The Container Tree Nursery Manual

Volume One
Nursery Planning, Development, and Management

Chapter 2
Site Selection

Contents

1.2.1 Introduction

different propagation structures that must also be matched to the site, so a basic knowledge of the types of structures and environmental control equipment is necessary during site evaluation (see chapters 3 and 4 Once the decision has been made to build a container tree nursery, the nursery's developer is faced with the formidable challenge of selecting a suitable site. Although site selection criteria for a container nursery can be fairly restrictive, they are less demanding than those for a bareroot facility. Container nurseries can be located on sites that would be totally inappropriate for a bareroot nursery because seedlings are grown in artificial growing media and with structures and equipment to modify the physical environment.

The basic objective of any nursery operation is to modify the natural environment so that plants can be produced quickly, efficiently, and economically. Container nurseries offer the potential for considerable environmental modification, but both development and operating costs increase with degree of modification. There are a variety of in this volume).

A successful container nursery must be carefully matched to the environmental conditions on the site; a nursery designed for one site will not necessarily be best for another. Therefore, nursery developers must analyze the climatic environment at each potential site by critically evaluating both short-term and long-term weather records as well as through direct observation.

Nursery developers should be prepared to devote a substantial amount of time to site selection because many biological and operational problems that develop later in nurseries can be traced back to problems with the selected site. Nursery sites that are selected mainly for economic or political reasons frequently fail to meet some of the more critical criteria, and these deficiencies limit the success of the nursery. Biological site selection criteria should always be paramount, but potential nursery developers must also consider business realities.

The things to look for in a potential container nursery site can be divided into critical factors and desirable factors (table 1.2.1). Critical site selection criteria are those factors that are essential to a successful nursery operation. Desirable attributes include those site factors that are not absolutely necessary but will increase the economy and efficiency of the nursery operation.

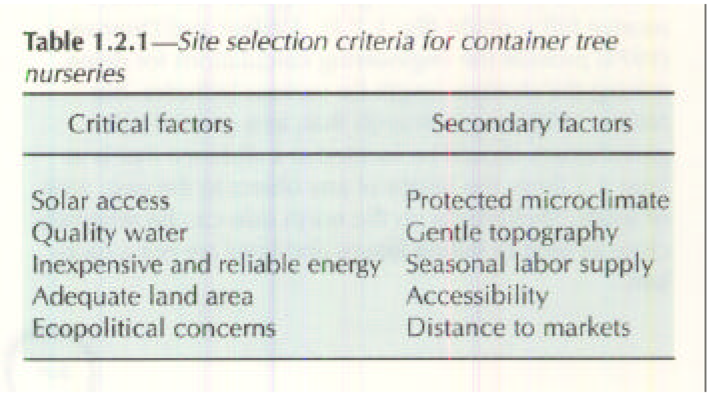

Table 1.2.1—*Site selection criteria for container tree nurseries*

Critical factors	Secondary factors
Solar access	Protected microclimate
Quality water	Gentle topography
Inexpensive and reliable energy	Seasonal labor supply
Adequate land area	Accessibility
Ecopolitical concerns	Distance to markets

1.2.2 Critical Site Selection Criteria

1.2.2.1 Unobstructed solar access

Although it should go without saying, container tree nurseries must be located on sites with good solar access, both throughout the day and during the growing season. It is usually considered uneconomical to supply enough light energy for photosynthesis, and so container nurseries must be located where they receive full sunlight for almost all of the solar day. Any amount of shading will decrease productivity and increase costs. This is most critical in northern latitudes or in perennially cloudy climates but also applies to sunnier locations, because it is relatively easy to provide the shading if it is required.

Growing areas must not be affected by shade from surrounding trees or buildings. If crops are to be grown year-round, the solar angle should be determined for all seasons to ensure that the growing area will always receive full sunlight (fig. 1.2.1). Walker and Duncan (1974) provide the engineering calculations for determining the shadow length for various latitudes, but Nelson (1991) recommends that, as a general rule, greenhouses should be located at a distance that is at least 2.5 times the height of any object to the east, west, or south. Shelterbelts on the north side can be relatively close as long as falling leaves and litter are not a problem.

1.2.2.2 Ample supply of high-quality irrigation water

Next to sunlight, a reliable supply of high-quality irrigation water is the most important site selection factor. Relatively large amounts of water are needed by the seedlings themselves and also for regulating the temperature of the growing environment. Container seedlings have very low moisture reserves, which are limited by the volume of the container and the moisture holding properties of the growing medium (Davidson and others 1988), so seedlings must be irrigated frequently. In hot climates, water is also essential for evaporative cooling. In cooler climates, growers may need to use irrigation water during the early spring or late fall for frost protection of seedlings in open growing compounds.

Assessing water quality. The definition of water quality is determined by its intended use. Water that would be entirely suitable for domestic or industrial purposes can be severely damaging to plants.

Components of water quality. For nursery site evaluation purposes, irrigation water quality is determined by two factors: suspended particles (sediments or pests) and dissolved salts.

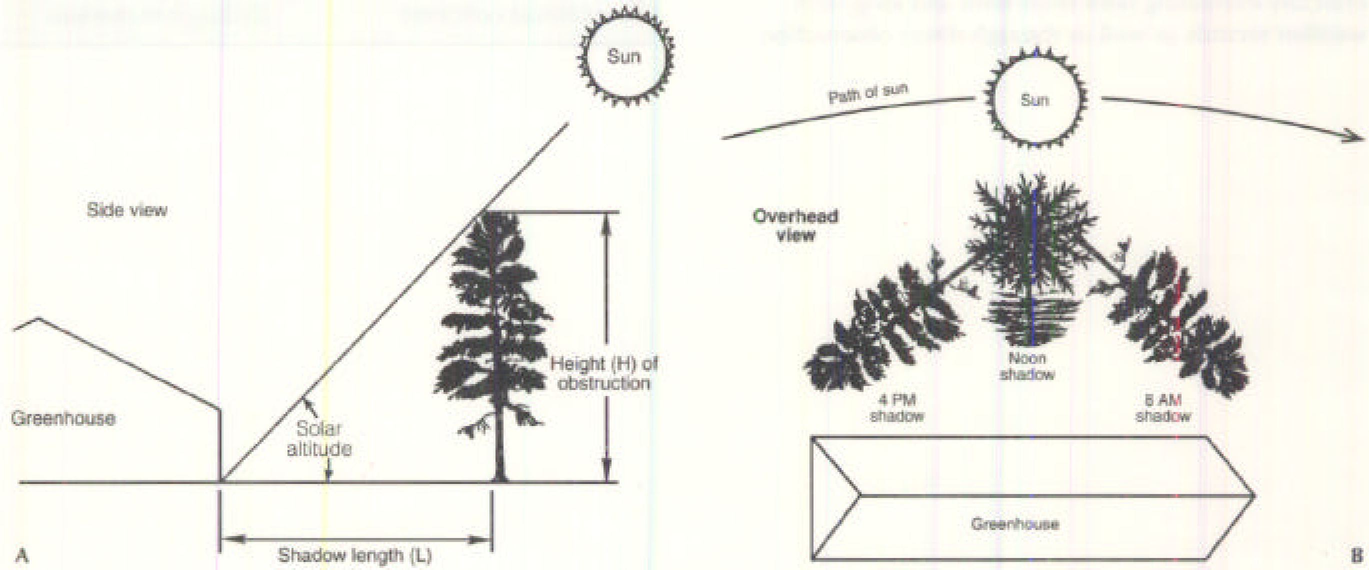

Figure 1.2.1—*Calculation of sun angles at the important times of the year is necessary to avoid shadows from objects near the greenhouse* **(A)**. *Shadows also change size and position during the day* **(B)**. *(Modified from Walker and Duncan 1974.)*

Suspended sediments and pests. Inorganic materials such as clay, silt, and even very fine sand particles are small enough to remain suspended and so must be mechanically filtered or removed by chemical treatments (Tchobanoglous and Schroeder *1985).* Suspended sediments are abrasive and can quickly wear out water pumps, fertilizer injectors, and sprinklers.

