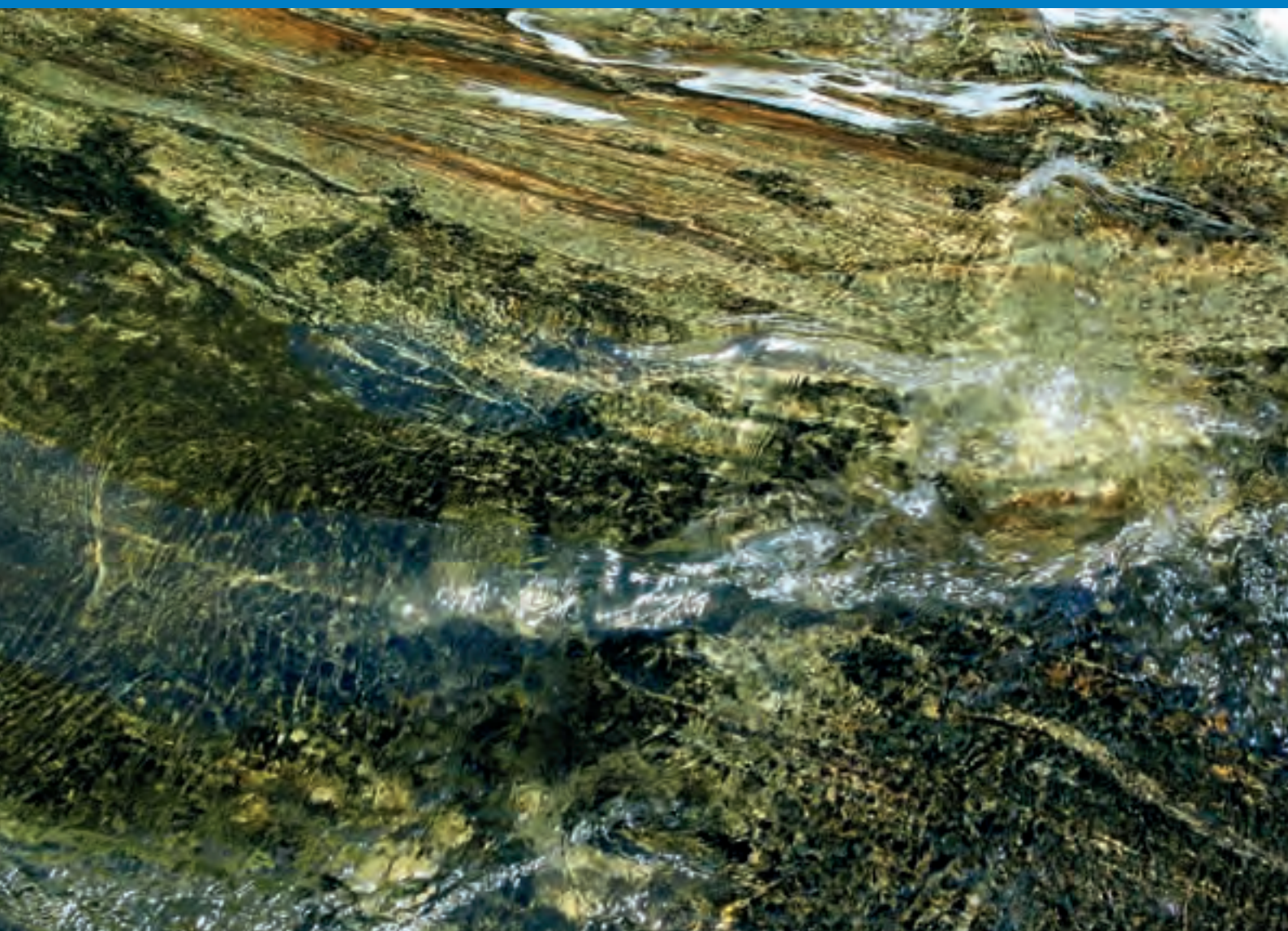


WRITINGS OF THE DIALOGUE



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PLANTATION FORESTRY AND WATER SCIENCE, DOGMAS, CHALLENGES.





