the tree, and trees the gardens of animals. Life depends upon life. All forces, all elements, all life forms are the biomass of the tree.

A large tree has from 10,000 to 100,000 growing points or MERISTEMS, and each is capable of individual mutation. Unlike mammals, trees produce their seed from multitudinous flowers. Evidence is accumulating that any one main branch can therefore be an "individual" genetically. Some deciduous poplars may produce a single evergreen branch. "Seedlessness" in fruit, or a specific ripening time, may belong only to one branch. Grafts and cuttings perpetuate these isolated characteristics, so we must look upon the tree itself as a collection of compatible genetic individuals, each with a set of persistent characteristics which may differ from place to place on the tree, and each of which may respond differently to energy and other stimuli. Like ourselves, trees are a cooperative amalgam of many individuals; some of these are of the tree body, but most are free-living agents. As little as we now know about trees, they stand as a witness to the complex totality of all life forms.

6.3

WIND EFFECTS

Vogel (1981) notes that as wind speed increases, the tree's leaves and branches deform so that the tree steadily reduces its exposed leaf area. At times of very high winds (in excess of 32 m/sec) the interception of light, efficient water use, and convective heat dissipation by the tree becomes secondary to its survival.

Vogel also notes that very heavy and rigid trees spread wide root mats, and may rely more totally on their weight, withstanding considerable wind force with no more attachment than that necessary to prevent slide, while other trees insert gnarled roots deep in rock crevices, and are literally anchored to the ground.

The forest bends and sways, each species with its own amplitude. Special wood cells are created to bear the tension and compression, and the trees on the edge of a copse or forest are thick and sturdy. If we tether a tree halfway up, it stops thickening below the tether, and grows in diameter only above the fixed point. Some leaves twist and reverse, showing a white underside to the wind, thus reflecting light energy and replacing it with kinetic or wind energy. In most cases, these strikingly light-coloured leaves are found only in forest edge species, and are absent or uncommon within the forest.

As streamlines converge over trees or hills, air speed increases. Density and heat may also increase, resulting in fast low-pressure air. To leeward of the obstruction, such streamlines diverge, and an area of slower flow, higher pressure, and cooler air may result. If rain has fallen due to the compression of streamlines, however, the latent heat of evaporation is released in the air, and this drier air can be warmer than the air mass rising over the obstruction. The pressure differentials caused by uplift and descent may affect evaporation as much as wind drying or heat.

Apart from moisture, the wind may carry heavy loads of ice, dust, or sand. Strand trees (palms, pines, and *Casuarinas*) have tough stems or thick bark to withstand wind particle blast. Even tussock grasses slow the wind and cause dust loads to settle out. In the edges of forests and behind beaches, tree lines may accumulate a mound of driven particles just within their canopy. The forest removes very fine dusts and industrial aerosols from the airstream within a few hundred metres.

Forests provide a nutrient net for materials blown by wind, or gathered by birds that forage from its edges. Migrating salmon in rivers die in the headwaters after spawning, and many thousands of tons of fish remains are deposited by birds and other predators in the forests surrounding these rivers. In addition to these nutrient sources, trees actively mine the base rock and soils for minerals.

The effect of the wind on trees is assessed as the Griggs and Putnam index (Table 6.1), and the accompanying deformations in both crown shapes and growth (as revealed in stems) is given a value which is matched to wind speeds with an average 17% accuracy.

Such scales and field indicators are of great use in design. When we go to any site, we can look at the condition of older trees, which are the best guide to gauge wind effect. Trees indicate the local wind direction and intensity, and from these indicators we

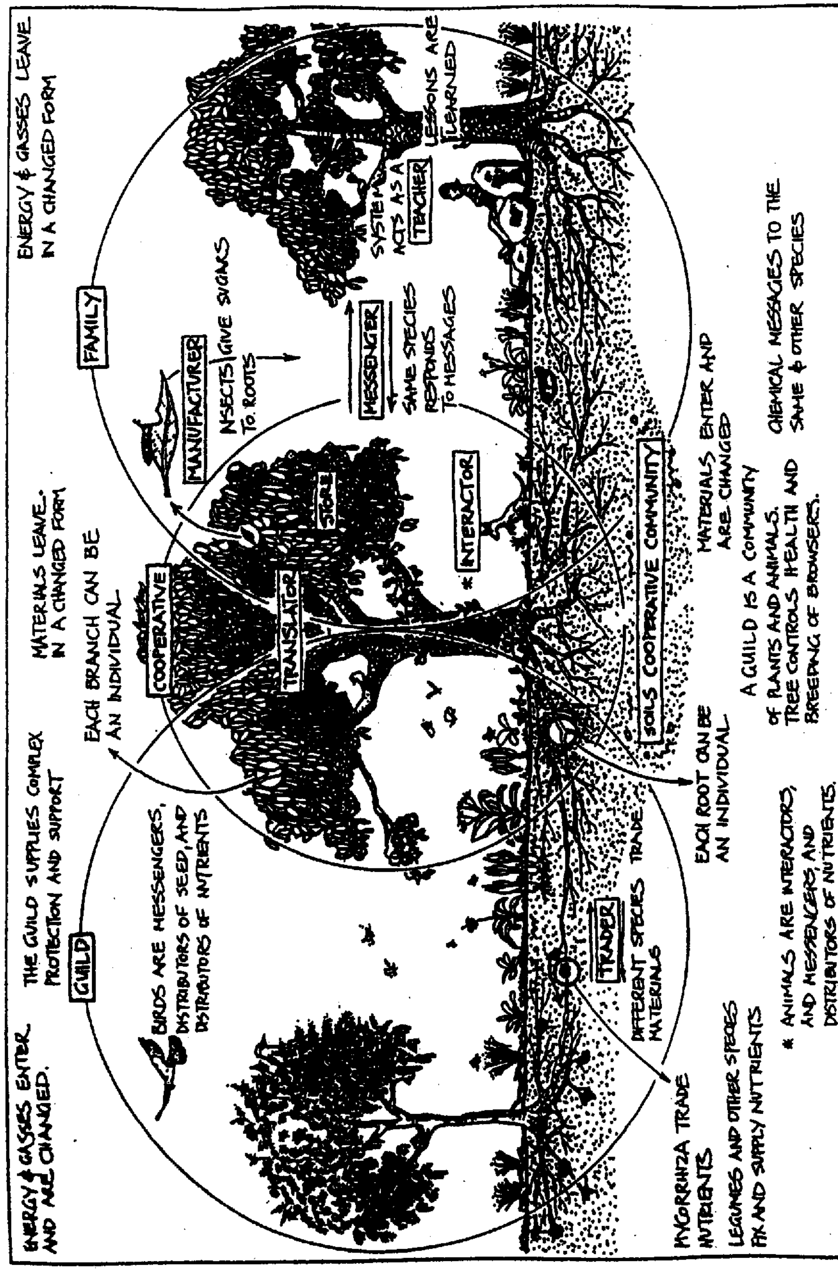
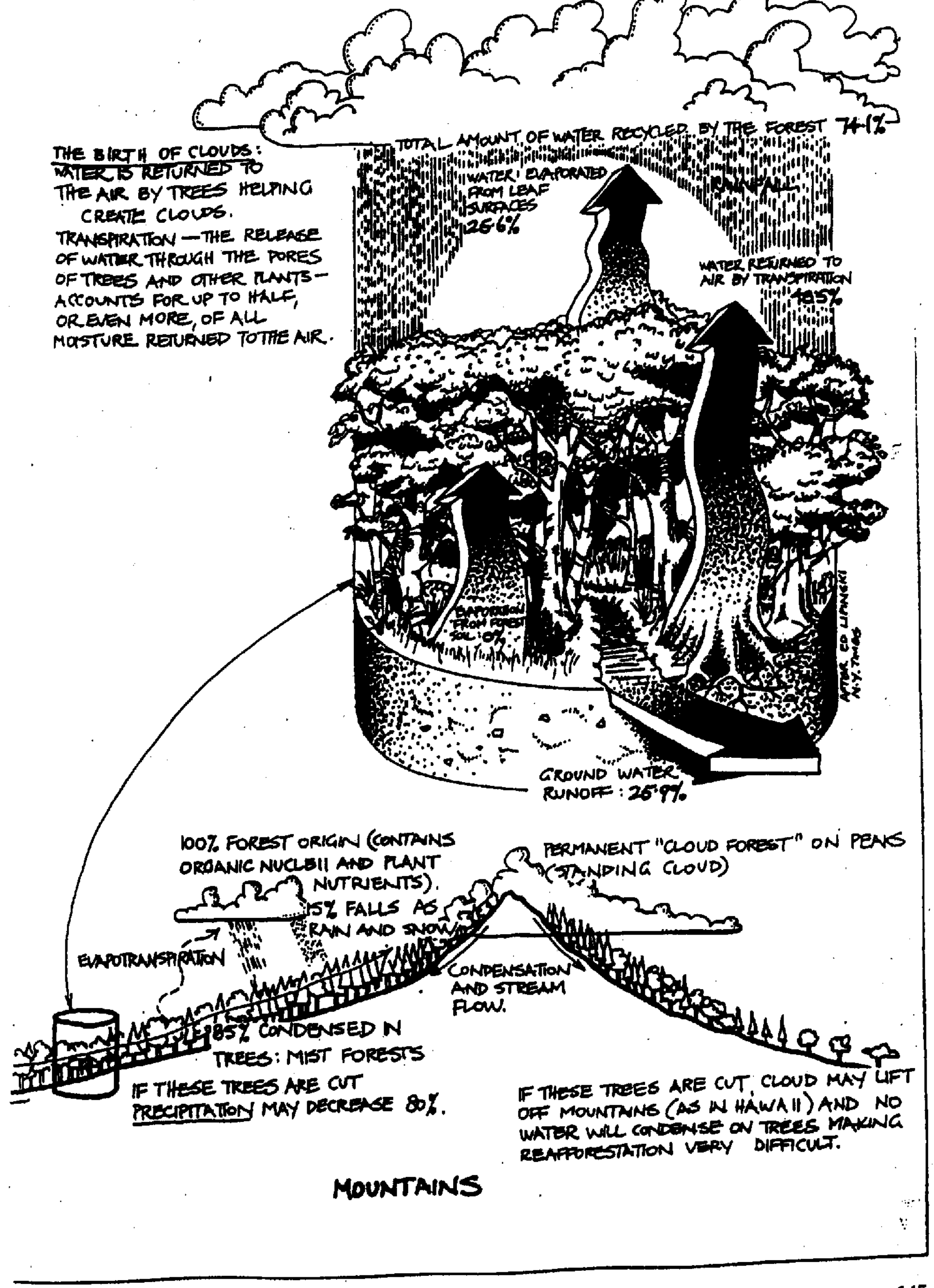


FIGURE 6.1
TREES IN A WHOLE SYSTEM
The tree itself is a cooperative, depends on a guild, is a member of a family of like species, and is involved in the creation of complex molecules from inorganic and organic elements – a transformer, or translator, of gases, liquids, and solids.