The source of the irrigation water determines what types of suspended materials it may contain, and typical irrigation sources for container nurseries include municipal water, surface water, and well water. Municipal water usually has been filtered to remove particulate matter, although this should be checked. Surface water often contains suspended silt or clay particles, especially after a heavy rain, and depending on the characteristics of the aquifer and type of casing, even well water may contain sand. Although suspended inorganic sediments can be easily removed from a potential irrigation source, the costs of water treatment can be considerable and so must be factored into the site development costs.

Pests can also be suspended in water. Water from surface sources, especially ponds in agricultural areas (fig. 1.2.2A), can contain propagules of potential nursery pests, which include weed seeds and spores of fungi, algae, mosses, and liverworts. Specially designed filters can remove the larger pests, including weed seeds, algae, and some fungal spores, but the cost of the filters increases as the minimum pore size decreases. Domestic water sources are normally well filtered and so these pests should not be a problem.

Chlorination effectively eliminates pathogenic fungi, bacteria, algae, and liverworts. Normal domestic chlorination produces a chlorine level of about 1 ppm, which is not injurious to most plants (Frink and Bugbee *1987).* Irrigation water can also be chlorinated at the nursery, but again, this treatment will increase the sitedevelopment costs. Fluoride is also added to some domestic water sources at the rate of around 1 part per million (ppm) to retard tooth decay. Although some ornamental crops have been injured by fluoridation (Nelson *1991),* plants grown for forestry or conservation purposes are apparently more tolerant. (Chlorination, filtration, and other potential irrigation water treatments are discussed in more detail in volume four of this series.)

Dissolved salts. Many different mineral ions can be dissolved in potential irrigation water, and even perfectly clear water can contain harmful salts. In coastal areas, potential nursery sites can have groundwater that is contaminated by saltwater intrusion (Nelson *1991);* in fact, container nurseries have had to be moved further inland because of problems with toxic sodium (Na^+) and chloride (Cl^-) ions (fig. 1 .2.213). Some cations, such as the calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions that are found in "hard" water, can be either troublesome or beneficial depending on their concentrations. Moderate levels of calcium and magnesium can be beneficial because they are plant nutrients and are often difficult to formulate into liquid fertilizer solutions. Higher concentrations cause deposits, or "scale," on irrigation nozzles and other surfaces. Other ions, especially those of boron (B), can be toxic to tree crops at concentrations of less than 1 ppm. Iron (Fe) is a necessary plant nutrient, but high Fe levels in irrigation water can cause unsightly staining of plant foliage and other nursery surfaces (fig. 1 .2.2C).

Testing water quality. Many different water quality guidelines have been published because different standards apply for each purpose. Both the total salinity and the concentration of the individual salt ions are important. Ionic concentrations may be expressed as milligrams per liter (mg/l) or parts per million (ppm) which, for our purposes, are equivalent. The other standard unit is milliequivalents per liter (meq/l). (The definition of these units and their conversions are provided in section 4.2.4 of volume four of this series.) f=or site evaluation purposes, four different factors are important:

pH. This index of relative acidity or alkalinity is the most frequently discussed water quality factor but, in terms of horticultural importance, it is actually overrated. The pH of typical irrigation water is usually about neutral (pH *6.5* to *7.5).* Most forest and conservation seedlings grow well at mildly acidic pH levels of *5.0* to *6.0,* and weak acid solutions can be easily injected into the irrigation system to achieve this target level (table 1.2.2). Irrigation waters with pH values below *6.0* are rare, but water that exceeds pH 7.5 should be further evaluated. These higher pH values are often symptomatic of detrimental concentrations of sodium.

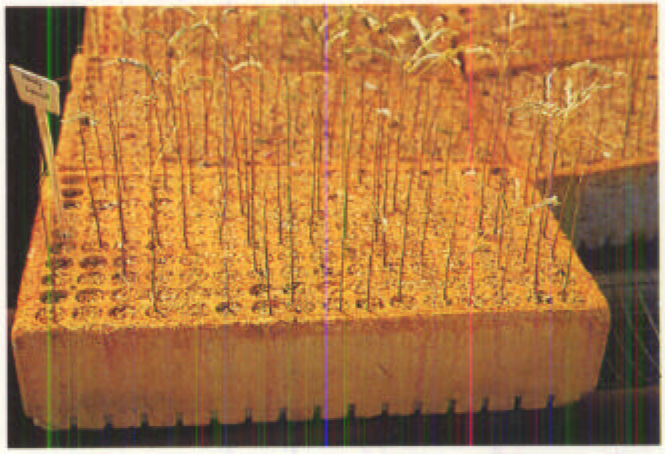

Figure 1.2.2--*Potential sources of irrigation water must be tested. Pond water may be contaminated with fungal pathogens* ***(A)****, and groundwater can contain high concentrations of salts, which can burn seedling foliage (****B)****. Other water sources may contain bicarbonate ions or iron, which can stain plants and containers* ***(C)****.*

Electrical conductivity (EC). This index of salinity measures the total concentration of dissolved ions by passing a weak electrical current through the solution. An EC meter reads the electrical conductivity in microsiemens per centimeter (µS/cm), which is equivalent to micromhos per centimeter (µmho/cm); the higher the reading, the higher the salt concentration in the solution. Irrigation water with an EC reading of more than 1,500 µS/cm is considered to be too saline for successful container nursery production (table 1 .2.2).

Toxic ions and heavy metals. Three salt ions that are commonly found in irrigation water can actually be directly toxic to seedlings at high concentrations: sodium (Na+), chloride (Cl-), and boron (B) (table 1.2.2). Contamination of irrigation water with elements (known as heavy metals) such as lead, chromium, cadmium, and mercury can also be a problem because even low concentrations can be toxic to plants (U.S. Environmental Protection Agency 1982). Standard water quality evaluations do not include tests for these elements and so special testing is warranted if the potential nursery site has a history of heavy metal contamination, or if the water comes from an aquifer containing metal ores. Water effluent from sewage treatment plants can also be contaminated with heavy metal ions. Water can also be contaminated by many other compounds including pesticides or other hazardous chemicals. Tests for organic chemicals such as pesticides are extremely expensive, however, because each potential pollutant requires a different testing procedure.