THE BRAZILIAN FORESTS DIALOGUE

**PLANTATION FORESTRY AND WATER
SCIENCE, DOGMAS, CHALLENGES.**

WRITINGS OF THE DIALOGUE – VOLUME 01 – ENGLISH

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FOREWORD

This publication, organized by The Brazilian Forests Dialogue and written by Professor Walter de Paula Lima, is a valuable analysis and reflection on two current and extremely important issues for the Atlantic Forest and other Brazilian biomes: forest management and its implications in the use and conservation of fresh water; and integrated land management and occupation. The author has presented in a didactic manner the scientific foundations for these topics, providing greater clarity to the challenges that this approach involves.

In the context of strategies for the use and conservation of biodiversity in Brazil, especially in the Atlantic Forest, one of the most prominent integrative themes is the conservation of fresh water and inland waters. Undeniably, in many parts of the country but especially in the Atlantic Forest, where nearly 70% of the population lives, there are already constraints and conflicting demands on the fresh water supply, for domestic, industrial and agricultural consumption; a fact which generates discussion and action for the protection, restoration and rational use of water resources.

Given the role of forests and other natural formations in water resource conservation, which in different degrees can influence the quantity, quality and regularity of the fresh water supply, the importance of a forum like The Forests Dialogue in uniting forces and purposes to innovate and seek new patterns of development is made even clearer. The present analysis will certainly be incorporated in strategic discussions of The Forests Dialogue and its regional forums, which have emphasized the significance of basing actions and commitments assumed by its members on a solid platform of science, learning and field experience.

Both generation and systematization of information of this nature are essential to making progress on the mechanisms and approaches so greatly needed to expand conservation efforts and the sustainability of strategic areas, to sustain natural ecosystems allied to economic activities and human welfare. Therefore, our expectation is that this publication will contribute to improving the quality and quantity of actions not only of The Forests Dialogue, but of all those interested in sustainable development in Brazil. Enjoy your read!

Luiz Paulo Pinto
Conservation International's Atlantic
Forest Program Director

José Luciano Duarte Penido
Fibria's Chairman of the Board

HISTORICAL PERSPECTIVE

WATER IS ESSENTIAL TO LIFE. NEVERTHELESS, DUE TO ITS UNIVERSAL DISTRIBUTION AND APPARENT INEXHAUSTIBILITY, MAN HAS NEVER PAID PROPER ATTENTION TO THE NEED TO CONSERVE THIS IMPORTANT NATURAL RESOURCE. FOR THE ORDINARY CITIZENS, WATER IS NOT THEIR PROBLEM, JUST AS LONG AS IT IS CONSTANTLY AVAILABLE IN THE TAPS.

These days, however, the concern of experts and lay people over water conservation is escalating. The scarcity of drinking water is a matter that is taken very seriously in many countries, where it is now recognized that there is a *water crisis*, making concern over the maintenance of water resources a vital and priority issue. The water crisis is here to stay, not in the sense that water will run out, but on account of the fact that we have reached the threshold of conflicts, in which those who suffer the most are the poor and, as is now recognized, the environment itself.

But the peculiar characteristics of the water resources make their conservation a complex problem. Water conservation cannot be achieved independently of the conservation of other natural resources. The behavior of water on earth, that is to say, the behavior of the land phase of the hydrologic cycle, is a direct result of the use and conditions of the land from which the water is obtained.

In nature, the conservation of water resources, in terms of water quantity, stream flow rate, constant minimum flow, water quality and the quality of the aquatic ecosystem derives from natural control mechanisms developed over the evolutionary processes of the landscape, which we now call "ecosystem services". One of these mechanisms depends precisely on the relationship between forests and water, which are closely linked. They have been





Photos: Miriam Prochnow

THE WATER CRISIS IS HERE TO STAY. ABOUT 40% OF THE WORLD'S POPULATION SUFFERS FROM A CHRONIC LACK OF WATER.

described as “the two sides of the same coin”, that is to say, the occurrence of forests is always associated with a natural abundance of water, with a climatic water balance characterized by average annual rainfall that is greater than the potential evapotranspiration, the definition of a humid climate. This gave birth to the myth that “forests make rain”, which generated a lot of controversy and was even evaluated in experimental studies.

