THE RIGHT TREE FOR A DRY PLACE

Water scarcity is an increasingly severe problem across the developing world, with many countries in East Africa already experiencing water shortages or severe water scarcity. ***Certain trees that are integrated into agricultural systems can increase the efficiency of water use, while plantations of fast-growing trees can exacerbate water shortages.*** The results of two decades of research on the water use and water balance effects of trees in Kenya have implications for water management, forestry and agroforestry in water scarce semi-arid and arid regions.

Key Findings

1. Trees use water – and that can be a good thing

Trees can increase water productivity in two ways: by increasing the quantity of water used — water otherwise lost — and by increasing the biomass per unit of water consumed.

2. Some trees can actually mitigate dry-season water shortages

Deciduous trees shed their leaves between 1 – 6 months of the year. During these periods deciduous trees consume less water than evergreens, lessening their competition with crops during crucial periods of water shortage.

3. Below the surface — where the action is

The main competition between trees and crops occurs below-ground for water and nutrients, rather than above-ground for sunlight. This competition can be managed by coppicing and root pruning, particularly during the early crop cycle.

Management implications

Tree water use can be optimized to decrease dry season demand and minimize below-ground competition with crops and the diversion of precious water from other uses by:

- Preferentially planting deciduous tree species (indigenous, as well as well-matched exotics that produce particularly high-quality products)
- Avoiding fast growing, evergreen species, such as pines and *Eucalyptus*, particularly in the most water-scarce areas
- Practicing root & shoot pruning to decrease below-ground competition
- Avoiding rotational woodlots with frequent harvesting.

Section 1: Trees use water — and that can be a good thing

The two ways trees can increase water productivity

In integrated tree-crop systems, the main competition effects between trees and crops are below-ground for water and nutrients, rather than above-ground for sunlight. Although trees compete for water, they are also able to increase water productivity.

With their limited growing seasons, annual crops can only use a finite portion of available water supplies. In India, sorghum transpiration accounts for 41% of rainfall (1), while in Niger millet transpiration accounts for 6-16% of the annual rainfall, with the remainder going to evaporation, runoff and drainage (2).

Trials confirm that intercropping with trees can result in much higher capture of annual rainfall. Particularly successful combinations include pigeonpea/groundnut where transpiration consumed 85% of the annual rainfall (3) and agroforestry systems that coupled *Grevillea*/maize, where transpiration reached 70% (4).

This evidence fits well with the hypothesis that trees increase water productivity in two distinct ways (3):

1. Increasing the quantity of water used, transpiration (Tw)
2. Increasing biomass per unit of water consumed (ew)

$$\text{Biomass} = (ew) \times (Tw)$$

Tree water use, as measured by sap flow, is a very good predictor of the production of biomass. Amongst the agroforestry tree species that have been studied to date, the primary biomass produced per unit of water consumed is relatively constant, meaning that the water use efficiency of biomass production is relatively constant across species (5).

Sap flow measurement technology

This equipment was originally developed at the World Agroforestry Centre (ICRAF) to measure the velocity of water movement in tree trunks. From these measurements it is possible to estimate total water use on an hourly basis (6).

Section 2: Some trees can mitigate dry-season water shortages

Assessing the water demands of different tree species

While the efficiency of biomass production is relatively equal across tree species, water consumption varies in two important ways: ***seasonality*** and ***quantity***. These differences shape the appropriateness of promoting a particular tree species in a given environment, particularly in water stressed environments, agricultural landscapes, and water catchment areas.

Seasonality

When it comes to assessing the seasonality of a tree's thirst, the most important distinguishing biophysical feature is leaf phenology — whether or not a tree experiences seasonal shedding.

Evergreen trees maintain their foliage throughout the year, while deciduous trees are defined as those that remain leafless for 1-6 months of the year. During periods of shedding, the tree uses less water, a physiological adaptation in tune with the long-term rainfall patterns where these species originate.