Accessory ions. Although they are not toxic to seedlings, several other ions indirectly affect irrigation water quality (table 1.2.2). Calcium (Ca^{2+}), magnesium (Mg^{2+}), sulfate (SO_4^{2-}), and bicarbonate (HCO_3^-) affect other water quality indices such as hardness and alkalinity, and HCO_3^- can also cause foliage spotting. Besides being mineral nutrients, Ca^{2+} and Mg^{2+} can partially counteract the deleterious effects of Na^+ and Cl^- ions.

Other indices. Several other water quality parameters are sometimes encountered in the literature:

- **Total dissolved solids** (TDS), an older measure of total salinity, is sometimes called the **total dissolved salts.** The TDS is calculated by merely adding up the concentrations of the various dissolved constituents

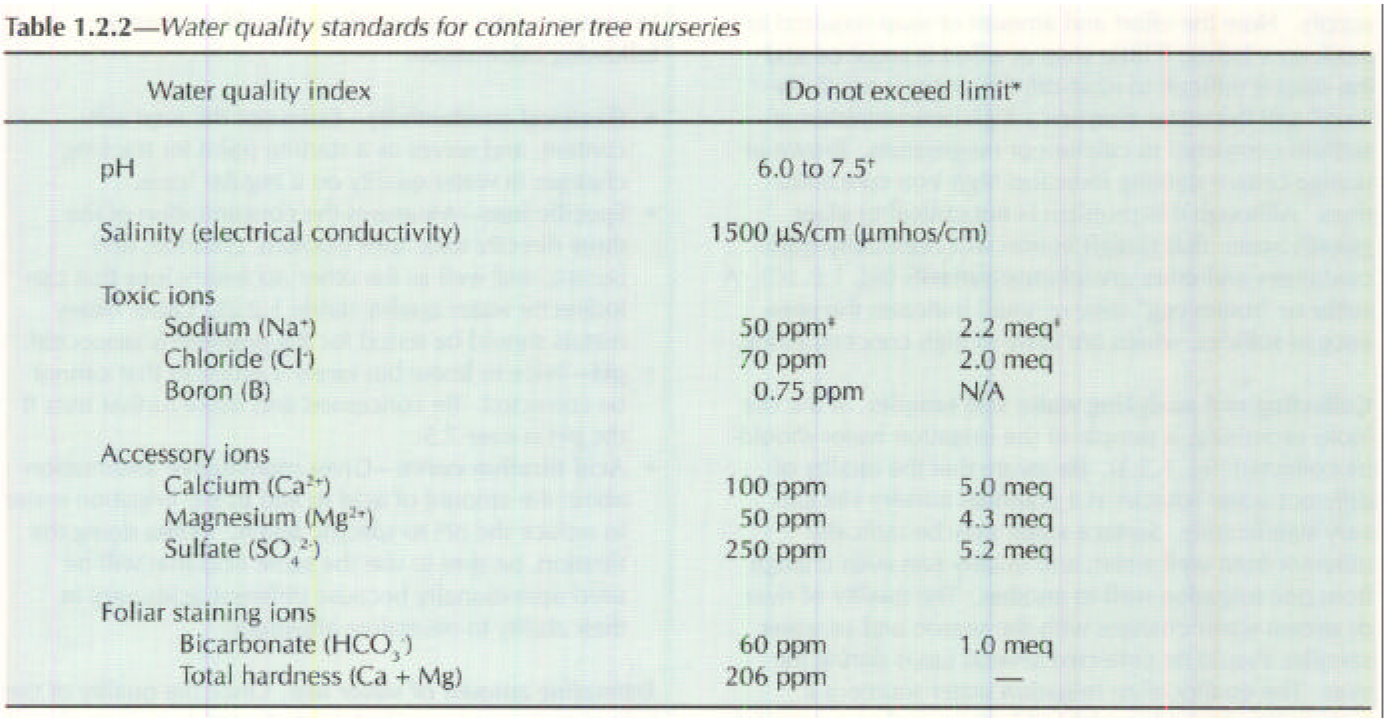

Table 1.2.2—*Water quality standards for container tree nurseries*

Water quality index	Do not exceed limit*	
pH	6.0 to 7.5†	
Salinity (electrical conductivity)	1500 µS/cm (µmhos/cm)	
Toxic ions		
Sodium (Na^+)	50 ppm‡	2.2 meq‡
Chloride (Cl^-)	70 ppm	2.0 meq
Boron (B)	0.75 ppm	N/A
Accessory ions		
Calcium (Ca^{2+})	100 ppm	5.0 meq
Magnesium (Mg^{2+})	50 ppm	4.3 meq
Sulfate (SO_4^{2-})	250 ppm	5.2 meq
Foliar staining ions		
Bicarbonate (HCO_3^-)	60 ppm	1.0 meq
Total hardness (Ca + Mg)	206 ppm	—

These values assume a porous and free-draining growing medium. Water with much lower salt concentrations can cause serious problems if poor drainage or irrigation practices allow salts to accumulate. Water pH limits are relatively easy to adjust with acid injection (see explanation in text).

4: 1 part per million (ppm) = 1 milligram per liter (mg/l); the conversion between milliequivalents (meq) and ppm varies with the atomic weight and electrical charge of the ion. Boron has several different ionic forms in irrigation water and therefore a specific conversion cannot be made.

Source: From various sources, see table 4.2.7 in volume four *of this* series.

(Hem *1992)* and is reported in parts per million (ppm). An approximate EC reading in microsiemens per centimeter (µS/cm) can be obtained by dividing TDS by 0.64.

- **Total alkalinity,** another traditional water quality index, is defined as the capacity to neutralize acid. In natural water, alkalinity is practically all produced by carbonate and bicarbonate ions, and so most water tests report alkalinity as the sum of these two ions (Hem *1992).* Alkalinity is closely related to pH and so the higher the reading the more acid will be required to lower the pH to target levels. When irrigation water has a total alkalinity rating of greater than 100 ppm, it becomes operationally difficult to lower the pH to the ideal range for plant growth (Tayama *1991).*
- **Hardness** is a traditional water-quality term referring to the precipitate ("scum") formed by reaction of soap with calcium and magnesium ions in the water. Most water analyses compute "total hardness as calcium carbonate (CaC03)" by combining the concentrations of these two ions (Hem *1992).* Although useful for determining water quality for domestic (cleaning ability) or industrial purposes (scale deposits), the relative terms "hard" and "soft" have no practical use for determining irrigation water quality. However, water for nursery use should never be "softened," for this process replaces calcium and magnesium ions with those of sodium. Domestic water that has been softened often contains levels of sodium ions high enough to cause injury to container nursery crops.

On-site *observations. Although* a complete water-quality analysis is always necessary, some basic observations will give the nursery developer some important clues to irrigation water quality. Water containing high levels of salts often tastes heavy and flat; if it tastes salty, chloride is probably greater than *250* ppm (U.S. Environmental Protection Agency *1982).* Whitish crusts or scale deposits on faucets indicate high concentrations of calcium and magnesium bicarbonates in the water supply. Note the effort and amount of soap required to work up a lather; if little soap or effort is required and the soap is difficult to rinse off, the water is relatively "soft" and the water contains a high concentration of sodium compared to calcium or magnesium. Brown or orange-brown staining indicates high iron concentrations. Although this problem is not critical to plant growth, water that is high in iron will eventually stain containers and other greenhouse surfaces (fig. 1.2.2C). A sulfur or "rotten egg" taste or smell indicates the presence of sulfides, which are toxic in high concentrations.