Broadly speaking, interception commonly falls between 10–15% of total rainfall. *Least* interception occurs in thinned and deciduous forests, winter rain, heavy showers, and cloudy weather conditions, when it is as little as 10% of rain. *Most* interception occurs with dense, evergreen trees, light summer rain, and sunny conditions, when it may reach 100% of the total.

However, if more rain falls, or heavy rains impact on the trees, water commences to drift as mists or droplets to earth. This water is called THROUGHFALL. Throughfall depends on the intensity of rain, and there is little interception effect in heavy downpours. As an average figure, the throughfall is 85% of rain in humid climates.

At this point, throughfall is no longer just rainwater, any more than your bathwater is rainwater; throughfall contains many plant cells and nutrients, and is in fact a much richer brew than rainwater. Dissolved salts, organic content, dust, and plant exudates are included in the water of throughfall (Table 6.2). "The results show that rain washes large amounts of potassium and smaller amounts of nitrogen, phosphorus, calcium, and magnesium from the canopies to the surface soil. Litter adds organic matter, and is a rich source of calcium and nitrogen and a moderately rich source of magnesium and potassium." (Murray, J. S. and Mitchell, A., *Red Gum and the Nutrient Balance*, Soil Conservation Authority, Victoria, Australia, undated).

Nor can throughfall be measured in rain gauges, for the trees often provide special receptors, conduits, and storages for such water. The random fall of rain is converted into well-directed patterns of flow that serve the needs and growth in the forest. In the stem bases of palms, plantains, and many ephiphytes, or the flanged roots of *Terminalia* trees and figs, water is held as aerial ponds, often rich in algae and mosquitoes. Stem mosses and epiphytes absorb many times their bulk of water, and the tree itself directs water via insloping branches and fissured bark to its tap roots, with spiders catching their share on webs, and fungi soaking up what they need. Some trees trail weeping branches to direct throughfall to their fibrous peripheral roots.

With the aerial resevoirs filled, the throughfall now enters the humus layer of the forest, which can itself (like a great blotter) absorb 1 cm of rain for every 3 cm of depth. In old beech forests, this humus blanket is at least 40 cm deep, and the earth below is a mass of fungal hyphae. In unisturbed rainforest, deep mosses may carpet the forest floor. So, for 40-60 cm depth, the throughfall is absorbed by the decomposers and living systems of the humus layer. Again, the composition of the water changes, picking up humic exudates, and water from deep forests and bogs may then take on a clear golden colour, rather like tea.

TABLE 6.2
Nutrient content of litter, canopy drip, and rain in the open of a naturally regenerating stand of red gum (*Eucalyptus camaldulensis*), Gringegalgona, VIC, Australia. [Source: Murray, J.S., and A. Mitchell, Red Gum and the Nutrient Balance, Soil Conservation Authority, Australia (undated)].

SOURCE	PERIOD*	TOTAL RAIN (in.)	NUTRIENT RETURN (LB/A.)							TOTAL LITTER (lb.)
			N	P	K	Ca	Mg	Na	Cl	
Old trees: (5% of Total) LITTER	1*	-	19.0	1.2	6.0	25.0	6.0	4.0	ND	2,800
CANOPY DRIP	1	30.67	6.0	1.1	28.0	13.0	11.0	71.0	143.0	-
TOTAL	1	30.67	25.0	2.3	34.0	38.0	17.0	75.0	-	
Regrowth: (95% of Total) LITTER	1		38.0	1.9	10.0	49.0	15.0	5.0	ND	5,400
CANOPY DRIP	1	30.67	3.0	0.7	16.0	6.0	5.0	29.0	51.0	
TOTAL	1	30.67	41.0	2.6	26.0	55.0	20.0	34.0	-	
Rain: Nearby	2*	9.25	0.5	0.1	0.7	0.8	0.7	4.2	7.0	
Coleraine§	3*	33.61	0.5	ND	1.5	3.0	3.0	21.0	38.0	
Cavendish §	4*	21.75	ND	ND	1.0	3.0	2.0	14.0	20.0	

*1: 5/5/60 - 4/5/61. *2: 22/11/60 - 4/5/61. *3: 1/9/55 - 1/9/56. *4: 1/9/54 - 1/9/55.
§ From Hutton and Leslie (1958). ND = Not Determined.

Chapter 6

TREES AND THEIR ENERGY TRANSACTIONS

On the dry island of Hierro in the Canary Islands, there is a legend of the rain tree; a giant 'Til' tree (*Ocotea foetens*), "... the leaves of which condensed the mountain mists and caused water to drip into two large cisterns which were placed beneath. The tree was destroyed in a storm in 1612 A.D. but the site is known, and the remnants of the cistern preserved ... [This one tree] distilled sufficient water from the sea mists to meet the needs of all the inhabitants."

(David Bramwell)

For me, trees have always been the most penetrating teachers. I revere them when they live in tribes and families, in forests and groves... They struggle with all the forces of their lives for one thing only: to fulfill themselves according to their own laws, to build up their own forms, to represent themselves. Nothing is holier, nothing is more exemplary, than a beautiful strong tree.

(Herman Hesse, "Trees", *Natural Resources Journal*, Spring 1980)

I am astonished to find whole books on the functioning of trees which make no mention of their splendid mechanical and aerodynamic performance.

(Vogel, *Life in Moving Fluids*, 1981)

A point which is often overlooked is the effect of trees in increasing the total precipitation considerably beyond that recorded by rain gauges. A large proportion of the rime which collects on the twigs of trees in frosts afterwards reaches the ground as water, and, in climates such as those of the British Isles, the total amount of water deposited on the twigs from fogs and drifting clouds is considerable, and most of it reaches the streams or underground storage, or at least replaces losses from subsequent rainfall.

Of more importance, however, to hydraulic engineers is the effect of woodlands in modifying the run-off. The rush of water from bare hillsides is exchanged for the slower delivery from the matted carpet of the woodland, losses by evaporation may be much diminished and the melting of snow usefully retarded. In catchments from which flood waters are largely lost, woodlands may increase the available runoff by extending the period of surface flow. The maximum floods of rivers are reduced, and the lowest summer flow increased. Woodlands are usually much more effective than minor vegetation, such as gorse and heather, in preventing the soil from being carried from the land into an open reservoir.

To protect a reservoir from silting, it may be unnecessary to plant large areas, the silt being arrested by suitable planting of narrow belts of woodland, or by the protection of natural growth, along the margins of the streams.

Some engineers consider that in the case of small reservoirs the shelter afforded by a belt of trees along the margins is of value in reducing the amount of scour of the banks caused by wave action. Afforestation over considerable areas in large river basins would, in many cases, reduce the amount of silting in navigable rivers and estuaries.

A matter which does not receive sufficient attention in connection with hydraulic engineering is the effect of judicious planting or woodland conservation over small areas. A narrow belt of woodland along the foot of a slope will arrest the soil brought down by rains from the hillside. The encouragement of dense vegetation along the bottom of a narrow valley may check the rate of flood discharge to a useful extent. The planting of suitable trees along ridges and for a little way down the slope facing the rain bearing and damp winds, will produce the maximum of certain desired effects, in proportion to the area occupied. Suitable tree and bush growths in swampy areas and around their margins will increase their effect in checking flood discharge, and may prevent these areas from contributing large quantities of silt to the streams during very heavy rains. Areas of soft, cultivable soil liable to denudation may similarly be protected. Generally, a country which is, in the ordinary English sense of the words, 'well timbered' is, from the point of view of the hydraulic engineer, a favourable country; and in the development of new lands the future effects of a poposed agricultural policy should be considered from this point of view, and in consultation with hydraulic engineers.

(R.A. Ryves, *Engineering Handbook*, 1936)

6.1 INTRODUCTION

This chapter deals with the complex interactions between trees and the incoming energies of radiation, precipitation, and the winds or gaseous envelope of earth. The energy transactions between trees and their physical environment defy precise measurement as they vary from hour to hour, and according to the composition and age of forests, but we can study the broad effects.

What I hope to show is the immense value of trees to the biosphere. We must deplore the rapacity of those who, for an ephemeral profit in dollars, would cut trees for newsprint, packaging, and other temporary uses. When we cut forests, we must pay for the end cost in drought, water loss, nutrient loss, and salted soils. Such costs are *not* charged by uncaring or corrupted governments, and deforestation has therefore impoverished whole nations. The process continues with acid rain as a more modern problem, not charged against the cost of electricity or motor vehicles, but with the inevitable account building up so that no nation can pay, in the end, for rehabilitation.

The "capitalist", "communist", and "developing" worlds will all be equally brought down by forest loss. Those barren political or religious ideologies which fail to care for forests carry their own destruction as lethal seeds within their fabric.

We should not be deceived by the propaganda that promises "for every tree cut *down*, a tree planted". The exchange of a 50 g seedling for a forest giant of 50–100 tonnes is like the offer of a mouse for an elephant. No new reafforestation can replace an old forest in energy value, and even this lip service is omitted in the "cut-and-run" forestry practised in Brazil and the tropics of Oceania.

The planting of trees can assuredly increase local precipitation, and can help reverse the effects of dryland soil salting. There is evidence everywhere, in literature and in the field, that the great body of the forest is in very active energy transaction with the whole environment. To even begin to understand, we must deal with themes within themes, and try to follow a single rainstorm or airstream through its interaction with the forest.

A young forest or tree doesn't behave like the same entity in age; it may be more or less frost-hardy, wind-fast, salt-tolerant, drought-resistant or shade tolerant at different ages and seasons. But let us at least try to see just how the forest works, by taking one theme at a time. While this segmented approach leads to further understanding, we must keep in mind that everything is connected, and any one factor affects all other parts of the system. I can never see the forest as an assembly of plant and animal species, but rather as a single body with differing cells, organs, and functions. Can the orchid exist without the tree that supports it, or the wasp that fertilises it? Can the forest extend its borders and occupy grasslands without the pigeon that carries its berries away to germinate elsewhere?

Trees are, for the earth, the ultimate translators and moderators of incoming energy. At the crown of the forest, and within its canopy, the vast energies of sunlight, wind, and precipitation are being modified for life and growth. Trees not only build but conserve the soils, shielding them from the impact of raindrops and the desiccation of wind and sun. If we could only understand what a tree does for us, how beneficial it is to life on earth, we would (as many tribes have done) revere all trees as brothers and sisters.

