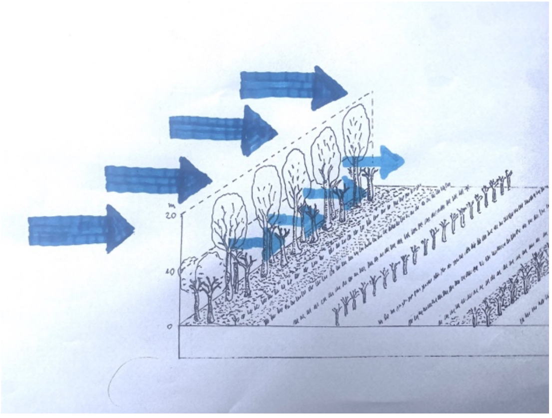
Fundamentals in Windbreaks Hedges (shelterbelt of trees)

1. Introduction to Windbreaking Hedges - WBH

We are talking about the practice of cutting the wind force by rows of trees, which form an open barrier and turn the wind into a breeze, reducing the negative effects on crops, orchards and gardens. Here's a row of casuarinas sheltering an orchard:

It is an ancient and global practice, widely used in open regions, beaten by the wind, with little remaining trees and where the farmer quickly realizes the advantages: the wind that passes the barrier is weaker. That is why trees and shrubs are protagonists in the protection of crops.



For what reasons can we say that a good windbreak can save crops? Or that it amounts to 1/3 of an additional irrigation? These are questions that need to be answered with an eye on the physiological effects of wind, reducing the harvest. Questions as real as the lack of fertility in the soil. With the same effect: reducing productivity.

It is necessary to know a little more about plant physiology to understand how the benefit of WBH (wind breaking hedges) in commercial crops occurs. Understand why the breeze is beneficial, but the wind and 'strong wind' are not. That wind damage is not only physical: broken branches in orchards (classic case in mango-trees). The physiological damage is much greater, taking away much of the productivity and/or increasing irrigation costs; even leading to the breaking of the harvest.

2. In practice, how are WBH made?

As the wind can blow from any direction, windbreaks hedges are installed on all 4 sides, surrounding the crops, taking advantage of the edge of paths, roads and the meeting of crops with forests, whether planted or natural. It is very common to use the planting of riparian vegetation as one of the 4 sides of a windbreak. Or even a block of eucalyptus, rubber tree, or other forest exploitation.

See two figures, adapted from *Leal, Alex Carneiro*, 1986

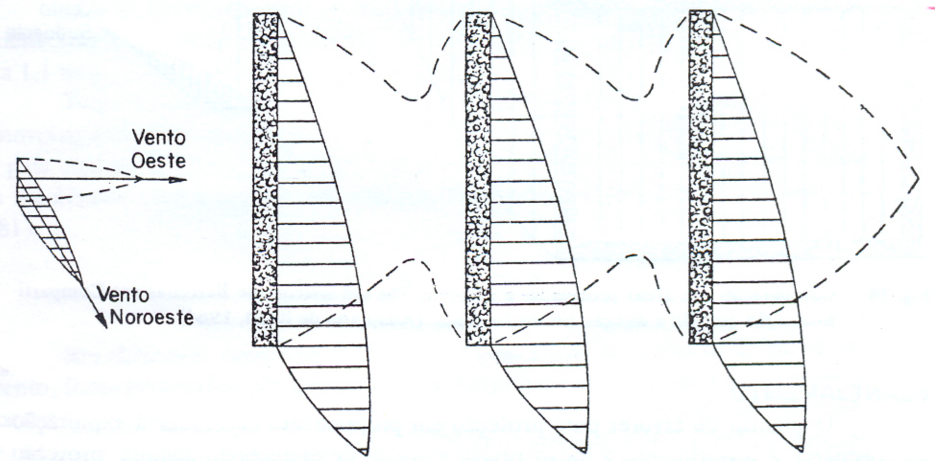


Fig. 13 – **Comparação das áreas protegidas a sotavento de um sistema de Barreiras Paralelas quando a direção do vento muda. (Adaptado de Read, 1964).**