Collecting and analyzing water test samples. If the site looks promising, a sample of the irrigation water should be collected (fig. 1.2.3). Be aware that the quality of different water sources at a potential nursery site can vary significantly. Surface water may be radically different from well water, and quality can even change from one irrigation well to another. The quality of river or stream water changes with the season and so water samples should be collected several times during the year. The quality of an irrigation water source is a composite of a wide variety of factors, and so a complete water analysis should be performed (table 1.2.2). In addition to the principal water quality indices and the concentrations of the toxic ions, the concentrations of other accessory ions (specifically calcium, magnesium, and bicarbonate) also should be determined. (Water sampling procedures and a complete discussion of irrigation water analysis are provided in volume four of this series.)

Figure 1.2.3-*The first step in determining the suitability of a potential nursery site is to collect water samples from all potential sources of irrigation water and obtain a complete water analysis.*

In summary, the water analysis should contain the following information:

- **Electrical conductivity**--Estimates the total salt content, and serves as a starting point for tracking changes in water quality on a regular basis.
- **Specific ions**--Measures the concentration of the three directly toxic ions (sodium, chloride, and boron), and well as the other accessory ions that can indirectly water quality (table 1.2.2). Other heavy metals should be tested for if a problem is suspected.
- **pH**-Nice to know but rarely a problem that cannot be corrected. Be concerned and make further tests if the pH is over 7.5.
- **Acid titration curve**--Gives quantitative information about the amount of acid to add to the irrigation water to reduce the pH to specific levels. When doing the titration, be sure to use the same acid that will be used operationally because different acids vary in their ability to neutralize alkalinity.

Estimating amount of water use. Once the quality of the irrigation source is verified, both the total amount of water per season and the rate at which the water can be supplied must be evaluated. Estimates of total annual water use will be needed from potential nursery developers when applying for water rights, and the peak water use rate must be estimated to determine the required irrigation pump capacity and to assess the need for water storage ponds or tanks.

Total water demand. During the site evaluation process, nursery developers should calculate the total amount of irrigation water that will be required per season or year. In addition to current water requirements, projected nursery expansion must also be considered when estimating total annual water demand. If the primary water source is unreliable, it may be wise to evaluate a potential backup source of irrigation water; for example, water availability can be a problem in nurseries with open growing compounds that need to irrigate for frost protection during cold weather (Appleton 1986). Nurseries that rely on surface water sources that freeze may want to dig a well for a backup source of irrigation water.

The total amount of water that a container tree nursery will require depends on many factors, including climate, type of nursery and irrigation system, container volume, and the water use patterns of the crop. Total water demand has been given in many different units, but volume of water that must be supplied over some time interval per unit area of growing space or per thousand seedlings is most useful for planning purposes (table 1.2.3).

Water will also be required for purposes other than crop production, such as cooling, landscape, and domestic uses, and estimates of these requirements can be developed with normal engineering calculations. Tinus and McDonald (1979) estimated that a nursery consisting of a 464-m^2 (5,000-ft^2) greenhouse and a 695-ml (7,500-ft^2) shadehouse would require approximately 3,800,000 l/yr (1,000,000 gal/yr) for other nursery and domestic uses.

Rate of water demand. During the site evaluation process, an estimate of the peak water use rate is needed to determine irrigation pump output. For example, if peak water use exceeds the maximum supply rate from a well, then water storage ponds or tanks may be needed (fig. 1.2.4). Peak water use information will also be needed during nursery development to determine the size of the irrigation pumps and supply pipes and the overall design of the irrigation system (Aldrich and Bartok 1989).

The peak use rate will vary significantly with different types of irrigation systems (sprinklers versus drip) and with irrigation system design. Although fixed sprinkler irrigation is the most common design in container tree nurseries at present, movable boom irrigation is becoming more popular and requires a much lower peak water use rate. The increasing concern about surface discharge and potential groundwater pollution will undoubtedly require increased irrigation efficiency with a corresponding decrease in the rate of water demand.