In this chapter, I hope to show that the little we do know has this ultimate meaning: *without trees, we cannot inhabit the earth*. Without trees we rapidly create deserts and drought, and the evidence for this is before our eyes. Without trees, the atmosphere will alter its composition, and life support systems will fail.

6.2 THE BIOMASS OF THE TREE

A tree is, broadly speaking, many biomass zones. These are the stem and crown (the visible tree), the detritus and humus (the tree at the soil surface boundary) and the roots and root associates (the underground tree).

Like all living things, a tree has shed its weight many times over to earth and air, and has built much of the soil it stands in. Not only the crown, but also the roots, die and shed their wastes to earth. The living tree stands in a zone of decomposition, much of it transferred, reborn, transported, or reincarnated into grasses, bacteria, fungus, insect life, birds, and mammals.

Many of these tree-lives "belong with" the tree, and still function as part of it. When a blue jay, currawong, or squirrel buries an acorn (and usually recovers only

The cowboys have won the day, but ruined the future to do so.

PROVISION OF NUCLEII FOR RAIN

The upward spirals of humid air coming up from the forest carry insects, pollen, and bacteria aloft. This is best seen as flights of gulls, swifts and ibis spiralling up with the warm air and actively catching insects lifted from the forest; their gastric pellets consist of insect remains. It is these organic aerial particles (pollen, leaf dust, and bacteria mainly) that create the nucleii for rain.

The violent hailstorms that plague Kenya tea plantings may well be caused by tea dust stirred up by the local winds and the feet of pickers, and "once above the ground the particles are easily drawn up into thunderheads to help form the hailstorms that bombard the tea-growing areas in astounding numbers... Kenyan organic tea leaf litter caused water to freeze in a test chamber at only -5°C, in comparison with freezing points of -11°C for eucalyptus grove leaf litter, and -8°C for the litter from the local indigenous forests" (of Colorado). That is, tea litter "is a much better seeding-agent than silver iodide, which requires -8°C to -10°C to seed clouds." (*New Scientist*, 22 Mar '79). Thus, the materials given up by vegetation may be a critical factor in the rainfall inland from forests.

All of these factors are clear enough for any person to understand. To doubt the connection between forests and the water cycle is to doubt that milk flows from the breast of the mother, which is just the analogy given to water by tribal peoples. Trees were "the hair of the earth" which caught the mists and made the rivers flow. Such metaphors are clear allegorical guides to sensible conduct, and caused the Hawaiians (who had themselves brought on earlier environmental catastrophes) to "tabu" forest cutting or even to make tracks on high slopes, and to place mountain trees in a sacred or protected category. Now that we begin to understand the reasons for these beliefs, we could ourselves look on trees as our essential companions, giving us all the needs of life, and deserving of our care and respect.

It is our strategies on-site that make water a scarce or *plentiful resource*. To start with, we must examine ways to increase local precipitation. Unless there is absolutely no free water in the air and earth about us (and there always is some), we can usually increase it on-site. Here are some basic strategies of water capture from air:

- We can cool the air by shade or by providing cold surfaces for it to flow over, using trees and shrubs, or metals, including glass.
- We can cool air by forcing it to higher altitudes, by providing windbreaks, or providing updraughts from heated or bare surfaces (large concreted areas), or by mechanical means (big industrial fans).
- We can provide condensation nucleii for raindrops to form on, from pollen, bacteria, and organic particles.
- We can compress air to make water more plentiful per unit volume of air, by forcing streamlines to converge over trees and objects, or forcing turbulent flow in airstreams (Ekman spirals).

If by any strategy we can cool air, and provide suitable condensation surfaces or nucleii, we can increase precipitation locally. Trees, especially crosswind belts of tall trees, *meet all of these criteria in one integrated system*. They also store water for local climatic modification. Thus we can clearly see trees as a strategy for creating more water for local use.

In summary, we do not need to accept "rainfall" as having everything to do with total local precipitation, especially if we live within 30–100 km of coasts (as much of the world does), and we do not need to accept that total precipitation cannot be changed (in either direction) by our action and designs on site.

6.6 HOW A TREE INTERACTS WITH RAIN.

Rain falls, and many tons of rain may impact on earth in an hour or so. On bare soils and thinly spaced or cultivated crop, the impact of droplets carries away soil, and may typically remove 80 t/ha, or up to 1,000 tonnes in extreme downpours. When we bare the soil, we lose the earth.

Water run-off and pan evaporation, estimated as 80–90% of all rain falling on Australia, carries off nutrients and silt to the sea or to inland basins. As we clear the land, run-off increases and for a while this pleases people, who see their dams fill quickly. But the dams will silt up and the river eventually cease to flow, and the clearing of forests will result in flood and drought, not a long-regulated and steady supply of clean water.

When rain falls on a forest, a complex process begins. Firstly, the tree canopy shelters and nullifies the impact effect of raindrops, reducing the rain to a thin mist below the canopy, even in the most torrential showers. There is slight measurable silt loss from mature forests, exceeded by the creation of soils by forests.

If the rain is light, little of it penetrates beyond the canopy, but a film of water spreads across the leaves and stems, and is trapped there by surface tension. The cells of the tree absorb what is needed, and the remainder evaporates to air. Where no rain penetrates through the canopy, this effect is termed "total interception". INTERCEPTION is the amount of rainfall caught in the crown. It is the most important primary effect of trees or forests on rain. The degree of interception is most influenced by these factors:

- Crown thickness;
- Crown density;
- Season;
- Intensity of rain; and
- Evaporation after rain.

pH can reach as low as 3.5 or 4.0 from natural humic layers, and rivers run like clear coffee to sea. Below the humus lies the tree roots, each clothed in fungal hyphae and the gels secreted by bacterial colonies. 30–40% of the bulk of the tree itself lies in the soil; most of this extends over many acres, with thousands of kilometres of root hairs lying mat-like in the upper 60 cm of soil (only 10–12% of the root mass lies below this depth but the remaining roots penetrate as much as 40 m deep in the rocks below).

The root mat actively absorbs the solution that water has become, transporting it up the tree again to transpire to air. Some dryland plant roots build up a damp soil surround, and may be storing surplus water in the earth for daytime use; this water is held in the root associates as gels. *Centrosema* and *Gleditsia* both are dryland woody legumes which have "wet" root zones, and other plants are also reported to do the same in desert soils (*Prosopis* spp.)

The soil particles around the tree are now wetted with a surface film of water, as were the leaves and root hairs. This bound water forms a film available to roots, which can remove the water down to 15 atmospheres of pressure, when the soil retains the last thin film. Once soil is fully charged (at "field capacity"), free water at last percolates through the interstitial spaces of the soil and commences a slow progression to the streams, and thence to sea.

At any time, trees may intercept and draw on these underground reserves for growth, and pump the water again to air. If we imagine the visible (above-ground) forest as water (and all but about 5–10% of this mass *is* water), and then imagine the water contained in soil, humus, and root material, the forests represent great lakes of actively managed and actively recycled water. No other storage system is so beneficial, or results in so much useful growth, although fairly shallow ponds are also valuable productive landscape.

At the crown, forceful raindrops are broken up and scattered, often to mist or coalesced into small bark-fissured streams, and so descend to earth robbed of the kinetic energy that destroys the soil mantle outside forests. Further impedence takes place on the forest floor, where roots, litter, logs, and leaves redirect, slow down, and pool the water.

Thus, in the forest, the soil mantle has every opportunity to act as a major storage. As even poor soils store water, the soil itself is an immense potential water storage. INFILTRATION to this storage along roots and through litter is maximised in forests. The soil has several storages:

- RETENTION STORAGE: as a film of water bound to the soil particles, held by surface tension.
- INTERSTITIAL STORAGE: as water-filled cavities between soil particles.
- HUMUS STORAGE: as swollen mycorrhizal and spongy detritus in the humic content of soils.

A lesser storage is as chemically-bound water in combination with minerals in the soil.

As a generalisation, 2.5–7 cm (1–3 inches) of rain is stored per 30 cm (12 inches) depth of soil mantle in retention storage, although soils of fine texture and high organic content may store 10–30 cm (4–12 inches) of rain per 30 cm depth. In addition, 0–5 cm (0–2 inches) may be stored as interstitial storage.

Thus the soil becomes an impediment to water movement, and the free (interstitial) water can take as long as 1–40 years to percolate through to streams. Greatly alleviating droughts, it also recharges the retention storages on the way. Thus, it almost seems as though the purpose of the forests is to give soil time and means to hold fresh water on land. This is, of course, good for the forests themselves, and enables them to draw on water reserves between periods of rain. (Odum, 1974).

6.7
SUMMARY

Let us now be clear about how trees affect total precipitation. The case taken is where winds blow inland from an ocean or large lake:

1. The water in the air is that evaporated from the surface of the sea or lake. It contains a few salt particles but is "clean". A small proportion may fall as *rain* (15–20%), but most of this water is CONDENSED out of clear night air or fogs by the cool surfaces of leaves (80–85%). Of this condensate, 15% evaporates by day and 50% is transpired. The rest enters the groundwater. Thus, *trees are responsible for more water in streams than the rainfall alone provides.*

2. Of the rain that falls, 25% again re-evaporates from crown leaves, and 50% is transpired. This moisture is added to clouds, which are now at least 50% "*tree water*". These clouds travel on inland to rain again. Thus trees may double or multiply *rainfall* itself by this process, which can be repeated many times over extensive forested plains or foothills.

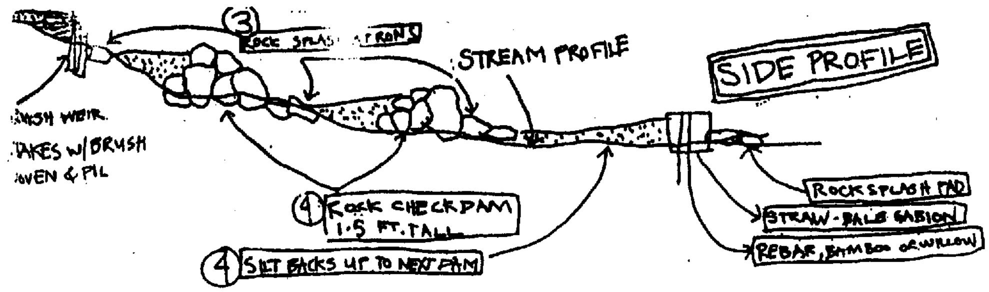
3. As the air rises inland, the precipitation and condensation increases, and moss forests plus standing clouds may form in mountains, adding considerably to total precipitation and infiltration to the lower slopes and streams.