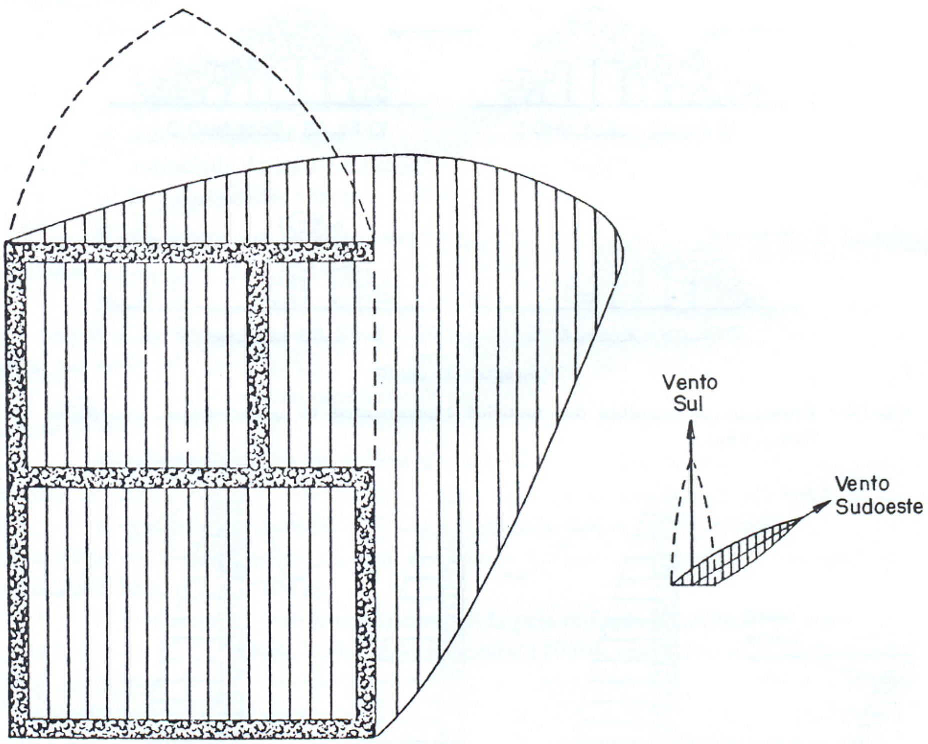


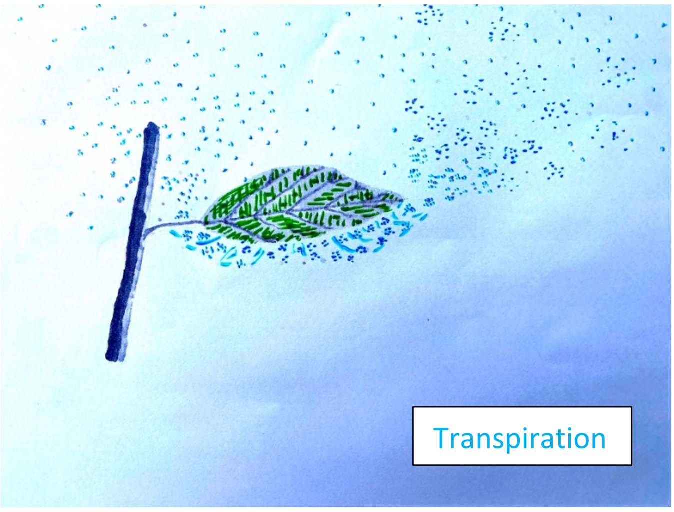
Fig. 14 – **Comparação das áreas protegidas a sotavento de um sistema de Barreiras em Compartimentação quando a direção do vento muda. (Adaptado de Read, 1964).**

The important thing is to understand that, when surrounding a crop of windbreak woody hedges, we are containing an imperceptible and sneaky anti-productive factor. The wind is always there, whatever its direction, drying the crop. But! As no one notices, we do not give due value to the resources of its containment.