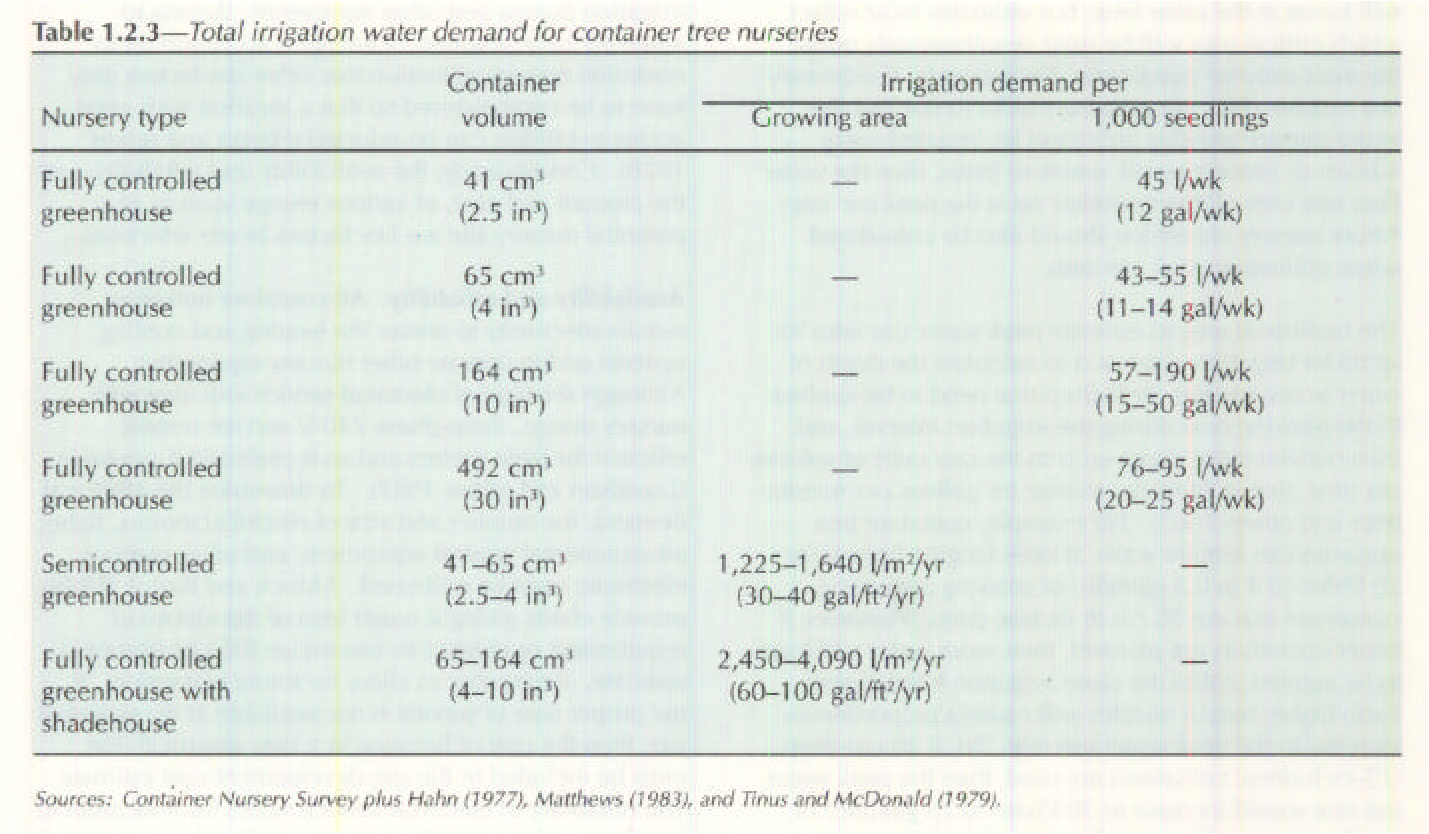

Table 1.2.3—*Total irrigation water demand for container tree nurseries*

Nursery type	Container volume	Irrigation demand per Growing area	Irrigation demand per 1,000 seedlings
Fully controlled greenhouse	41 cm^3 (2.5 in^3)	—	45 l/wk (12 gal/wk)
Fully controlled greenhouse	65 cm^3 (4 in^3)	—	43–55 l/wk (11–14 gal/wk)
Fully controlled greenhouse	164 cm^3 (10 in^3)	—	57–190 l/wk (15–50 gal/wk)
Fully controlled greenhouse	492 cm^3 (30 in^3)	—	76–95 l/wk (20–25 gal/wk)
Semicontrolled greenhouse	41–65 cm^3 (2.5–4 in^3)	1,225–1,640 l/m^2/yr (30–40 gal/ft^2/yr)	—
Fully controlled greenhouse with shadehouse	65–164 cm^3 (4–10 in^3)	2,450–4,090 l/m^2/yr (60–100 gal/ft^2/yr)	—

Sources: Container Nursery Survey plus Hahn (1977), Matthews (1983), and Tinus and McDonald (1979).

Figure 1.2.4—*If the flow from wells or streams is not enough to meet peak irrigation demand, it may be necessary to build water storage reservoirs or tanks.*

Peak water use rates should be expressed as volume of water per unit time per unit area of growing space. The total water use rate estimate for the proposed nursery facility need not assume that the whole irrigation system will be on at the same time, but estimates must reflect which critical uses will be used simultaneously under the most extreme conditions. For example, if extremely hot weather dries out growing media so fast that the entire nursery growing area must be irrigated every 4 hours to prevent severe moisture stress, then the water flow rate with all the sprinklers on is the peak use rate. Future nursery expansion should also be considered when estimating peak use rates.

The traditional way to estimate peak water use rates for sprinkler irrigation systems is to calculate the depth of water in centimeters (or inches) that need to be applied to the growing area during the irrigation interval, and then convert those depth units to the rate units of volume per time, that is, liters per minute (or gallons per minute) (Pair and others 1983). For example, container tree nurseries can require water at rates ranging from 16 to 20 l/h/m^2 (0.4 to 0.5 gal/h/ft^2) of growing area using containers that are 20 cm (8 inches) deep. However, if larger containers are planned, then more water will have to be applied within the same irrigation interval and these higher output nozzles will cause a proportionate increase in the peak water use rate. So, if 30-cm-deep (12-inch-deep) containers are used, then the peak water use rate would increase to 30 l/h/m^2 (0.75 gal/h/ft^2) of production area (Tinus and McDonald 1979) .

Peak rates must consider all types of water use that may be used at the same time: production, cooling, landscape, and domestic. Assuming a 20 l/h/m^2 (0.5 gal/h/ft^2) application rate for a 464-m^2 (5,000-ftZ) greenhouse, the peak water use rate would be 11,800 l/h (3,125 gal/h), or about 200 l/min (52 gal/min) (Tinus and McDonald 1979). The authors calculated other nursery uses at 150 l/min (40 gal/min). Therefore, after adding the production and other water use rates and rounding up, the total water rate requirement would be around 378 l/min (100 gal/min).

1.2.2.3 Inexpensive and reliable energy source

Container tree nurseries require relatively large amounts of energy, although the exact requirements will vary with the climate, the type of propagation structures, the sophistication of the environmental control equipment, and the type and timing of the crop. Fully controlled structures require large amounts of fuel for heating and electricity for operating environmental control equipment. Even nurseries that grow seedlings in open growing compounds require electrical energy to operate irrigation pumps and other equipment. Access to relatively large amounts of energy is so important to container nursery operation that other site factors may have to be compromised so that a location with good access to utilities can be selected (Hanan and others 1978). Consequently, the availability and reliability, and the amount and cost, of various energy sources at a potential nursery site are key factors in site selection.

Availability and reliability. All container nurseries require electricity to power the heating and cooling systems and to operate other nursery equipment. Although the type of electrical service will vary with nursery design, three-phase 240-V service is most efficient for large motors and so is preferred if available (Davidson and others 1988). To determine the electrical demand, the number and size of electrical motors, lights, environmental control equipment, and other users of electricity must be estimated. Aldrich and Bartok (1989) provide charts giving a rough idea of the electrical requirement or contact an electrician for a professional estimate. Remember to allow for future expansion. If the proper type of service is not available at the potential site, then the cost of bringing in a new electrical line must be included in the site development cost estimate. The reliability of electrical service varies from location to location, and it would be wise to inquire about potential problems from other local businesses. Although all container nurseries should have a backup generator in case of short-term power failure, chronic problems with reliability of electrical power are unacceptable.

Because heating is not necessary in milder climates, electricity is the only energy source that is needed. In colder locations, however, container nurseries require an additional source of energy for heating. Although electricity can be used for heating growing structures, it is almost always too expensive compared to other energy sources. Most common fuels have been used to heat container tree nurseries including natural gas, propane, and fuel oil, and so nursery developers should determine the availability and cost of these fuels for each potential site. The practicality and cost of delivering fuel to the nursery must also be considered; natural gas may not be available in some locations, but propane and fuel oil can be delivered to almost any site. Some nurseries heat their growing structures with alternative energy sources, such as wood, used oil, and waste heat (see chapter three in this series for more information on fuels).

Quantity required and cost. In order to compare the relative costs of different energy sources, an estimate of energy requirements of the proposed nursery facility should be made. In traditional greenhouses, maintaining temperatures at ideal levels for plant propagation is by far the most energy-demanding operation. Heating requires the greatest amount of energy in temperate zone nurseries, consuming between 70 to 85% of the total energy budget. Cooling is the second-most energy demanding operation, using from 5 to 10% of the total energy demand (Roberts and others 1989).

The amount of energy required to keep a growing structure at optimum temperatures is a function of the type of heating system and the rate of heat loss. Heat loss calculations consider factors such as greenhouse area, type of structure and covering, and surrounding climate. Sample calculations can be found in general greenhouse publications, including Aldrich and Bartok (1989) and Roberts and others (1989). Cameron (1982) presents a detailed analysis of energy requirements for producing a winter crop of tree seedlings in the Maritime Provinces of Canada.