4. Whenever winds pass over tree lines or forest edges of 12 m (40 feet) or more in height, Ekman spirals develop, adding 40% or so to rainfall in bands which roughly parallel the tree lines.

5. Within the forest, 40% of the incident air mass may enter and either lose water or be rehumidified.

6. And, in every case, rain is more likely to fall as a result or organic particles forming nucleii for condensation, whereas industrial aerosols are too small to cause rain and instead produce dry, cloudy conditions.

Thus, if we clear the forest, what is left but dust?



Once the water has reached the arroyo or stream, your object is to spread it out and slow it down. Your work will have the greatest effect high in the watershed, where trickles turn into streams. Here you can build low, leaky check dams out of rocks or brush, or you can plug small flows with one or more strawbales. As you work, you will become familiar with patterns of water flow. Start small, and watch the effects your structures have.

1. Make sure your dams are "keyed in", that is, make sure they are dug far enough into the banks that the water will not eat around them.

2. Make them broader in the center, where the flow is strongest.

3. Also make them lowest at this point, and make a splash pad of rocks below the check dam.

4. Don't make your structures taller than about a foot and a half, and try to design them so that the silt trapped in one dam reaches up to the bottom of the next.

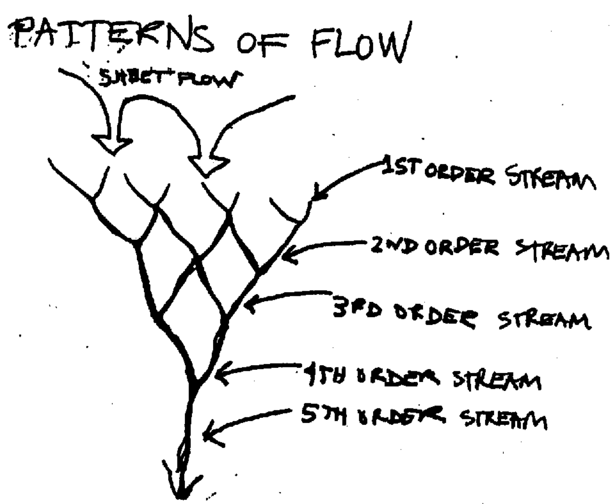
5. Once your check dams have filled with silt, you can build them up higher.

Remember that these structures work only in first and second order streams. If your structures blow out, Don't be discouraged. Key them in better, or better yet move higher in the watershed and try again.

My friend joel says the best thing you can do for a watershed is line up sticks on the contour lines. You can also make microcatchments on a slope or flat area by pitting the land with a shovel. The pits collect seeds, water, animal droppings and mulch, creating rich, sheltered microclimates for plants to establish. Just laying down mulch on bare spots will conserve enough water to allow many seeds to germinate.

Also keep in mind that the structures you build are only temporary. Their primary function is to allow plants to establish. Long after your swales and check dams have silted up, they'll be visible as lines of trees along the hillsides. These trees' roots reach deep into the soil to hold it in place, tapping into the underground streams and sharing nutrients along webs of mycorrizal fungi. Their shade and mulch allows other plants to grow, reweaving the web of life that existed there before.

These ideas work in the city too. In Tucson, AZ, people marked the contours of a gently sloping parking lot. They removed a three-foot wide section of asphalt along the lines they had marked, and planted native trees there. The runoff from the rest of the parking lot watered the trees. Bust up your driveway and divert the water from the street to the street trees. In asphalt or concrete-covered lots, remove the pavement from the low spots and plant trees there. Plant native plants in your guerrilla gardens-- they can survive on local rainfall, and they bring the real world into the heart of the city.



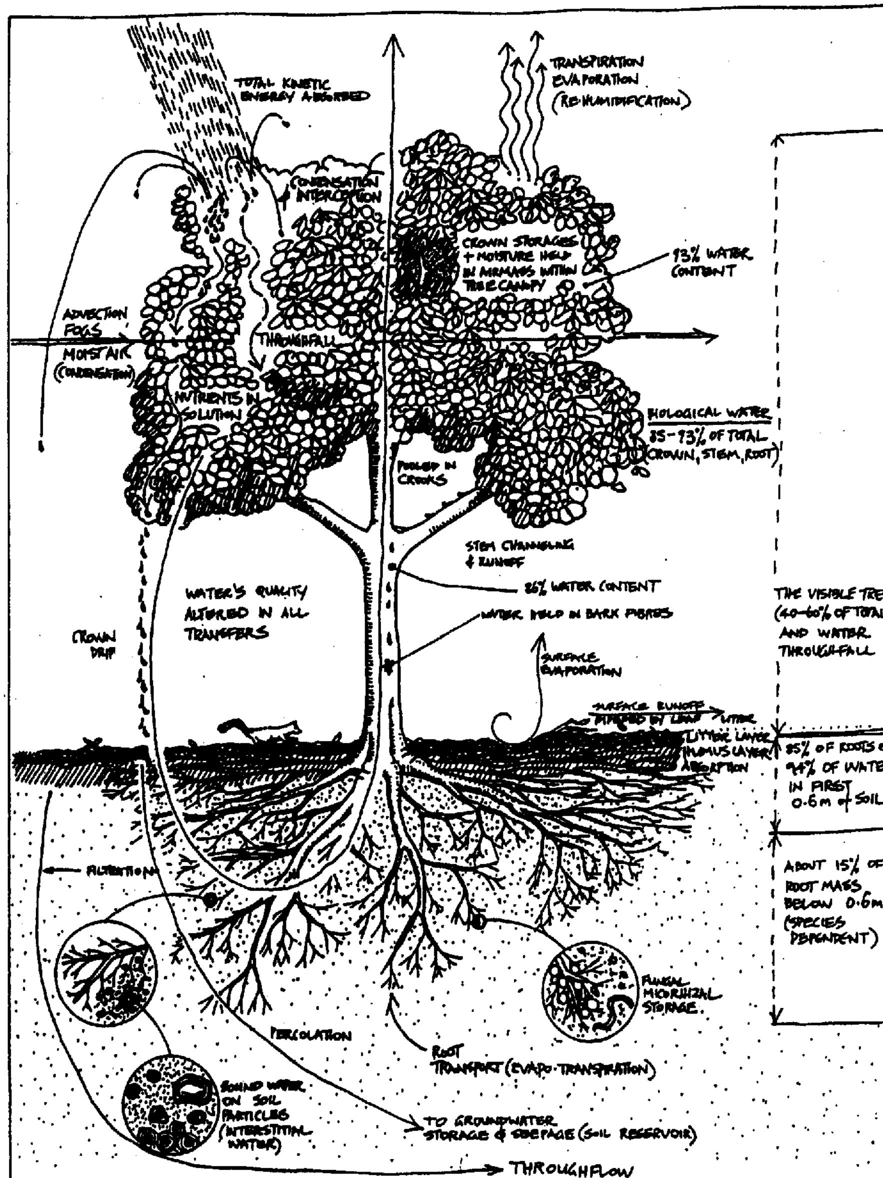


FIGURE 6.6
HOW A TREE INTERACTS WITH RAIN
Every tree, every plant species, intercedes in rain to change the composition, energy, and distribution of water; the overall effect of trees is to *moderate and conserve* incoming energy.

year hive enjoys more than we do the variety and succession of blooms as well as the moist, carpeted banks of the ponds. We attract and feed beneficial insects with umbellifers and composities. Prospective mulchers may be a bit confused by the disorderly array that confronts them! As many elements as possible are multi-functional. The lovely passion-flower, for instance, grew 15 feet high last year and shaded part of our hot south side. We also ate its leaves, flowers, fruit, and stem. Overall, maintenance effort is low. A lot of our work is cutting back, harvesting, and imagining how we can better work with nature.

We feel that our cooperation with nature has begun to generate a highly functional, productive, and beautiful homestead. This has led us to think that the most significant act of urban permaculture is *restoring* a balance between human society and nature. Since almost every inch of urban and suburban land has been ransacked, covered, poisoned, and altered, it begs to be restored. This does not necessarily mean returning it to its original form, i.e., forest, prairie, or marsh, but restoring a sustainable balance that enriches and provides for all, now, and for future generations. The place where this happens most visibly is the garden. This is where we grow, learn, swap stories, play, relax, and wonder.

Front view of the Headingtons', after permaculture.

It is not hard to imagine cities and suburbs as large gardens. Nature shifts from background to foreground. Each human activity and institution feeds into the loops of natural systems. The *Wall Street Journal* (July 14, 1994) reported front page: "Amid Destruction, Sarajevo Blooms as a Garden Spot: The corn grows tall, beans sprout as residents spread seeds of new civilization." Tragedy has pushed Sarajevo's inhabitants to conserve, grow food, and become self-sufficient. "Beans rise above balcony railings. Tomatoes ripen on rooftops. Onions frame sidewalks. Cows graze on median strips." Former CEOs become master gardeners. Amid the destruction, one can say, "We have all what we need here."

This brings to mind another important practice of urban permaculture: conferring particularity, identity, and conviviality to a place—in other words, making it a "somewhere." Perhaps I should say that one evokes the uniqueness of a place. To convert a lawn into a garden is to give it particularity and, according to the way it is done, an identity. Our front garden says something about who we are and what nature can be. Its diverse interactions evoke the latent conviviality of the home, the sidewalk and porch, and the neighborhood. An elderly woman from England walked by, turned around, and came through the rose arbor. "I feel I've come home," she—a "stranger"—said.

Our homestead is a microcosm of what can happen elsewhere, anywhere, in city or suburb. You can begin where you are, right now, on whatever scale suits you. You can initiate systematic or random acts of restoration and evoke the spirit of the place.

Discovering harmonious patterns

Urban permaculture is intensely social. Everything you do is within sight, sound, or touch of a neighbor…or an inspector. Everywhere you turn, you bump into another person's body, land, home, or advice. Taking others into account may mean making compromises. This intense interaction is one of the defining and charming features of urban life. Rather than privatize and control daily activities as modern design and technology do, urban permaculture seeks to increase, open up, and share the diverse paths, places, and patterns of urban convivial-ity. For instance, my next door neighbor, Vincent, lets us use his backyard as a playing field. We also exchange lawn care (yes, we cut his lawn!) for the privilege of using the south side of his garage as a greenhouse site.

Thus urban permaculture embraces social diversity and interaction, and generates designs that maximize their frequency, intensity, and continuity. Just as we design plant guilds in the garden, we design people guilds in the neighborhoods. We can put people in touch with one another, match somebody's needs to another persons's skill and surplus, connect the cycles and flows of human energy, letting everyone join in and have fun.