Moreover, that same close relationship between forest and water can be observed in the regularity and quality of stream flow in river basins covered with natural forest. This applies in both large and medium-sized catchment areas, but especially in small catchment areas. This spawned the belief that forests increase river flow, and this myth generated even greater controversy in the past, giving rise to the formation of groups in favor and against the notion, with each one trying to find arguments to justify their position, but neither side offering sufficient evidence or proof.





Wigold B. Schaffer

These two historical aspects can be considered the embryos of Forest Hydrology, the science that studies the relationship between forest and water, which has developed since the early 19th century and has produced consistent and valuable experimental results that have cleared up myths and provided powerful tools for the suitable management of natural resources. However, the relation between forests and water is still a controversial subject, when it comes to determining public policies for water conservation and encouraging the sustainable use of natural resources. The protection of forest remnants and the restoration of forest cover continue to be the basis of public policies aimed at environmental improvement and water conservation. In some countries, including Brazil, this has led to the development of programs involving payment for

**THE RELATION BETWEEN FORESTS
AND GOOD QUALITY WATER CAN ALSO
BE OBSERVED IN THE SCALE OF THE
MAJOR RIVER BASINS.**

ecosystem services, often linked to the maintaining or increase of forest cover on rural properties.

Paradoxically, the introduction of planted forests – and especially the recent expansion of the area of forest plantations, due to their growing economic importance – was accompanied by a widespread public belief that, unlike natural forests, they would be detrimental to water resources. It includes a bit of everything, starting with the stigma associated with the word

HISTORICAL PERSPECTIVE

“eucalyptus”: “ forest plantations consume too much water”, “they dry up the soil”, “their roots penetrate the water table”, “they inhibit cloud formation”, “they destabilize the hydrologic cycle”, etc.

In regard to past beliefs, the main concern that fed the controversies related to the gradual disappearance of the native forests to make way for development. It was necessary to find a strong ally to help slow down the deforestation, and the possible negative effect on water of the disappearance of the forests certainly could not

**IS IT REALLY TRUE THAT A LANDSCAPE
IN WHICH FOREST PLANTATIONS
PREDOMINATE MUST INVARIABLY
MAKE IT MORE DIFFICULT TO
CONSERVE WATER RESOURCES?**

be ignored by society, because of the vital importance of water. The more forests, the more water was the motto.

In the case of forest plantations, the controversy, which is recurrent and far from being resolved, is intensified not by their disappearance but, rather, by the expansion of these areas. In this case, the belief is that the more forest plantations, the less water.

The widespread public opinion that natural forests are, in all circumstances and in any situation, always beneficial to water resources, in the sense that they make it rain, increase river flows, reduce flooding and maintain water quality, is questionable and should be replaced by the modern perception, based on the scientific experimentation, that this is a much more complex relationship, the results of which depend on the interaction of many factors, not just the presence or absence of forests.





By the same token, the general belief that forest plantations, in all circumstances and in any situation, are always harmful to the water resources fails to pass scientific scrutiny. It is necessary to examine the whole context. In the case of the notion of establishing forest plantations for the recovery of degraded areas, for example, in some situations the results are really promising, even with regard to the restoration of ecosystem services. However, depending on the extent of the degradation, or if the soil has already lost its resilience or capacity for self-renewal, the results will be negligible.