Solar and alternative energy sources. The potential use of energy sources other than fossil fuels should always be considered during container nursery site selection. Greenhouses are designed to capture solar energy, and so the orientation of the growing structure is of paramount importance (see section 1.2.2.1). The possibility of using solar energy as a sole source of heat has been thoroughly analyzed (Midwest Plan Service 1983), but even the most sophisticated solar greenhouse designs will require a supplementary source of energy. Although limited to certain sites, geothermal energy is another potential source of energy for heating greenhouses (White and Williams 1975), but this option can be quite expensive unless circumstances are very favorable (McDonald and others 1976). By locating next to a power plant or major industry, greenhouses can make use of the waste heat that is a byproduct of energy generating processes (White 1976). Although these alternative energy sources should be considered wherever the opportunity exists, traditional fuels will continue to be the major source of energy at most locations.

1.2.2.4 Adequate land area

The amount of land selected for a container tree nursery must be large enough for the production areas and support buildings, and also-allow for efficient movement of equipment and materials. The shape of the parcel may be more important than the actual area because greenhouse ranges tend to be elongated facilities. In addition to immediate needs, the nursery developer should evaluate potential nursery sites on the basis of their space for possible expansion. In fact, Nelson (1991) recommends looking for a site that has at least twice the planned growing area. Sketching potential expansion areas on the existing site plans along with access roads and support buildings is strongly recommended. It is much easier to sell surplus land at some future date than to acquire some much-needed space for expansion or try to operate at two separated locations. Many nurseries have been developed in rural locations, only to find themselves surrounded by urban development a few years later (fig. 1.2.5).

Figure 1.2.5—*Nurseries that were originally located at the perimeter of urban areas are often engulfed by growing cities (courtesy of Tim McConnell, USDA Forest Service).*

1.2.2.5 Ecopolitical concerns

This site selection factor was not even considered a few years ago, but it has since become one of the most critical evaluation criteria. Restrictive land-use laws and concerns about pesticide use and potential soil and groundwater contamination have severely reduced the number of sites suitable for nursery development.

Land-use zoning and building restrictions. Many areas, especially those around municipalities, have zoning laws that affect development, and some even prohibit certain types of businesses. In general, container nurseries are considered agricultural businesses and can be constructed wherever agriculture is permitted, but potential developers should always discuss their plans with local authorities just to be certain. Nursery type is also an important consideration, as some local governments restrict the type of propagation structure that can be constructed on a site. Developers should attempt to predict future zoning changes by studying development patterns for the surrounding region (Nelson 1991). It is also a good idea to talk to your potential neighbors because existing landowners are becoming more involved in local zoning issues. This is not just a problem in urban areas, as many former city dwellers are moving to the country and often object to any type of new development. This can even occur in areas that are already zoned for agriculture and greenhouses (Roberts 1992).

Most zoning commissions require that potential nursery developers submit a detailed development plan and map, and a public hearing is often necessary. Be aware that all this may take considerable time. It can take from 3 months to 3 years to get through all the bureaucratic hurdles and obtain the necessary building permits (Roberts 1991). And, even if you can get the necessary permits, the cost may be restrictive, especially for container nurseries with many small propagation structures. Although generally classified as temporary structures, some municipalities tax plastic-covered greenhouses as permanent structures (Boodley 1981). A complete discussion of zoning ordinances and how they may affect container nursery development and operation is given in Bartok and Aldrich (1989).

In addition to providing information on building codes and zoning restrictions, the city or county clerk can provide valuable advice on other permits, tax laws, and business licenses that could affect the practicality of developing a container nursery on a particular land parcel (Davidson and others 1988). One city in California has just recently been assessing a new traffic-impact tax that adds $21.50 per mz ($2 per ftz) to the cost of constructing any new building (Roberts 1991). Some local governments encourage nurseries by classifying them as agricultural businesses, which can be some protection against the prohibitive tax increases that can result from future rezoning.

Potential chemical pollution. The fate of agricultural chemicals and the possible pollution of soil or water must be considered during nursery site selection. The principal agricultural pollutants that are associated with container tree nursery operations are pesticides (and their degradates), nitrates, and phosphates. Pesticides and nitrates can adversely affect human health, and nitrates and phosphates pose a significant threat to general water quality through eutrophication. Because container nurseries typically apply most of their pesticides and fertilizer through the irrigation system, the surplus water either runs off the growing area or soaks into the ground (fig. 1.2.6A). Irrigation water that runs off the site legally becomes a **discharge,** which is becoming regulated in many areas of the country (Landis and others 1992). For example, concerns about agricultural pollution in western Oregon resulted in the development of the "Container Nursery Irrigation Water Management Plan," which gives nurseries two options: eliminate all irrigation runoff discharges or obtain runoff discharge permits (Grey 1991).

Figure 1.2.6—*Managing the surface runoff from container nurseries is a growing problem because of its pollution potential* **(A)**. *One innovative solution is to treat irrigation discharge with a constructed wetland* **(B)**.

Developers should conduct an environmental audit of a candidate nursery site to determine baseline levels of potential pollutants and determine the potential for future problems (Aylsworth 1993). Nurseries that are constructed on already contaminated soil could be liable for any resultant pollution, and many banks are requiring environmental audits before approving loans to buy new property. Talk to local environmental protection and agriculture agencies and, if there is concern, it may be wise to hire a professional consultant to do soil and water testing (Kammel 1991). There are new techniques for managing agricultural pollution. Some progressive nurseries are constructing on-site water treatment facilities including recirculation ponds (Skimina 1992) and constructed wetlands (Dumroese and others 1992) (fig. 1.2.613). Constructed wetlands and other water treatment facilities require a fair amount of land area, which must be considered during initial site selection, and their construction costs must also be included in site development plans.

1.2.3 Secondary Site Selection Criteria

Although not as important as the criteria discussed in the previous section, the following factors should be considered during site evaluation. They can greatly increase the efficiency of a nursery operation and reduce operating costs.

1.2.3.1 Protected microclimate

In addition to having unobstructed solar aspect, a potential nursery site should be located in a protected area with the most equitable climate in the local region (fig. 1.2.7A). Within any geographic area, nurseries should be located in areas that are not subject to extremes in temperature or damaging winds (Davidson and others 1988). On the other hand, a moderate degree of air movement is necessary for ventilation during warm weather (Hahn 1982). As long as they do not shade the growing area, trees on the windward edge of the nursery site can act as a natural windbreak and protect against damaging winds or snow accumulation (fig. 1.2.713). However, trees or other obstructions on the lower edge of the site can serve as barriers to cold air drainage, and valley bottoms or other low sites that collect cold air should be avoided (Nelson 1991).

Obviously, potential nursery sites near industries or utilities that could generate possible pollutants should never be considered. Air pollution is an increasingly serious problem in industrial or urban areas, and so nurseries should never be located in confined locations where photochemical smog may accumulate Chic to poor air circulation (Davidson and others 1988).

1.2.3.2 Gentle topography

The general topography of a potential nursery site i> important for both biological and economical reason A relatively level site reduces the cost of land leveling. during construction and increases the ease of moving equipment, supplies, and vehicles after the site is developed (Nelson 1991). South-facing slopes (in the northern hemisphere) are preferred because the higher solar input will lower heating costs (fig. 1.2.7A); this becomes more critical in areas where energy costs are high (Boodley 1981). Modern nurseries should be designed so that irrigation runoff can be collected and recycled, thus making a slightly sloping topography desirable.