Community building is very much a matter of good design. There are patterns that connect and patterns that alienate. I often turn to Christopher Alexander's *A Pattern Language* for good ideas. There is also a growing body of literature on sustainable urban design. Some of these ideas may go mainstream, as indicated by the cover articles of *Newsweek* (May 15, 1995): "Bye-Bye, Suburban Dream," and "15 Ways to Fix the Suburbs."

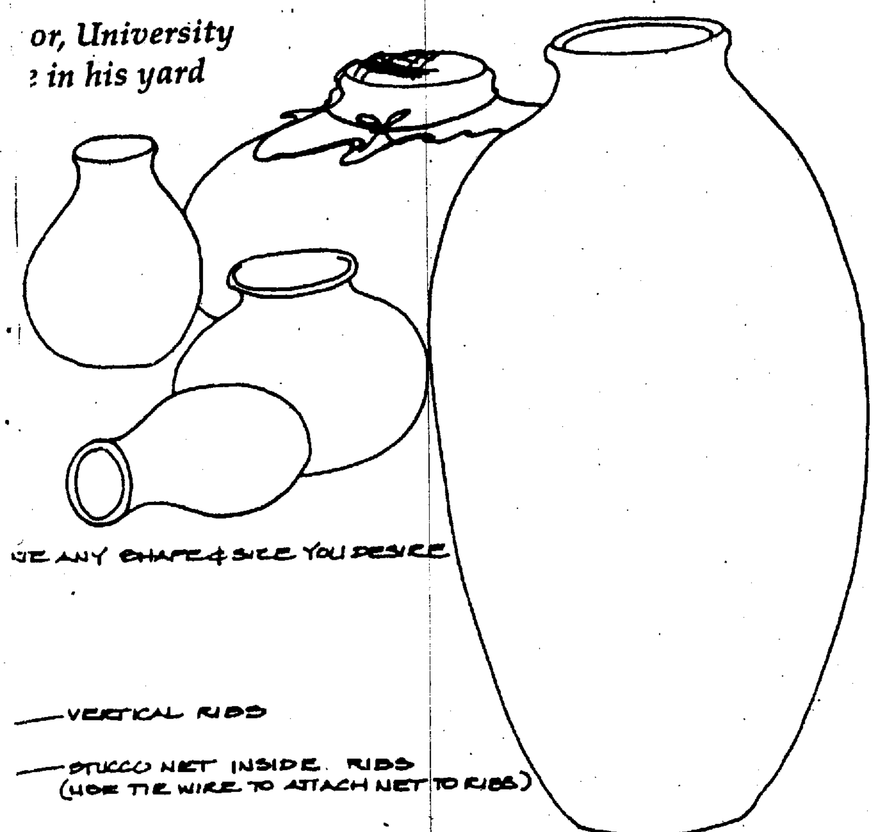
Lest this sound too theoretical, let me turn to some things happening in Greensboro and hereabouts. Last year, a team of eighth-grade teachers at Kiser Middle School asked me to work with students to create a permaculture garden. A year later, we sit within our garden of trees, fruit bushes, an herb spiral, pond, swirling paths (they chose an amoeba shape!), and ripe strawberries. From the beginning, I foresaw the most important part of this venture, namely, the building of community: teacher and student, principal and janitor, gardeners and non-gardeners, bus drivers and parents. With regard to learning, it brought together hand and mind, text and deed, classroom and outdoors. The garden will continue to grow and with it, the community and curriculum, because social and natural ecologies are connected.

Other examples

Under the expert guidance of Ben, a local gardener, our neighborhood joined together to restore nearby Buffalo Creek. Our interventions have been minimal, mainly consisting of planting native species, so the creek is largely on its own. In two years, the vegetation grew lush and diverse; animals, insects, and birds flourished; the water temperature *dropped*, improving

Jar

or, University
? in his yard



...E ANY SHAPE & SIZE YOU DESIRE

— VERTICAL RIBS

— STUCCO NET INSIDE RIBS
(USE TIE WIRE TO ATTACH NET TO RIBS)

— PREPARE CEMENT SLURRY & SOAK BURLAP, CANVAS, RAGS, OLD SHEETS, ... POSSIBLY EVEN NEWSPAPER WILL WORK — PLACE OVER STUCCO NET TO FORM A SHELL OR BACKING FOR FERROCEMENT (SIMILAR TO PAPIER MACHE)

— AFTER BACKING SHELL HAS SET ATTACH STUCCO NET OVER OUTSIDE OF RIBS

— PLASTER INSIDE AND OUTSIDE NET WITH FERROCEMENT (1 PART CEMENT TO 2 PARTS CLEAN MORTAR SAND). APPLY 1 OR MORE COATS TO ACHIEVE DESIRED THICKNESS AND FINISH TEXTURE. PARTIALLY FILL COMPLETED URN WITH WATER, KEEP OUTSIDE DAMP AND COVER WITH POLYETHYLENE TO CURE

"THOROSEAL" INTERIOR TO ASSURE A LEAKPROOF URN (NOT REQUIRED)

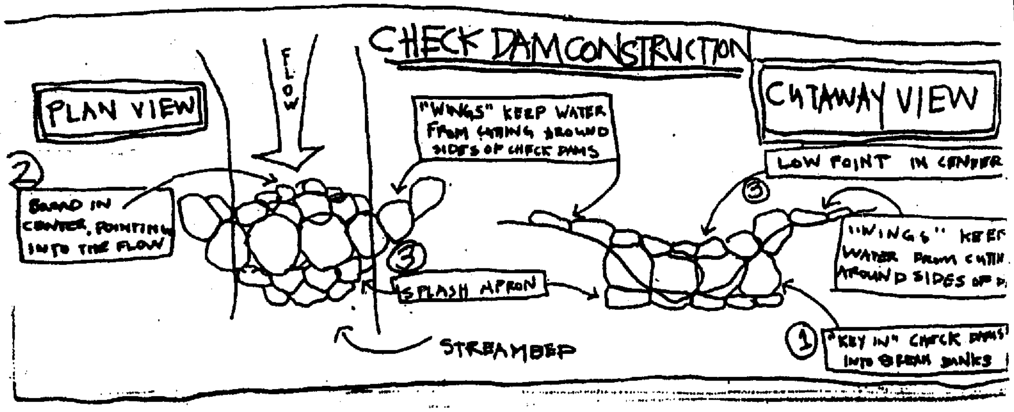
OIL FINISH, PAINT OR LEAVE NATURAL EXTERIOR FINISH

...UCTION BY S.B. WATT, 1978, ISBN 0-903031-51-5, ...ECHNOLOGY DEVELOPMENT GROUP OF NORTH AMERICA, INC.

Broadscale Restoration

The cheapest and easiest place to store water is in the soil. Grazing, logging, roads and agriculture all cause erosion. Once the topsoil has washed away, plants cannot establish themselves. Without vegetative cover, water can't infiltrate into the soil, so it runs off, causing more erosion. So the first step in restoring a watershed is slowing down the flow of water across hillsides (called sheet flow) and allowing water to infiltrate before it reaches the streams. On gentle slopes (less than 15 degrees) broad, shallow ditches called swales that follow the contours of the land will hold storm runoff and infiltrate it over time. They will also fill up with silt over time and form terraces. Swales should be mulched to reduce evaporation, and planted with trees.

On slopes steeper than 15 degrees, dig networks of v-shaped "boomerang " swales. These are v-shaped berms, pointing downhill, forming basins that direct water to one tree. Steep slopes can also be terraced with straw bales. Dig a shelf on contour for bales to rest on, and pin each bale into the ground with two stakes (willow, bamboo and rebar all work well). Swales and straw terraces work best if their ends are anchored by a tree or bush, then water is less likely to erode around the ends. Plant a native tree or shrub behind each straw bale. When it rains, the bales soak up water like a sponge and water the trees. The bales will decompose in a few years, and the line of trees you have planted will hold the hillside in place with their roots.



To Mend the Broken Circles: Thinking Green in City Spaces

Charlie Headington

The urban scene is the least studied yet most important arena of permaculture. Its importance stems from the apparently unstoppable, albeit misguided, march of humanity to dwell in the centers of commerce and industry. While what we need is a more balanced pattern of settlement—of villages with hub-cities and tracts of wilderness large enough to allow for speciation—what we have is an unruly mosaic of metropoli with sprawling suburbs, a defeated rural culture, and multiple-use "wilderness" tracts. The city, by virtue of its control over financial and political decisions, social and cultural conventions, and industrial inertia, sucks dry the rural and wild places and reshapes them into a homogeneous landscape. Thus we have a "geography of nowhere," a soulless landscape. Therefore, for the foreseeable future, the urban-suburban scene deserves our best thinking and our best design. All of this is possible on a small or city-wide scale. It can begin here and now.

Several years ago, my wife (Deborah Seabrooke) and I wondered whether to move to the country or stay in Greensboro, a city of 200,000 in the mid-Atlantic Piedmont of North Carolina. At the time, I thought I could do permaculture *only* in the country, with acreage, and without restrictive city social conventions and building codes. We came very close to buying 17 acres, but we decided instead to play an urban tune. We had three pre-teens, for whom existing friendships were very important, we wanted to continue bicycling to work, stores, and friends' homes, and we had some nascent idea about making our 80-year-old home on a 50' x 150' lot an urban homestead.

Turning to our front yard (on a busy and narrow street), we had a few ideas from a variety of sources—Fukuoka, Ruth Stout, English cottage gardens: make it easy, mix it up, mulch, perennialize. We'd also heard about sheet mulching from permaculture. So in early spring of 1992, with newspapers, leaf mulch (six pickups full), and straw, we covered over an American obsession, the lawn. We scavenged for rocks, fence materials, trees, plants, and ideas. We planted annuals and perennials, and waited.

Within two months, the garden filled out. Neighbors attest that it sprang up overnight with ten foot sunflowers, the three sisters (corn, beans, and squash) by the street, goldfinches on thistles, toads in broken pots, cherry tomatoes running over azalea bushes, eggplants popping up next to the yarrow. Plants, animal friends, and neighbors all found a niche in our garden. From an ordinary city scene, the garden converted the area in front of our house to a sacred space of conviviality and intersecting life patterns. Our front porch enjoyed a renaissance as a connector of home and garden. A rose arbor signaled the entrance and symbolized the movement from profane to sacred space. An old maple at long last revealed in its own guild of understoried trees, bushes, and herbs. A new tune and a new culture sprang from the old.

We turned to the backyard. By then I had some formal permaculture training and, with all we'd learned from our front yard experiments, we had much more specific ideas about design and ecosystems. We negotiated with our kids about social space; they tolerated most of our ideas, but vetoed my favorite—using the jungle gym as the entry trellis, laden with hardy kiwi. We also had a problem to turn into a solution, as the city sewer works had just put in a neighborhood drainage pipe and left a 15' wide swath of hard subsoil where our main garden wanted to be.