3. Quantities which are not easy to see

It is common to see clearly all physical movement & extremes:
- Strong wind, lifting dust and folding the canopy (mechanical damage).
- Rainfall/irrigation equalizing water balance by water replenishment.

However, there is a flow of fluids in the agricultural system that is invisible to the naked eye, creating initial difficulty to be apprehended, measured and evaluated. How to accept without seeing directly? That the following flows exist and are decisive:
a. Upward/downward flows of the raw/prepared sap of all plants.
b. Transpiration = water vapor coming out of dozens of stomata on each green leaf.

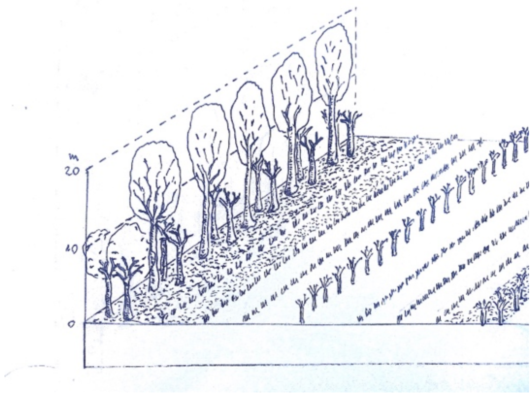


c. Evaporation = water that is lost, from the ground straight into the atmosphere, without transpiration, without being useful to crop yields.
d. Drying wind (dries the soil-plant system) = acts day and night, subtracting water.

e. Water available in the soil = if it decreases, will strangle the transpired water. On how to increase the water holding capacity (field capacity) of a soil there will be another specific text, which will be published as soon as possible.

4. Leaked windbreaks hedges are better! 40%/60%

Who would have thought? Today we know that a permeable row of trees is more efficient than a compact row. Around 50% of gaps in the row reduce wind speed without creating turbulence, as would a compact row. As the canopy occupies a very dynamic volume, we can accept variations of 50%/50%, such as 40%/60% or otherwise, 60%/40%. At the limit, 70%/30% or 30%/70% are acceptable.



5. Basic physiology: whole plant, Canopy & Root

Every plant is autotroph. It lives from photosynthesis, from generating assimilates (sugars and amino acids) in the chloroplasts of its leaf parenchyma. Therefore the process is also called assimilation. Clearly, the nutritional process that forms all the anatomical organs of the plant is photosynthesis. It is from it that the basic components (sugars and amino acids) derive carbohydrates and proteins, later.

They circulate throughout the plant, through the channels of the “phloem”, nourishing all living tissues. According to the needs of each organ, they become proteins, storage substances such as starch and fatty acids, structural substances such as hemicellulose, cellulose, even lignin and substances of multiple secondary functions, such as pigments, phytoalexins and flavoring compounds.

All the organs of the plant are fed by organic compounds, even roots, flowers, fruits and their seeds: they will be filled with carbohydrates and proteins.

The so-called "nutrition from the soil, performed by the root" is complementary to nutrition by photosynthesis, providing water and mineral nutrients, the ‘raw sap’, as essential components of photosynthesis and all physiology. To fulfill its role, the root receives from the crown the ‘elaborate sap’, forming its tissues and keeping active all its heterotroph physiology. That’s right! Roots do not photosynthesize and breathe, as if they were an animal.

If we eat a tasty banana, sweet and soft, full of sugars, starch and fibers, these compounds are a direct result of photosynthesis, advised by the minerals brought by the root, which act as rare components, or cofactors, in the biosynthesis of organic substances. Banana with banana gives a small bunch. Many small bunches gives a big bunch. If we add all them, it results in the productivity of Banana plantation.

All agricultural productivity has two parents: soil fertility and photosynthetic regularity. We cannot consider just one factor and find that we have done enough to guarantee production. If we open our view, we take care of the whole plant.

6. What does this have to do with windbreaks hedges?

Windbreaks protect and promote photosynthesis:
- First, by saving water, reducing the evaporated portion of the soil.
- Second, avoiding closing the stomata in gusts of wind.
- Third, by shortening periods of water restriction, making soil water "yield".