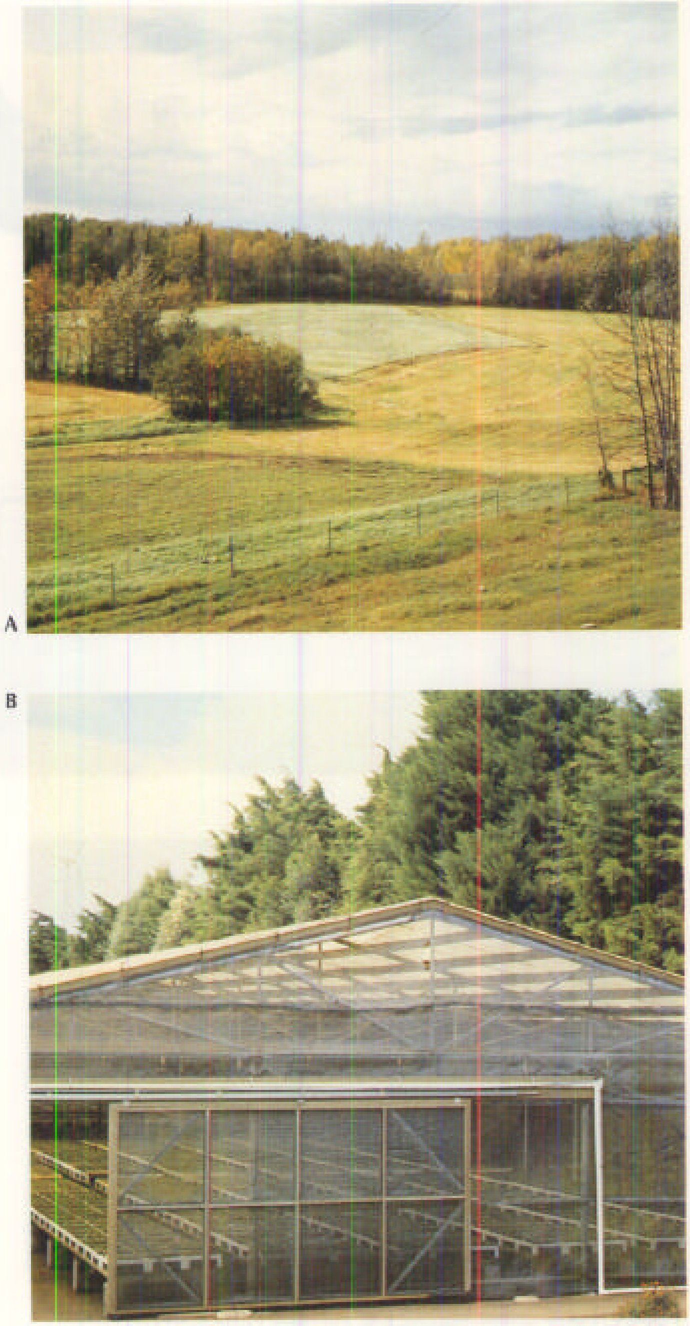

Figure 1.2.7—*A good nursery site should have maximum solar exposure, but be protected from the wind and have a slight slope to promote collection of water runoff* **(A)**. *In exposed locations, a properly designed shelterbelt can provide protection from wind and snow drift* **(B)**.

1.2.3.3 Seasonal labor supply

The success of a container tree nursery depends on the quality of the available work force (Boodley 1981). In addition to a small permanent professional staff, a container tree nursery requires a reliable source of semiskilled labor for several peak work periods during the year, when tasks such as sowing or grading must be completed in a short time (fig. 1.2.8). During the site evaluation process, it is a good idea to contact the local employment agency and other agricultural businesses in the vicinity to learn about available labor sources and skill levels. You should also inquire about other seasonal labor demands in the area and compare the temporal patterns to your own needs. The existence of other employers of part-time workers can be an advantage if the other business is able to use workers at times when the nursery labor demand is low. Because of perennial problems with locating workers, however, some nurseries are experimenting with contracting most labor-intensive tasks (Davidson and others 1988)

The number of employees required depends on the size and complexity of the operation. An average of one laborer for each 200,000 seedlings, and at least one technical supervisor for each 3,000,000 seedlings may be used as a rule of thumb. Nurseries should also considering hiring one additional person as a backup supervisor.

Figure 1.2.8—*The local labor pool should be adequate to supply the nursery during peak periods such as lifting and packing.*

1.2.3.4 Accessibility

A good nursery site must be accessible for regular delivery of nursery supplies and shipping of nursery stock. Most supplies and the vast majority of container nursery stock are delivered by truck, making good all-weather roads and accessibility to regular shipping routes and highways important. Access roads should not have any steep slopes or sharp turns that would prohibit safe operation of large delivery trucks. Weight limitations may be a restriction in some parts of the country and so check with the local highway department (Davidson and others 1988). Essential supply and maintenance services should be available nearby. Remote locations may increase the cost of supplies, particularly in locations where fuel oil or propane must be delivered regularly (Nelson 1991).

A good nursery location will require an all-weather surfaced road system for handling supplies and seedling deliveries (fig. 1.2.9A). For forest and conservation projects, the "planting window" is determined by the availability of soil moisture or when the outplanting site becomes free of frost, and so seedlings often must be harvested and processed during rainy or snowy weather (fig. 1.2.913). For nurseries with customers in mountainous terrain, the delivery season can go on for many months; for example, container nurseries in the Pacific Northwest begin shipping seedlings to low-elevation coastal planting sites in February and often continue deliveries until high-elevation sites become free of snow in May or June. Therefore, a good container nursery site must have good year-round accessibility.

Nurseries must also be easily accessible to workers, especially the key personnel who respond to emergencies. Regardless of how well a nursery is designed for reliable operation, there will be times when key nursery workers must be able to respond within a hour or less. If accessibility is a potential problem, then it may be necessary to provide a dwelling on the site, and this cost must be considered during site evaluation.

Figure 1.2.9—*Nurseries need surfaced roads to allow loading equipment to handle supplies and to ship seedlings* **(A)***; these roads must be passable during wet or snowy weather* **(B)**.

1.2.3.5 Distance to markets

The distance from the potential nursery site to the delivery point must also be considered during the site evaluation process. The prospective nursery developer should contact potential nursery customers and inquire about their delivery needs or desires. In some situations, customers will pick up their seedlings at the nursery but often customers expect the nursery to deliver the stock to intermediate storage or to the outplanting site. Most large government agencies or forest companies have their own refrigerated delivery vans and seedling storage facilities, but smaller customers will probably require delivery direct to their outplanting location. A few container nurseries deliver most of their seedlings by overnight mail or parcel delivery. In this case, the pickup costs and reliability of the various parcel carriers must be evaluated.

Seedling delivery can present an interesting dilemma when trying to locate a forest nursery: whether to locate a container facility in a mild climate where the cost of heating and other services will be less or whether to select a more remote location where delivery costs will be minimal. Traditionally, nurseries were located close to outplanting sites to minimize shipping distances, but with modern refrigerated storage and delivery vehicles, this is no longer necessary. Of course, the cost of delivery increases with distance as does the potential for problems, and so all aspects of the situation should be carefully evaluated (see section 1.1.4.3 for more discussion).