On the other hand, in the case of forest plantations for industrial supply, the popular perception is often answered by those who are responsible for their management with the allegation that planted forests are beneficial to the environment in all circumstances

THE ENVIRONMENTAL BENEFITS OF FOREST PLANTATIONS DO NOT ARISE ON THEIR OWN, BUT DEPEND ON OUR MANAGEMENT STRATEGIES.

and in any situation, as if the mere existence of these plantations was sufficient to ensure environmental improvement. In fact, since they are products of human engineering, using silvicultural technology for the formation and management of homogeneous forest stands aimed at the maximization of productivity, the environmental benefits will crucially depend on the management plan and the interaction of forest plantations with other landscape elements, from planting to harvesting.

HISTORICAL PERSPECTIVE

Nevertheless, water resources may also be affected by countless other human actions and natural events, and not merely by the presence or absence of forests and forest plantation management. However, although some of these other causes of water resource degradation are even more striking, one does not see the same level of attention that is usually directed at the forests. Consequently, it is difficult, for example, for a particular rural landowner to be awarded payment for ecosystem services if he has planted some trees on his property, yet continues to impact water resources by means of inappropriate soil management.

WATER THAT FLOWS FROM FORESTED CATCHMENT AREAS IS GENERALLY OF GOOD QUALITY.

Thus, for a more consistent assessment of the prevailing conditions of our water resources, the causes of their degradation and public policies that effectively contribute to water conservation, it is necessary to take into account the results, the information and certain principles established in the science of Forest Hydrology. In short, one should accept the following principles (CALDER, 2007):

- Water consumption by forests is generally higher than the consumption by lesser vegetation and non-irrigated agricultural crops.
- Forest plantations with fast growing species also show higher water consumption in comparison with lesser vegetation, as well as with natural forests or plantations of slow growing species. As a result, in some situations a significant decline in catchment water runoff can be observed.
- Similarly, it has been observed that the percentage of occupation of the catchment area by forest plantations is a very important factor governing the presence or absence of these effects. In fact, the results of some studies show that there is no change in water runoff if the forest plantations occupy only 20% of the catchment area.





Miriam Prochnow

- The quality of the water flowing from catchment areas covered with forests is generally good. In the case of forest plantation management, some unsustainable practices can cause erosion and loss of sediments and nutrients in catchment areas, leading to downstream impacts, as well as the hydrological degradation of soils and, eventually, of the catchment area itself.
- On the small catchment area scale, forest cover can certainly mitigate the effects of flooding; but this is generally not the case on the scale of larger river basins.
- It has not yet been possible to substantiate the beneficial effects of forest cover on the minimum flow, although it is possible to accept, on a theoretical basis, that the higher rate of infiltration resulting from forest cover is sufficient to offset the higher water consumption, thus resulting in higher aquifer recharge, which helps to maintain the minimum flow.

Therefore, it is essential that the planning of forest plantation management take into account the natural limitations of the environment, in terms of natural availability of water and the existing demands on this resource, as well as the occupation of the productive areas within the landscape, to ensure the permanence of landscape attributes (biodiversity, riparian areas, riparian forest, etc.) that together ensure the maintenance of the catchment area's health and

**WELL-PROTECTED RIPARIAN
AREAS HELP TO MAINTAIN THE
ENVIRONMENTAL HEALTH OF
CATCHMENT AREAS.**

ecosystem services, the most important of which is preserving the quantity and quality of the water flowing from the catchment area.

It is also crucial, when determining public policies for the conservation of water resources, to exclude dogmas which contribute only to policies and actions that address the symptoms, rather than the causes of hydrological degradation.

Equally essential in this struggle is the unrestricted involvement of the whole of society, so that we can evolve from a democracy that only recognizes rights to a democracy that acknowledges our responsibilities towards the environment as well.

THE MYTH SURROUNDING THE EUCALYPTUS

A CLASSIC POPULAR BELIEF INVOLVING THE RELATIONSHIP BETWEEN FOREST PLANTATIONS AND WATER CAN BE SUMMED UP IN THE ASSERTION THAT THE EUCALYPTUS DRIES UP THE SOIL. IT WOULD BE PERTINENT TO ADDRESS THIS MATTER, SINCE IT HAS FREQUENTLY BEEN USED IN DEFINING PUBLIC POLICIES AND RESTRICTIVE LEGISLATION, AS WELL AS TO INCITE HEATED BUT USELESS ARGUMENTS, OFTEN CHARACTERIZED BY STRONG EMOTIONAL AND IDEOLOGICAL APPEAL.