7. How high should the WBH be?

Whereas:
- Average tree row height = H.
- That the windbreak effect greatly reduces at distance >> 8 times its height.

<u>Simplified calculation of s case</u>:

The row of casuarinas is about 10 meters high. The effective reducing effect of wind speed extends up to 10 x 8 = 80 meters from the tree trunk.

<u>Answer</u>: if 80m between rows of windbreaks are enough, then the Casuarina with its 10m height is suitable to protect that gap. This is the simple way of calculation.

8. How much is the wind speed reduction?

The ability to reduce wind depends on two major factors:
- the distance a particular part of the crop is from the windbreak.
- the wind-breaking row configuration, the correct volume/empty ratio.

See three adapted figures of Leal, *Alex Carneiro, 1986*:
the percentages, %, are the remaining wind velocities, after passing the windbreaks

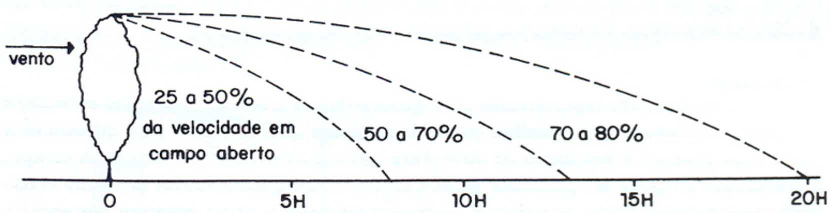


Fig. 7 – Zonas de redução da velocidade do vento, escala vertical exagerada. (Adaptado de Read, 1964).

TABELA 4 – Redução da velocidade do vento em função da velocidade em campo aberto.

Velocidade do vento em campo aberto (m.p.h.)	Velocidade do vento a sotavento da barreira		
	5H	10H	15H
20	5 a 10	10 a 14	14 a 16
40	10 a 20	20 a 28	28 a 32

(Adaptado de Read, 1964)

13

Windward

Leeward

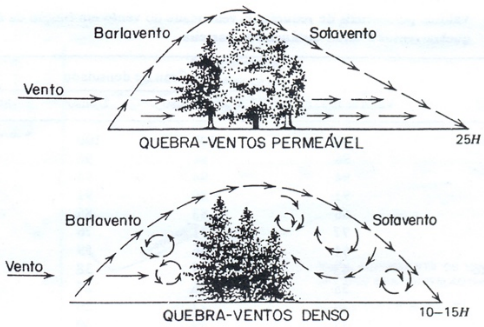


Fig. 8 – Diferença entre a ação aerodinâmica de uma barreira permeável e uma densa. (Adaptado de Rosemberg, 1974).

In the figure below, highlight the factor "density of the set of canopies". See how the "C" line, with the moderately dense (therefore moderately permeable) canopy assembly, achieves the greatest wind speed reduction:

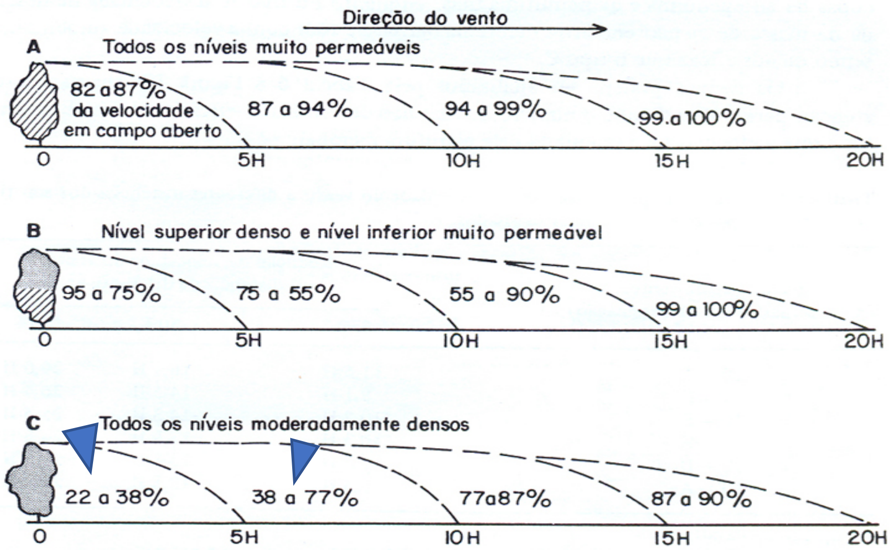


Fig. 11– Influência das diferentes densidades dos níveis inferior e superior na redução da velocidade do vento. (Adaptado de Read, 1964).

Full calculation for row spacing:
Considering line C , "all moderately dense levels", the distance of:
Leeward: (downstream): 8xH a 50% reduction of the original speed or more.
Windward: (upstream): 2xH a 35% reduction of the original speed or less.
Summed, the recommended distance value between forest strips of 10xH

9. A personal statement

It took me a long time to understand and recognize the value of windbreaks. When I graduated as an agronomist, they seemed to be "unnecessary". Do for what? It took me a while to get my record: what helped me build a real view of plant physiology, were my experiences with irrigation. It was irrigation that led me to transpiration, stomata, gas exchanges in any plant and the resulting photosynthesis.

10. The biggest leaps in productivity are through irrigation

Recently formed, I passed through the state of Maranhão and learned that the rice crop jumped from a productivity (rainfed) of 1,600 kg/ ha to a productivity (flooded) of 5,000 kg/ ha, maintaining the same climate, soil and almost zero fertilization. Simply because plants could transpire permanently and make photosynthesis uninhibited.

Volkmann: Biodynamic rice in flooded fields, at Farm *Capão Alto das Criúvas*, Southern Brazil.

Similarly, in other crops, the highest productivity gains are also obtained by irrigation. In tomato productivity rises, from rainfed to irrigated, from 1.5 to 6 kg/m_2. In cocoa, irrigated can produce 200 arrobas/ ha, against 40 or 50 of the rainfed. Many crops respond favorably to increased water availability, especially in tropical climates.

Sacramenting the factor "availability of water for transpiration" to define the small daily productivities, which throughout the cycle will generate the Summery: amount of assimilates generated by photosynthesis" = productivity at harvest.

Irrigation is active throughout the crop cycle, day after day. Once formed, thanks to the good climate, the appropriate season and also thanks to the fertility of the soil, the canopy "keeps working photosynthesis" as long as there is water available to transpire!

11. Competitive factors/impact of irrigation

Yes, we also know how that new fertilization techniques and breeding technologies can multiply productivity. So we have to be absolutely clear:

Keeping the other factors constant, irrigation (the windbreak too!) will be so much more impactful the smaller or irregular are the rains!

12. All transpirated water comes from a balance!

Transpired water = water in the soil (rains, irrigation) - water losses (evaporation) "predominant factors that generate losses: heat (sun) and wind (intensity)".

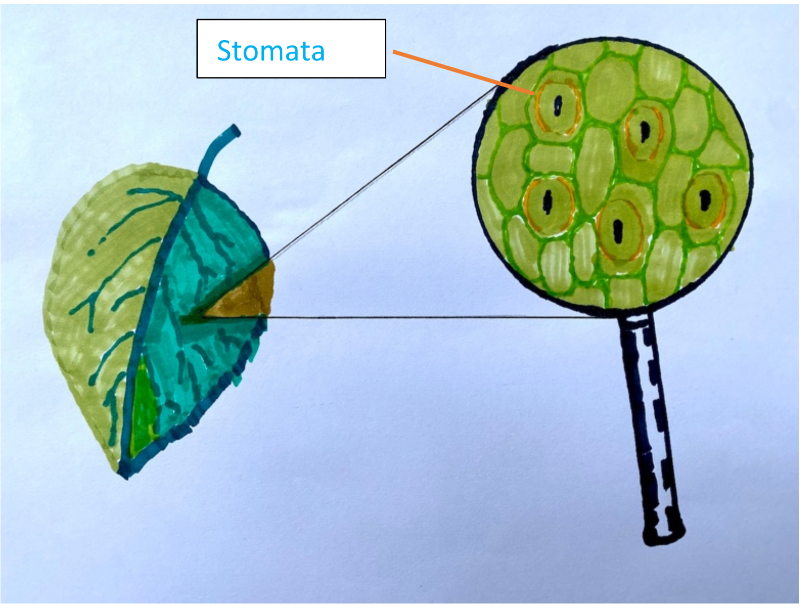
Every crop is an open system, with water inlets and outlets. When a drought occurs, it means that the balance is negative, more water is coming out than entering, leaving nothing or little for transpiration/ photosynthesis.