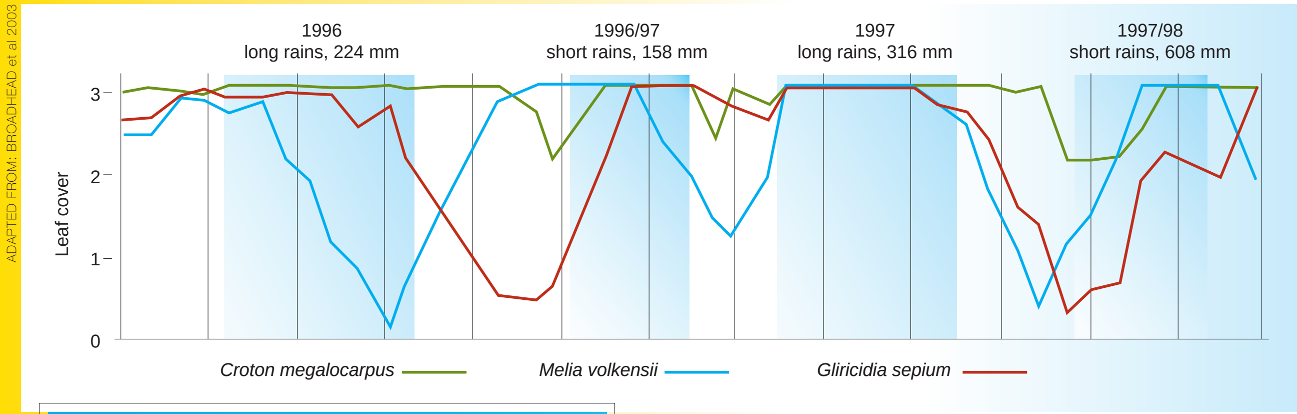

Figure 1. Loss of leaf cover corresponding with long-term rainfall patterns.

Select Deciduous Species

Cordia africana – Indigenous to East Africa • Bimodal shedding • Produces high-value timber for furniture construction • Time to harvest for timber: 10 years • Flowering good for honey production.

Paulownia fortunei – Indigenous to tropical China • Unimodal shedding • Produces high-value timber often used in veneers • Time to harvest for timber: 10 years.

Melia volkensii – Indigenous to East Africa • Bimodal shedding • Termite resistant • Time to harvest for timber: 10 years.

Croton macrostachys – Indigenous to East Africa • Bimodal shedding • Good for honey production.

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Seasonal shedding is especially critical in semi-arid and arid areas, where both crop and tree rooting tend to be uniform across species with the roots concentrated in the top metre of soil. This puts the tree in direct competition with crops. By consuming less water during the dry season(s), deciduous trees lessen their competition with crops during crucial periods of water shortage. Known as temporal complementarity, the trees and crops make demands on available resources at different times. From a management perspective, this infers an advantage on deciduous species that are most closely adapted to local long-term rainfall patterns (7).

Although not as aesthetically pleasing when the leaves are first dropped, shedding triggers flowering in many species — an economically important physiological feature that makes these species useful for the production of honey.

Quantity

Fast-growing evergreen species can quickly draw significant quantities of water from below-ground, raising serious concerns about their impact on landscapes. Tree species with water requirements that exceed available rainfall (as they draw upon other water sources), can produce large negative trade-offs for other local water uses and for downstream water users. This is an especially important finding for fledgling carbon sequestration programmes that tend to favour fast-growers such as *Eucalyptus* that can have severe impacts on river flow.

Many species characterized by high water demand are favoured for their economic value, and are thus harvested and replaced on a rotational basis. These plantations of 'thirsty' species will only be viable in areas of high rainfall and run off, where water collects and where ground water is more readily available.

Average rainfall in East African catchments is between 1200-1800mm. *Eucalyptus* alone can consume most of this water. Therefore in watersheds with average rainfall below 1600mm, it is prudent not to plant evergreen species such as *Eucalyptus* or pines.

"'Thirsty' species will only be viable in areas of high rainfall and run off"

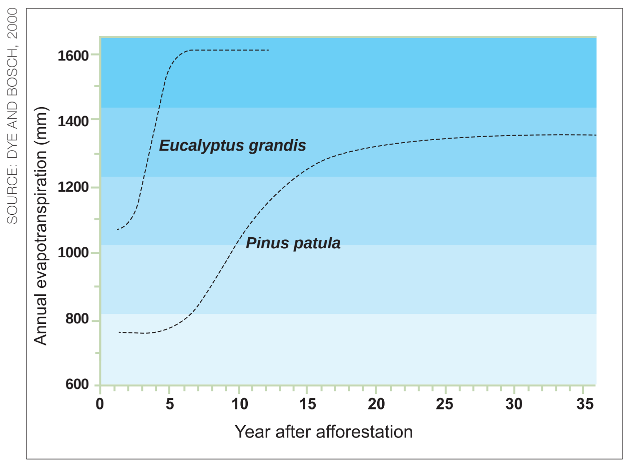

Figure 2. Water requirements of two popular evergreen species.