Clearly the vast majority of responses to this statement may be summarized as a resounding “no”, and it is easy to understand why. From the scientific standpoint, for instance, the numerous experimental results accumulated on the subject of water consumption by eucalyptus plantations, both in Brazil and abroad, are available to clarify the situation. And yet it endures, reemerging here and there whenever the subject is brought up and, for that matter, every time certain segments of society express their apprehensions about issues that sometimes have nothing to do with this subject.

There are two possible explanations: either science, for one reason or another, is not succeeding in eliminating this concern, or the problem is not just technical, or physical, or biological, which seems to be the case. Certainly, the resolution of environmental problems cannot be achieved through conventional science alone, based simply on the results obtained in experimental studies. It is necessary to analyze the full complexity of ecological, social and cultural aspects involving each one. So, despite continuing to produce more scientific information, the question will still remain for a long time,

or at least as long as science seeks merely to show that water consumption by the eucalyptus does not differ significantly from the consumption of other forest species. There is already a pretty full body of evidence in the literature.

And yet, the question still remains because this experimental evidence is only part of a bigger problem (LIMA, 2004). Why, then, does the soil dry out? Why do streams, creeks and brooks disappear? Why do entire catchment areas become degraded? Why do our rivers suffer? Why all the concern about water, which really does seem to be running out?

Maybe part of this problem can be attributed to climate change, evidence of which has been provided in the results of simulations performed by complex models developed since the verification of a gradual increase in the concentration of carbon dioxide in the atmosphere, the so-called greenhouse effect, resulting mainly from the burning of fossil fuels. Some say that reforestation can help to sequester this excess carbon from the atmosphere, but others say this will further aggravate water shortage. The worst part is that, in theory, both are right.





However, the problem derives not only from things that are happening on the macroclimate scale. There are many other things going on on a smaller scale that may also be having an effect. For example, on the mesoclimate scale – that on which we live on a daily basis, and therefore more comprehensible to most people – one must consider that the climatic conditions governing the availability or natural supply of water for the different uses varies from region to region. There is the semi-arid

region, for example, where it is hot, the evapotranspiration (the sum of all water loss through evaporation, including transpiration by plants) is always high and the total annual rainfall is usually low. Hence, there is very little rainwater left over to recharge the soil and aquifers, and water only flows in the streams and rivers when it rains.

On the other hand, there are regions where there is considerable rainfall, spread over practically all the months of the year, giving an average

THERE ARE MANY NON-SUSTAINABLE ACTIONS THAT CAN ALSO AFFECT WATER RESOURCES. IN THE PHOTO, ROADS CROSS RIPARIAN AREAS WHERE RIPARIAN VEGETATION HAS DISAPPEARED TO MAKE WAY FOR AGRICULTURAL PRODUCTION.

annual yield well in excess of the losses through evaporation. In such cases, there is always surplus water to recharge the soil and aquifers and to feed the perennial stream and river flows.

THE MYTH SURROUNDING THE EUCALYPTUS

Between these two extremes lies a whole variety of conditions of the so-called climatic water balance. And in all of them there are significant annual variations; sometimes years go by with less rain than the historical average, causing a diminishing in volume of surface water, which some people immediately attribute to the eucalyptus. At other times, there may be several years of above average rainfall in the region, possibly even causing flooding, and there are those who quickly attribute this to deforestation.

Anyway, a very important aspect of mesoscale analysis is that, under conditions or in regions where the natural water supply is already low, any unplanned alteration of the landscape, such as replacing low vegetation with forests, may result in increased water consumption and generate conflicts. That is why there needs to be ecological zoning that takes into account these regional variations in water availability, in order to regulate land use.