Obvious symptoms of drought (water stress):

a) In the soil: opening of crevices, the soil becomes dry and cracked (clay soil).
b) In the leaves of the crops and the spontaneous herbs, which become frizzy, curled, seeking to actively reduce transpiration in acute moments of water deficit.
water deficit in any culture = water loss by transpiration >> that water available from the soil

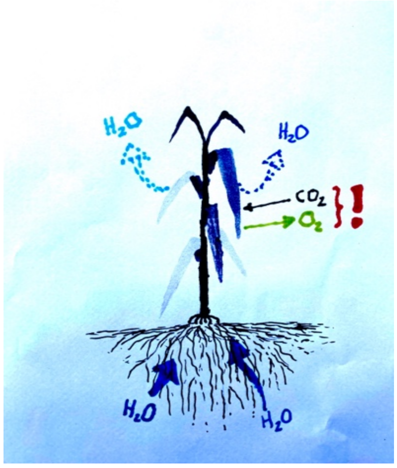
Stomata: dozens of pores on each leaf

Where does the plant release the water it has absorbed? On each leaf there are dozens of orifices, called stomata. This is where the leaf changes its gases: first water in the form of vapor and then oxygen (O_2) and carbon dioxide (CO_2). Attention please: if there is no water to release (drought), the stomata close and the assimilation stops. The losses of the drought begin. They can be short, but they are losses of productivity.



Abundant assimilation due to water sufficiency:

If it then rains enough to replenish the soil with water and the symptoms of drought in the soil and plant disappear, the crop cycle will continue: we will have, for a time, enough water for transpiration and opening of stomata, therefore the exchange of gases, notably the inspiration of CO_2, important "brick" of the assimilated.
Until the arrival of new drought, stopping everything again. In this way, the climatic irregularity forces us to consider the windbreaks.



13. Limitations of Irrigation

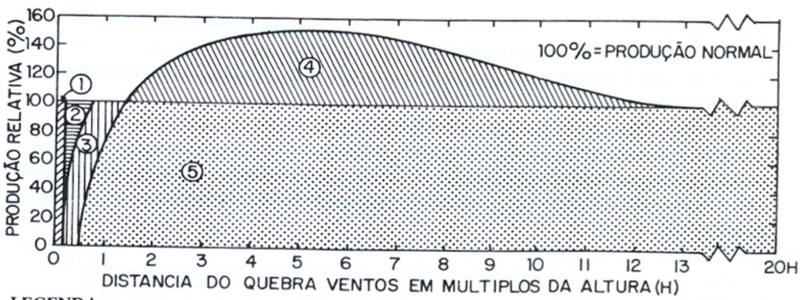
When we irrigate a crop, we keep the positive balance "for entries in a row", forced conduction of water to economic cultivation. When irrigating, the focus is on addition.

Irrigation does not reduce water losses, subtraction of water lost by wind drying action, so it is only part of the solution.