In permaculture fashion, we built *up* from the surface, bringing in more leaf mold and forming a terrace with large elm stumps. Then we established several gardens: key-hole shaped beds for annual vegetables, an orchard garden of dwarf fruit trees, fruit bushes, and insectary plants...and (surprise!)—a secret garden by our first three ponds. Closer to the back door, we put in

Front view of the Headingtons', before Pc.

a plucking garden of greens and edible flowers, an herb spiral, a blueberry grove, another orchard garden with a canopy of plum and persimmon trees and, most recently, a patio garden and pond shaded by a grape-laced pergola. These gardens are now in their second growing season, so most of the bushes and several dwarf trees are yielding fruit. Soon we'll have lots of fruit, 18 varieties, ripening from early May to early December.

If you think we have lots of sun space, we don't. About half the back of our lot is shaded, so we have room for shade guilds, shade fruit like black and red currant, gooseberry, and pawpaw, as well as herbs and ponds. Shade and sun means lots of edge, and it's fun to come up with edge-guilds. Some winter squash, scarlet runner bean, H-19 pickling cucumber, elderberry, raspberry, and even a fig do nicely. Shade in the hot Piedmont often creates a social space, and thus we also planned paths, a tree house, a hammock site, a fire pit, three ponds, and several benches to help connect humans and other-than-humans.

At our place, everybody contributes. We never till; we just mulch and let the worms turn the soil. Bees pollinate. Our first-

Appendix A

LIST OF SOME USEFUL PERMACULTURE PLANTS

Most of the species below are perennial, although some annuals are included. This list is by no means complete; it is intended only as an informal start to your own local permaculture species lists. The plants below range from temperate to tropical climates; many temperate species can also be grown in the subtropics or highland tropics. In most cases heights are given (in metres - m) but these will vary according to climate, care, soils, and cultivars.

ACACIAS (*Acacia* spp.)
Leguminous trees and shrubs ranging from 3-25m; species growing from arid regions to the tropics; often spiny. USES: Some species are important fodder plants of drylands, with leaves, pods, and seeds used; firewood and (some species) timber. Nitrogen-fixing; Fukuoka planted silver wattle (*A. dealbata*) in his fields to boost production. Erosion control.

Fodder: Mulga (*Acacia aneura*) widespread in Australian drylands, fast-growing and palatable to stock; to 7m tall. Camel thorn (*Faidherbia albida*) thorny tree to 25m; foliage and pods important fodder yielding 135 kg pods/tree in Sudan. Deciduous in wet season, full leaf in dry. Myall (*A. pendula*) grows on heavy soils where no other trees will grow (protects soil and gives shade as well as fodder). Other fodder trees are *A. salicina* (native willow), *A. senegal*, *A. seyal*.

Timber: Blackwood (*Acacia melanoxylon*), fast-growing, long-lived, cool climate acacia used in fine furniture (in warm climates *A. melanoxylon* is a scraggly, short-lived tree). Silver wattle (*A. dealbata*) and hickory wattle (*A. falci-formis*) also important timber trees.

ALBIZIA (*Albizia lopantha*, *A. julibrissin*)
Leguminous, evergreen, quick-growing trees with feathery leaves. Height: 9-15m. Warm temperate to tropical climates.

USES: Shade tree, with ornamental leaves and flowers. Windbreak if lopped to encourage bushiness. Pioneer tree; in the tropics, chili peppers, pineapples, banana, and fruit trees are grown under widely-spaced albizia, providing a 3-tier productive system. Most species are palatable to stock (*A. lopantha*, *A. chinensis*). Nitrogen-fixing.

ALDER
(*Alnus* spp.): Fast-growing, short-lived trees mainly forming dense thickets. Height: 10-25m. Although not legumes, are nitrogen-fixing, and create a thick, black humus. Useful if already present for rough mulch, composting. Use as a nurse crop for other trees; provides shelter, mulch, and nitrogen. Can eventually be cut out altogether, or a few trees allowed to grow on for nitrogen-fixing, mulch. As firewood it may burn too hot, but stickwood is useful. Some *Alnus* spp. are *A. tenuifolia* (mountain alder), *A. crispa* (downy alder).

AMARANTH (*Amaranthus* spp.)
Upright annuals to 1m of which grain amaranth (*A. hypochondriacus*) and leaf amaranth (*A. gangeticus*) are most valuable. Grown in full sun or even partial shade; grain amaranth needs a 90-day growing season to set seed. Temperate areas through highland dry tropics.

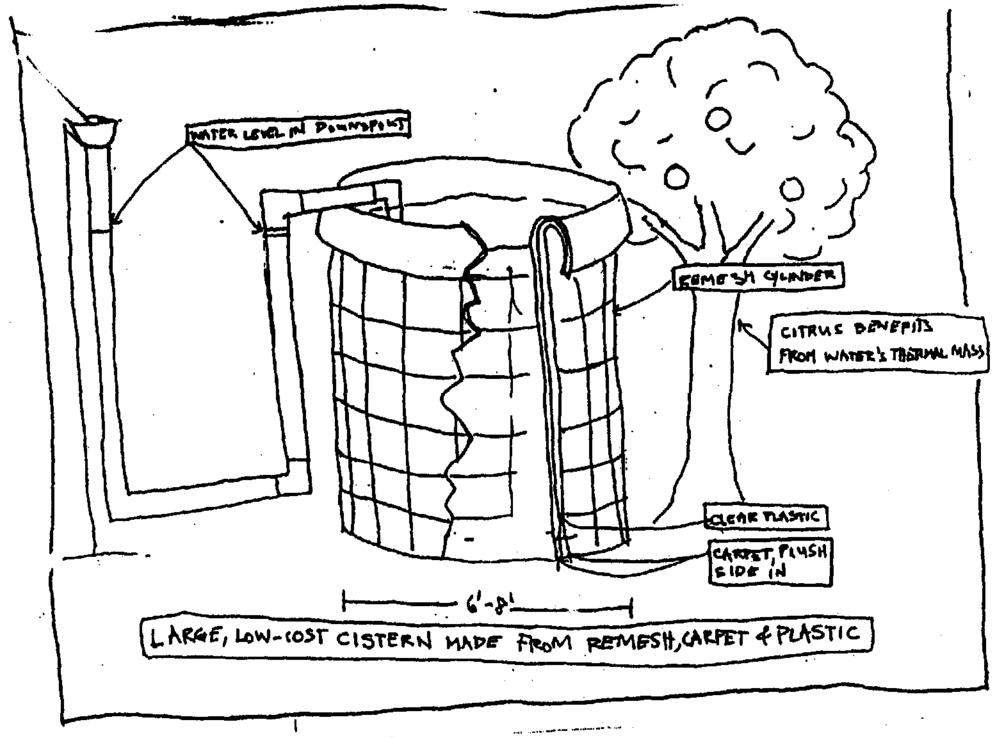
USES: Grain amaranth a high protein crop (18%); seeds eaten popped or ground into flour. Leaves eaten raw or cooked. Leaf amaranth grown throughout year in warm climates; tasty leaves are bright red and green. Valuable vitamin and mineral plant. Chicken fodder (seeds); leaves for stock—can be turned into silage. Cover crop.

ARRACACHA (*Arracacha xanthorrhiza*, *A. esculenta*)
Also known as Peruvian parsnip. Grown in high-altitude tropics to subtropical climates. Herbaceous perennial, producing large, starchy roots. Propagated by tubers.

USES: Eaten like potatoes or cassava. Coarse main rootstocks and mature leaves fed to animals. Young stems for salads. Excellent understorey crop.

ASPARAGUS (*Asparagus officinalis*)
Perennial rootstock with new, edible shoots each year, yielding well for at least 20 years if manured and watered. Yields after 3 years, in spring. Easily propagated in winter by crown division. Naturalises along sandy watercourses, though does not produce large stalks as does manured asparagus. USES: human food, bank stabilisers for sandy steams. Temperate to subtropical climates.

AUTUMN OLIVE and RUSSIAN OLIVE (*Elaeagnus umbellata*, *E. angustifolia* & other spp.)
Fast-growing, nitrogen-fixing shrubs to 4.5m and 20m respectively; Autumn olive forms thickets or hedges when clipped. Tolerates poor soil, drought. Likes full sun, although other species will tolerate partial to full shade.



Cheap Salvage Water Catchment

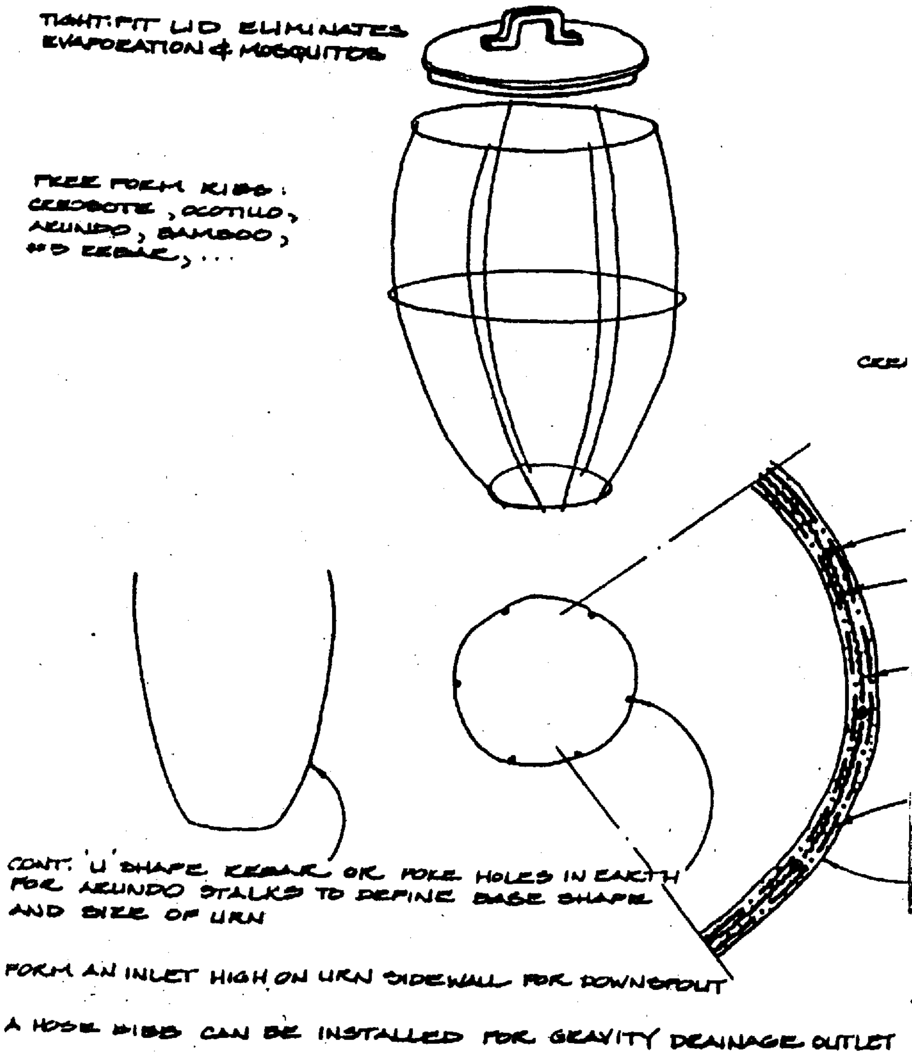
Put a trashcan under a downspout and you've got water for your garden. 55-gallon drums, available free from bakeries, can be linked together with pvc pipe to provide hundreds of gallons of water storage. Ferrocement tanks are also cheap to build, though they can crack in earthquake country. You can make a 1200 gallon cistern for under $20 using remesh, plastic and carpet.