Section Three - Below the surface — where the action is

In both wet and dry landscapes, the water use of trees can be managed in integrated systems. The water requirements of trees can be mitigated and managed by pruning of roots and shoots (the latter being less labour intensive), especially during the early crop cycle, thereby decreasing tree-crop competition (8).

SOURCE: THE AFRENA-PROJECT UGANDA

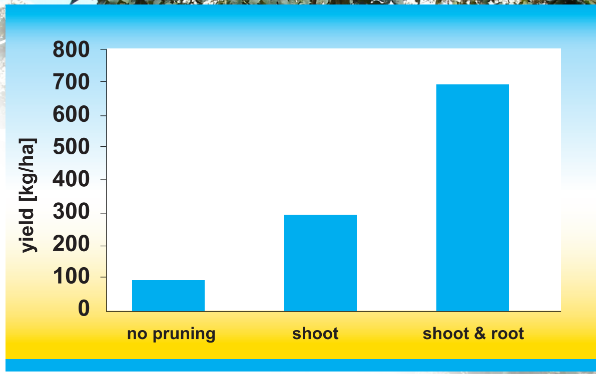

Figure 3. The effect of pruning on bean yield (average of 12 farms near Kabale, first season 2000). Shoot = trimming of all branches; shoot and root = trimming all branches and lateral roots.

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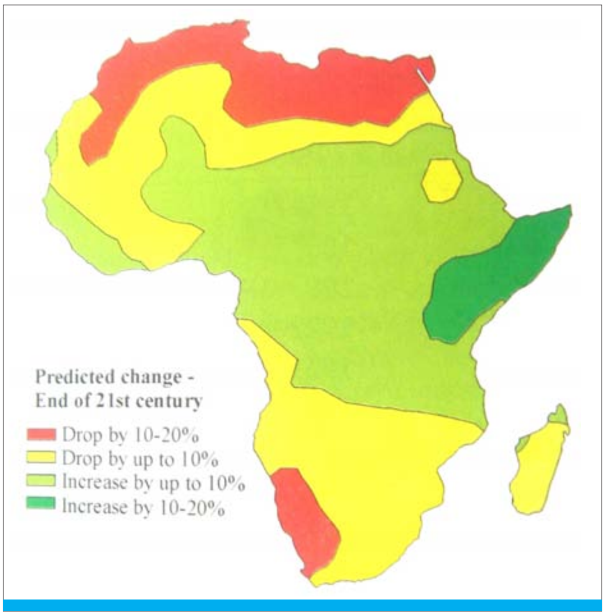

Figure 4. Predicted changes in rainfall by the end of the 21st century

Future Implications

Recent findings suggest a decline in rainfall throughout several regions in Africa (9). Under this scenario the water use and water balance effects of trees will be critical to management of agricultural landscapes and water catchments across North Africa, the Sahelian belt, Southern Africa and Madascagar.

In agricultural landscapes, preferentially planting indigenous deciduous species or exotic deciduous species that produce high-value tree products, while practicing root and shoot pruning, will increase the efficiency of water use while providing new economic opportunities. At the same time, avoiding plantations of fast-growing trees that can easily exacerbate water shortages, will decrease the impact of climate change and declining rainfall.

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Figures

Figure 1. Broadhead JS, Ong, C.K.; Black, C.R. 2003. Tree phenology and water availability in semi-arid agroforestry systems. Forest Ecology and Management 180(1-3): 61-73.

Figure 2. Dye, P.J. and Bosch, J.M. 2000. Sustained water yield in afforested catchments – the South African experience. In: von Gadow, K., Pukkala, T. and Tomé, M. (Eds.) Sustainable Forest Management. Dordrecht, Netherlands. Kluwer Academic Publishers. 99-120.

Figure 3. Pruning trees growing in cropland. 2001. Tree management in agroforestry. Technical Bulletin no.3. AFRENA-Project Uganda, ICRAF.

Figure 4. De Wit, M. and Stankiewicz, J. 2006. Changes in surface water supply across Africa with predicted climate change. *Science Express*, 2 March 2006. pp. 1-10. www.sciencexpress.org.

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