"irrigation acts only by addition"

14. Windbreaks reduce subtraction = balance rises!

The task of reducing the amount of water lost for evaporation and protecting photosynthesis in the open field, is the task of the windbreak system, becoming protagonist in sustaining the productivity of each protected crop. As a general calculation, see the balance presented by Leal, Alex *Carneiro, 1986:*



LEGENDA

Efeitos no campo aberto, desprotegido

1 =bordaduras não plantadas
2 =perdas de colheita nas bordaduras
5 =produção normal

Efeitos adicionais dos quebra-ventos nos campos protegidos

3 =perda de produção por competição na faixa adjacente ao quebra-ventos.
4 =ganhos na produção devido ao efeito do quebra-ventos.
4 – 3 =efeito real do quebra-ventos na produção.

Fig. 5 – **Comparação da produção de grãos em áreas protegidas e desprotegidas. (Adaptado de Read, 1964).**

Important: in area 4 we have the summed gains of productivity because of WBH.

15. Common objections to the installation of WBH (wind breaking hedges)

Area loss

In fact, WBH ranges occupy a certain area that could be occupied by commercial culture. But the gains in the crop with the presence of WBH (between 20 and 40%, but rising because of climate change) are much higher than these losses (around 7%).

"When we irrigate we don't need WBH"

Quite the reverse! We gain an important reason to install the WBH, because the energy costs (electricity, fuel) are high and should be reduced: the WBH allows to extend the irrigation shift, from approximately 6 x per week to 3 x per week.

Difficulties in managing the trees

If one day I have to cut down WBH trees, the felling could harm the crop. Argument that undoes with good planning: the management will be done in between-harvest.

16. Criteria for choosing species for WBH

The task of choosing the appropriate species to make up a windbreak, needs to consider some basic criteria, necessary for the success of the investment:

a. Exotic species: are preferable as they are not subject to "native forest" restrictions.
b. Height of adult trees: fundamental to be adjusted with the distance between tracks.
c. Final canopy volume: is determinant to fulfill the criterion "leaked barrier".
d. Growth speed: important for the 1st years. When WBH are made of two or more species, at least one should be fast-growing.
e. Economic value: the economic use of WBH products (wood and non-woody) is an important criterion for every farmer. The ease of forming seedlings too.

17. Species frequently used in Brazil

Australians:
- *Casuarina equisetifolia*
- *Grevilha robusta*
- *Eucaliptus* spp.

Indian, Indonesian:
- Malabar Plum or Jambolan, *Syzygium cumini*
- Jack-fruit, *Artocarpus heterophyllus*

Mexican / North & Central American:
- Avocado, *Persea americana*
- *Pinus* spp.

And many others!

18. WBH producing RCW (ramial chipped wood)

When the tree strips are designed to be suppliers of the regenerative fertilizer RCW = ramial chipped wood, their usefulness redoubles. The benefits of RCW are described in the "full fertility" sub-tab of this website.

<u>Polycultures below the canopy of trees</u>

We can still grow several economic crops below the canopy of WBH trees, such as coffee, exotic fruits (tangerines, lemons, other citrus), cassava, okra, rosela, passion fruit, mustard, pumpkins, green corn and many others. This arrangement further improves the notion of usefulness of the strips.

<u>The orchard that turned WBH</u>

On the contrary, we can plan like this: if a farm has the intention of planting an avocado orchard with 1,200 trees, it can be planted by the traditional way, in block, or it can be distributed in rows, around other crops, such as WBH.

<u>Fodder plants, like tropical grasses or tropical legumes, used as WBH</u>

Similarly, if a vegetable producing farm needs elephant grass as fodder (or Guandu to increase protein feed) for its animals, it can make small, 35 x 35m courts, fenced with rows of elephant grass (or Guandu), doing double function: forage for offseason of animals and windbreak function for vegetables.

19. Closing

I hope I have elucidated some aerodynamical features and the eco-physiological need of any crops for windbreaks. With the evolution of practical achievements, new articles will be published here. After all, we are on a crusade against the tormentor "lack of rains". The time has come for WBH to show their value.

Itápolis, Brazil, December 2022,

Manfred Osterroht
Project ART

agricultura@regenerativa.art.br

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On perspiration:

https://www.youtube.com/watch?v=4plE5qJFFIk

About Stomata

https://mundoeducacao.uol.com.br/biologia/estomatos.htm