1.2.4 Evaluation of Alternative Sites

All the different site selection factors at a variety of potential nursery locations need to be considered analytically. Sometimes one or two factors are so important that the choice is obvious, but more typically, each site has both good and bad points, and so the decision becomes more difficult. In these situations, the various sites and site selection criteria should be arrayed in a decision matrix, produced in the Kepner-Tregoe decisionmaking process (Kepner and Tregoe 1965).

The decision matrix (table 1.2.4) is constructed by listing the potential nursery sites across the top and the significant site selection criteria down the left side. The next step is to assign each site selection criterion an importance value or weight on a scale from 1 to 10, with the most critical factors receiving the highest scores and the less important ones progressively lower scores. Next, the suitability of each potential nursery location is evaluated and rated, again on a scale of 1 to 10, based on the information that has been gathered. Once that is accomplished, the score for each cell in the matrix is calculated by multiplying the weights for each site selection factor by the rating for each site. Finally, the weighted scores are totaled for each site and, if the weights and rankings have been objectively assigned, then the potential nursery site with the highest total ranking should be the best. If all of them are close in score, then the process should be repeated, and careful attention paid to the relative weights and the ratings of the factors. If the scores are still close, the sites are probably equally good.

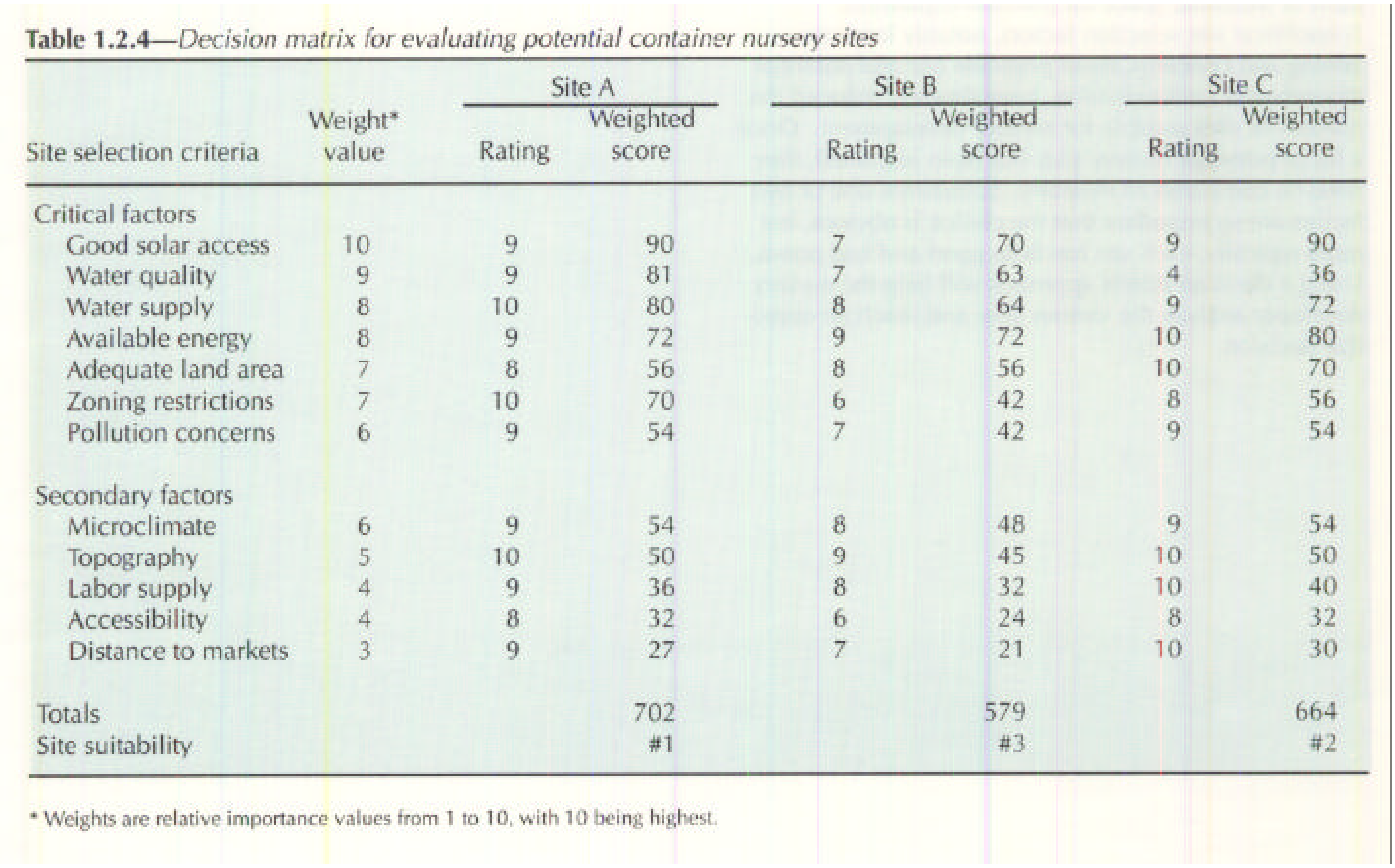

Table 1.2.4—*Decision matrix for evaluating potential container nursery sites*

		Site A		Site B		Site C	
Site selection criteria	Weight* value	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Critical factors							
Good solar access	10	9	90	7	70	9	90
Water quality	9	9	81	7	63	4	36
Water supply	8	10	80	8	64	9	72
Available energy	8	9	72	9	72	10	80
Adequate land area	7	8	56	8	56	10	70
Zoning restrictions	7	10	70	6	42	8	56
Pollution concerns	6	9	54	7	42	9	54
Secondary factors							
Microclimate	6	9	54	8	48	9	54
Topography	5	10	50	9	45	10	50
Labor supply	4	9	36	8	32	10	40
Accessibility	4	8	32	6	24	8	32
Distance to markets	3	9	27	7	21	10	30
Totals			702		579		664
Site suitability			#1		#3		#2

* Weights are relative importance values from 1 to 10, with 10 being highest.

1.2.5 Summary

The selection of a suitable site for a container tree nursery is a formidable challenge. A successful container nursery must be carefully matched to the environmental conditions on the site and so developers must carefully analyze climatic records. A potential container nursery site consists of critical factors and desirable factors. Critical site selection criteria, especially unobstructed solar access and good water quality, are essential to a successful nursery operation. Desirable attributes include those site selection criteria that are not absolutely necessary but will increase the economy and efficiency of the nursery operation. The amount of land selected for a container tree nursery must be large enough for the production areas and support buildings and also allow for efficient movement of equipment and materials. In addition to immediate needs, the nursery developer should evaluate potential nursery sites on the basis of available space for possible expansion. Ecopolitical site selection factors, notably land-use zoning and concerns about pesticide use and potential groundwater contamination, have severely reduced the number of sites suitable for nursery development. Once a list of potential nursery sites has been identified, they need be compared analytically. Sometimes one or two factors are so important that the choice is obvious, but more typically, each site has both good and bad points. Using a decision matrix approach will help the nursery developer analyze the various sites and reach an objective decision.

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