If your neighbor's roof drains near your garden, harvest their water too. Maybe they'll realize what a resource they're wasting.

When creating water catchment systems, let gravity move the water. If your yard slopes, site the tank at the top of the slope. In flat areas, elevate the tank a few feet off the ground on a pad of rock or broken concrete. Water tanks have a lot of thermal mass. They trap the sun's heat during the day and radiate it at night, so they can help protect sensitive plants like citrus and tomatoes from frost.

Building a Water

by Rocky Brittain (Designer and Assistant Research Profess of Arizona College of Architecture). Rocky built one of thes using creosote branches for ribs.



...ENCE: FERROCEMENT WATER TANKS AND THEIR CONSTR

conditions for stream life— and the city spends less money on maintenance. The project is soon to be emulated in other locations.

I also think about a local architect, Bob Powell, who wants to develop Greensboro's first sustainable, mixed-use, low-income housing community. And I think of Elaine Stover's efforts to educate the city council, city planners, developers, and builders about green alternatives and sustainable strategies. Louey Gamble in Madison and Harvey Harman in Bear Creek grow good food and establish urban-rural links through CSAs. Dozens of people have taken one-day workshops in permaculture. No one is in charge, yet the various activities, visions, and livelihoods are beginning to merge.

Charlie Headington and Deborah Seabrooke

The last point I'd like to make about urban permaculture concerns the flows and cycles of energy and matter. Cities use a tremendous amount of energy. Sadly, they use it inefficiently, wastefully, and unwisely. Permaculture teaches us to harvest energy, use less of it, and use the right form of energy for the right job. If the sun can heat food, water, and homes, we should design systems to let it do so. We might think of letting gravity work for us as well. Our home is not yet a model of energy efficiency, but we use fewer appliances than most households and practice low-use (our average, combined utility bill is $45 monthly). We are also planning to install a solar batch water heating tank, a solar oven, and a wood stove, though large-scale conversions seem daunting and expensive.

When it comes to cycles of materials, our homestead does a little better. The meta-pattern of all matter—water, minerals, nutrients—is to move from the environments of air, water, and soil to living organisms and then back again. These cycles connect us now and with the past. The molecules you breathe may have been inhaled by Walt Whitman, or Eve. To disrupt these cycles or to lock up nutrients creates imbalances in the soil, air, and water we depend on. Bagging leaves and grass clippings, pouring high-dose fertilizers on the soil, allowing runoff of phosphorus and nitrogen, destroying whole ecosystems, overwhelming the waste facilities, drinking the 700 or more additives in city water, paving the land—all of these disrupt natural cycles on a large scale and within the human body.

The work of urban permaculture is obvious: to complete the cycles, to mend the broken circles. Here again you can begin now, where you are. Think of all the revolutions in your backyard: soil breathing, plants growing, leaves falling, water flowing, matter decomposing, children playing, sun shining, neighbors talking. Loop upon loop, all form cycles within a larger web. Now learn about the the cycles and their elements, observe them, and understand their transactions. Soon you'll discern which human actions assist their efforts and how these natural events can help you. For example, we're using ponds and the slope of the yard for greywater filtration and garden irrigation. The water loop is extended from the home through the ponds and to the garden. If we caught all our water in cisterns, the loop would be complete.

You'll soon find yourself going beyond your home. You can forage and guerrilla plant in city parks, you can rehab streams, set up community gardens, begin river festivals. Everywhere you go in urban settings, there are opportunities to restore broken cycles. A community in Greensboro, Eastside Park, was racked by drug dealing, crime, pollution from highways, and social injustice. A consortium of voluntary home construction organizations, the city, and the remaining inhabitants of the neighborhood formed a plan and staged a comeback. A team of permaculture designers spent a week there integrating the natural cycles into the newly restored physical and social cycles. The team proposed a solarized community center, gardens and orchards, stream rehab, pedestrian pathways, mixed-use zoning, access to safe and restful places, and waste recycling. A constructed wetland could also have been included.

This is the challenge of urban permaculture: to facilitate the revolutions, the dynamic interactions of the web of Life, and to reestablish natural ecosystems as the context of urban form and activity. This is the basis of sustainable development. Now is the time to experiment and construct models of possibility. Now is the time to invite others to potlucks, workshops, and presentations, so that knowledge can be recycled through the community. Look to your friends. I learned from Dan, Chuck, Peter, and Michael. Close by are other permaculture designers—Erik, Harvey, Louey, Darrell, and Randy. Others speak a similar language; scores have attended events, and hundreds more want to learn. Reach out to city officials, professionals, schools, churches, and your neighbors. View them all as potential allies.

In fifty years, this coalition building will be a necessity. Now it is a choice. Don't, like Sarajevo, wait for war. Plant the seeds of a new culture, a sustainable culture, now. Δ

Charlie Headington teaches Religion at the University of North Carolina, Greensboro. He regularly leads workshops in permaculture design and ethics. His home at 515 N. Mendenhall, Greensboro NC 27401 is an inspiration for all city gardeners.

Patterns of Settlement

"Keep interlocking fingers of farmland and urban land, even at the center of the metropolis. The urban fingers should never be more than 1 mile wide, while the farmland fingers should never be less than 1 mile wide."

City-Country Fingers

ages flowers and young fruit, but not the trees; very wet weather in autumn can rot the ripening pods. A leguminous tree, although does not fix nitrogen.

USES: Human food: ground meal is a chocolate or coffee substitute, widely used in health food products. Pods as stock feed for energy and protein concentrate (ground as meal or fed whole to large animals). Yields in Mediterranean climates are 45-225 kg/tree. The seeds yield a gum with water-absorbing qualities, used in cosmetic and chemical industries.

CASSAVA (*Manihot esculenta*)
Lowland tropical crop, with starchy tubers. Widely used in Africa, South Pacific, Latin America. Grown on ridges or mounds, interplanted with annual food crops. Can withstand neglect, grows in nutrient-poor soils; tolerates drought (except after propagation). Can be kept in the ground until required.

USES: Eaten (after peeling) boiled or baked. Dried slices may be kept for several months; cassava flour is made by grinding these dried chips. Fermented pulp is eaten in West Africa. Starch, or tapioca, is used for puddings, biscuits, and confectionary.

CHESTNUT (*Castanea mollissima, C. sativa*)
Large, spreading deciduous tree to 30m; long-lived. Grafted trees yield in 7-9 years. Temperate Mediterranean climates; tolerate dry conditions. Like well-drained soils. Need cross-pollination for best results. May not bear well in climates with cool summers.

USES: As food: Spanish or sweet chestnut (*C. sativa*) important commercial crop in Europe, while Chinese chestnut (*C. mollissima*) grown in U.S. because of resistance to blight fungus. Chestnuts are eaten whole, roasted and husked, or ground for sweet flour, rich in starch. High-grade stock fodder, especially for pigs.

CHICORY (*Cichorium intybus*)
Herbaceous perennial long used as a vegetable in Europe and the Orient; grows from 0.6-1.6m. Likes full sun and grows from temperate to subtropical regions. Naturalises in fields and on disturbed soils.

USES: Bee forage; early and long-flowering. Roots roasted for coffee-like beverage. Mineral-rich leaves (from deep taproot mining the soil) excellent component in pasture as forage crop; improves milk quality and quantity. Medicinal (both human and animal); used for rheumatism, eczema, blood diseases.

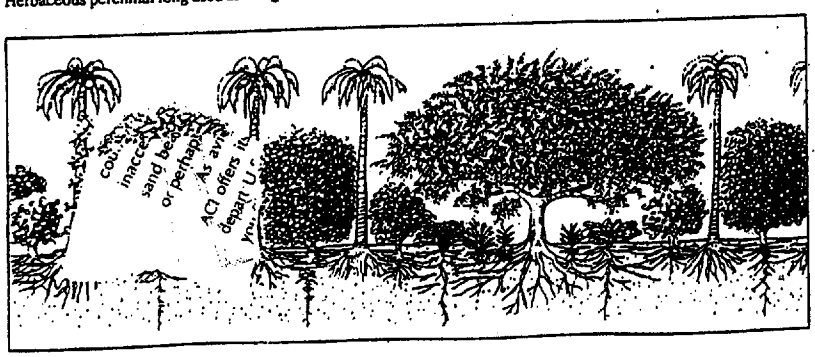
CHINESE WATER CHESTNUT (*Eleocharis dulcis*)
Aquatic rush with edible culms, grown in shallows or damp mud. Subtropics/tropics: can be grown wherever there are 8 frost-free months. May need to be netted against ducks when green shoots are emerging. Caution: As with many aquatic plants, these may accumulate heavy metals, so make sure pond water is not polluted (or use these to help clean up water; do not harvest). USES: Valuable human food, high in carbohydrate, used extensively in Asia.

CITRUS (*Citrus* spp.)
Wide range of evergreen shrubs or trees to 10m, including lemon, lime, cumquat, orange, grapefruit, mandarin. Dry, warm temperate (Mediterranean) climates to tropics. In marginal temperate areas, place in warm, sunny position. Tree can withstand light frost, but frost at -2° C kills flowers and young fruit. Need shelter in high wind areas.

USES: Fresh fruit or juice, marmalade, concentrated for cordials. High vitamin C source, especially if white pith is also eaten. Waste pulp fed to cattle. Peel is source of essential oils (used in flavouring and perfumes); also provides pectin.

CHOKO or CHAYOTE (*Sechium edule*)
Herbaceous scrambler, vigorous, perennial on thick rootstock. Subtropics to tropics; not hardy to frost.

USES: Roots used for starch, boiled or baked; young shoots eaten as a salad, steamed. Most commonly-eaten is



home brew, and the termites were denied direct access into the house. We also applied beneficial nematodes which eat termites, but not earthworms.

We used the soil from the subfloor excavations to build the base for the cistern, and to build berms to both block some of the noise coming from the bordering street and to harvest rainwater. The termite damaged flooring was then replaced with flooring our neighbor had just ripped out of his house. The flooring was sanded then oiled with a mix of 1 quart boiled linseed oil, 1 pint white vinegar, and 1 quart turpentine. Once dry, the floor was waxed.

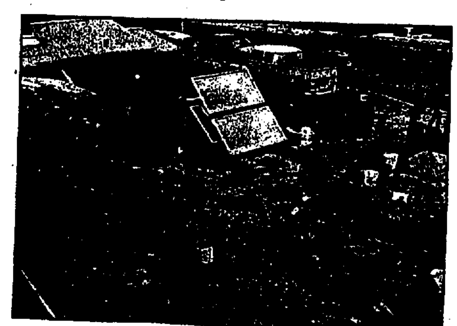
We moved in and hooked up our ceiling fans, our sole source of mechanized cooling. My partner, Marci, and I then made exterior window shades from hemp vine and salvaged hesperaloe flower stalks from the university research fields. We built more rebar trellises on which we're growing grapes and bougainvillaea. We shaded the perimeter of the house even further by extending a shade cloth (blocking 47% of the sun) from the house to the garage. We took support poles from our old chain link fence and bolted them flat against the ends of the rafters on each structure, and stretched shade cloth between them with clothesline.

Under the shade cloth we dug sunken garden beds through solid caliche earth and built raised paths around our mini-orchard with the dug-up caliche. This, in turn created sunken planting basins that would harvest water runoff. Caliche acts like decomposed granite as it doesn't get muddy or blow away. The beds dug through the caliche were then partially filled with good soil and salvaged composted manure. The surrounding soil was graded to drain all rainwater from the north of the house and the south of the garage into the garden. The north side of the garage is guttered, with rainwater diverted to a 330-gallon cistern of six salvaged 55-gallon barrels we got from a bakery. The barrels are elevated by bricks we pulled from a torn-down store.

We incorporated an herb spiral into our kitchen garden, watered by submerged, unglazed ollas. A rock lid cuts evaporation loss while water seeps through the sides of the olla and is delivered right to the root zone of the plants. The chipped and damaged ollas we bought were cheap. The herb spiral sits next to our worm/compost pit which is covered with an old carpet.

A basic principle of permaculture — turning waste into resource — enabled Rodd and me to buy our house, and then to fix it up! Diving through dumpsters for materials, reusing resources on site, and repairing this old adobe ourselves has saved us a bundle while giving us skills, knowledge, and a confidence we didn't have before. We now have far more than we would have had we somehow purchased a new property, and all for a fraction of the impact on the earth. Is that dumpster starting to smell good yet?

Upper right: Planting beds dug into caliche, filled with compost and soil.
Right: The recycled ramada sleeping platform and work area.
Below: The site in progress, viewed from ramada roof. Horno oven under construction on right.



Water Catchment and Restoration

Remember back to third grade, when you learned about the water cycle. First it evaporates from the oceans, then condenses in clouds. Above forests, pollen and other organic particles seed the clouds, raindrops form, and rain falls back to earth. Some flows back to the earth, some evaporates or drains into saltpans.

We humans have tried to create our own water cycle. The East Bay's water travels from high in the Sierras, down the Muknolumne River, past a series of dams, through miles of aqueduct, concrete tunnels and steel pipes. It crosses the Coast Ranges through siphons and pumping stations, then is treated by chloramine and other toxic chemicals before flowing out the faucet. Most urban water follows a similar path.

Unlike the natural water cycle, the system of aqueducts and reservoirs benefits only ourselves. River life dies out, wetlands are drained, canyons and valleys disappear behind dams. Even the oceans are slowly dying.

Meanwhile, millions of gallons of water fall in city roofs and streets and run off into the sewers. If we catch this water and use it in our homes and gardens, we step outside of the destructive cycle of dammed rivers and depleted aquifers. Infiltrating the runoff from hillsides, roads and parking lots allows trees to grow. Under trees, natural systems to regenerate through the cracks in the concrete. In the same way that composting creates rich soil from trash, water catchment and graywater cycling create opportunities for growth in barren places.

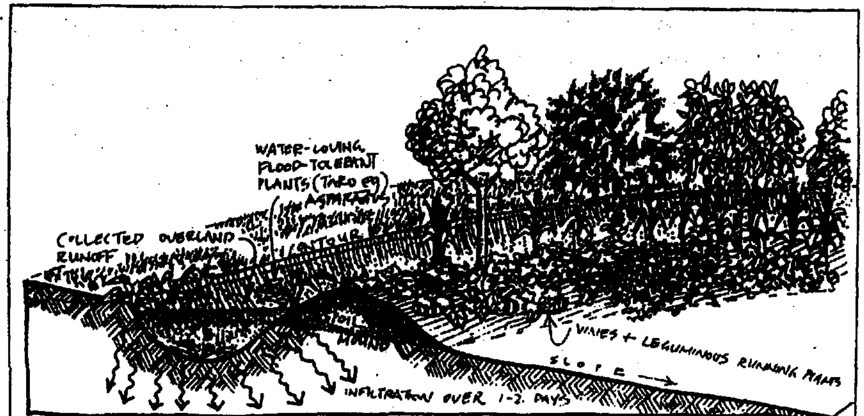


FIGURE 2.21 Swales on contour do not flow; they first stop and then absorb overland water flow. Swales are planted

Temperate and cold area plants.

USES: Good windbreak and erosion control plant. Edible berries for birds and poultry; cold area chicken forage plant. Ornamental screen hedges. Silverberry (*E. commutata*) and cherry elaeagnus (*E. multiflora*) also important wildlife, poultry berry plants.

AZOLLA (*Azolla* spp.)
Free-floating, small water ferns (red or green) which contain a nitrogen-fixing bacteria (*Anabaena azollae*). All climates, although dies back in hot weather. USES: Duck fodder. Nitrogen mulch for rice or taro crop for nitrogen. Can be skimmed off surface of ponds and used as a rich mulch on adjacent crops; or ponds drained, *Azolla* turned under, and crops grown.

BAMBOO (1250 species)
Two main types are running bamboos and clumping bamboos. Generally the tropical/subtropical varieties are clumpers and the temperate varieties are runners. In the case of runner bamboos, care must be taken so that they do not become rampant; they do not cross water, so may be contained on an island in a dam.
Bamboos grow from the equator to about 40° north and south. Propagation is by division of clumps, rhizome cuttings, and basal cane cuttings; bamboo grows best in rich organic soil with plenty of water.

USES: human food (clumps are hilled to produce large, tender shoots) and foliage as animal forage (some species such as *Arundinaria racemosa*, *Sasa palmata*). Structural: stakes, fishpoles, spears (small canes), building frameworks, concrete reinforcing (big canes). Clumps: windbreak, steep bank stabilisers. Other: utensils, mulch, artisanry.

BLACK LOCUST (*Robinia pseudoacacia*)
Deciduous tree 10-20m, thin foliage, lives up to 200 years. Grows rapidly and forms thickets by root suckers (very aggressive). Very hardy and suited to cool areas, poor soils.

USES: Pasture improver on very poor country (nitrogen fixer); erosion control; windbreak tree; bee forage; seed for poultry; and timber suited to beams, tools and shafts. Poles last over 20 years untreated in the ground.

BLACKBERRY, RASPBERRY (*Rubus* spp.)
Cultivars include boysenberry, loganberry. Vigorously-growing prickly thickets (some thornless varieties have n developed). High-value commercial crop on trellis. ckberry easily becomes rampant, spread by seeds and ooting. Can be marooned on islands. Blackberry (*R. laciniatus*) has a thornless variety (Oregon thornless) which is best for gardens. Loganberry and boysenberry are preferred cultivars, with very large berries. May need netting against birds. Bee forage.

BLUEBERRY, HUCKLEBERRY, CRANBERRY (*Vaccinium* spp.)
Deciduous shrubs from 2.5cm to 3.6m tall; cool temperate to subtropical climates. Tolerate partial shade or full sun. USES: Understorey berry crop. Most species good bee forage.

High bush blueberry (*V. corymbosum*) grows to 1.2-3.6m and is grown as a commercial crop, needs to be netted against birds. Low bush blueberry (*V. angustifolium*) can be used as a groundcover (8-20cm); avoid frost pockets.

Huckleberry (*V. membranaceum*, *V. ovatum*) are not commercially grown for berries, but these are tasty for human use; also poultry forage. Evergreen huckleberry produces best in partial shade. Species grow 30cm-3m tall.

Cranberry (*V. oxycoccus*) is about 25cm tall; it is an evergreen, prostrate undershrub, and grows well in peat bogs, with soil pH of 3.2 to 4.5. A constant water supply is necessary for good fruiting, but plants should not be swamped. Rich humus and thick mulches are ideal. Avoid planting in known frost pockets; fruits must ripen before hard frosts. High-value commercial crop.

BORAGE (*Borago officinalis*)
An upright, self-seeding annual to 0.6m at maturity. Can be grown in full sun or partial shade; tolerates poor soils but needs regular watering. Easy to propagate in large quantities; sow seed in spring. Temperate climate. USES: Good bee forage, with a long flowering season. Leaves and flowers in salads. Compost/manure tea with comfrey: rich in potash and calcium; breaks down very quickly. Medicinal properties: anti-inflammatory.

BROAD BEAN (*Vicia faba*)
Annual legume 0.5-1m; temperate to subtropical climates, likes full sun but grows well in cloudy maritime climates over winter. USES: Human food—young leaves, pods, beans (fresh or dried). Also used as stock fodder. Cover crop over garden beds, fields; green manure crop and nitrogen fixer, with crop cut and used for mulch before flowering (nitrogen stays in the soil).

CAPE GOOSEBERRY (*Physalis peruviana*)
A perennial, tender, creeping bush of the tomato family (Solanaceae) with small greenish-yellow fruits surrounded by a papery calyx or husk. Fruits ripen in late summer and are used fresh or stewed. Used in Mexico as a hot sauce when mixed with chillies and onions. Easily frost-damaged; grown as an annual in cold temperate climates.

CAROB (*Ceratonia siliqua*)
A long-lived tree 5-15m grown for its sugary pods. A tree of the Mediterranean, it does best in dry temperate climates and can tolerate poor soil conditions. Frost dam-