THE UNPLANNED OCCUPATION OF HYDROLOGICALLY SENSITIVE LOCATIONS, SUCH AS STREAM HEADWATERS AND RIPARIAN AREAS, IN AREAS OF MANAGED FOREST, AS WELL AS DEFORESTATION AND DISFIGURING OF THE LANDSCAPE, MAKE IT HARDER TO MAINTAIN THE WATER RESOURCES.

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However, there is another scale, the principal one used in this analysis, where actions that also affect water resources take place. Let us call it the microscale. This is the scale where management practices take place, where mankind cultivates, harvests, destroys, deforests, compacts the soil, builds bad roads over riparian areas, paves, impermeabilizes, organizes the land, buries springs, sets fires, ploughs, fences off, grows extensive monocultures, plants up to the edge of streams - sometimes even in the water, burns riparian forest, does not take care of pastures, confines cattle on top of riparian areas, builds dams, installs sprinklers, irrigates, fertilizes, and so forth. These activities are carried out on the scale of rural properties, where small catchment areas are located and can be greatly affected by these actions. And it is on the scale of the small catchment areas that the focus of sustainable water resource management practices needs to be centered, because they are the major feeders of river flow and river basins. Unfortunately, however, stronger public policies that encourage and strengthen this operational scale have yet to be developed in this country. And that is why paying for ecosystem services simply in return for planting trees on rural properties, without taking into account all the other factors, will not necessarily turn the landowner into a "water producer". Small catchment areas are different from larger river basins in several ecological and hydrological aspects - and one of these differences is that they are highly sensitive to management actions, to the extent that it is possible to observe a direct relationship between management practices and the ensuing environmental impacts. So, the key concept can be summed up in the expression integrated catchment management, which means the planning of management activities (forest management, crop management, etc.) so as to safeguard the catchment values, which are the hydrological processes, geochemical cycling of nutrients, biodiversity, protection of hydrologically sensitive areas and its overall long-term resilience, that is, its ability to withstand change without suffering irreversible degradation. One of the most important factors for enduring catchment resilience is the integrity of the riparian ecosystem, meaning vigorous riparian vegetation properly protecting all the riparian areas within the catchment area, and not restricted to 30 meters along both banks of the watercourses, but also including stream headwaters, as well as other parts of the catchment area, even those located on higher slopes that tend to remain saturated most of the time. That is



why these areas are earmarked, under the Brazilian Forest Code, for "permanent preservation", in the sense that keeping them in good condition provides important ecosystem services. Water is undoubtedly the most important of these services that are freely provided to us by the ecosystem, in the form of water quantity, water quality and a continuous minimum outflow. When catchment areas lose these natural characteristics they become vulnerable to disturbances that would otherwise normally be assimilated. Therefore, it can confidently be said that the gradual loss of resilience of the riparian ecosystem in countless small catchment areas, and the entire hydrological degradation resulting therefrom, has been the main factor in the reduction and degradation of surface water resources, the drying-out of the soil and the succumbing of brooks and streams.

It is therefore clear that the eucalyptus is, after all, merely part of the problem of the drying out of the soil,



THE GRADUAL LOSS OF THE RIPARIAN ECOSYSTEM, DUE TO UNSUITABLE LAND MANAGEMENT IN COUNTLESS CATCHMENT AREAS, HAS BEEN THE PRIMARY CAUSE OF THE DEGRADATION OF WATER RESOURCES.

which can actually occur when management actions do not take into account the concept of integrated catchment management. But the problem is really much more complex than this and must be dealt with through the vital restoration of all the environmental and hydrological values discussed above, especially those related to the development and implementation of adequate planning for the occupation of the productive areas of the landscape for agricultural or forest production. Throughout the landscape, there are areas that are suitable for the production (of grains, fibers, wood, meat, milk, etc.) that society needs,

but there are also areas that are clearly appropriate for environmental protection, whose preservation is necessary to provide the ecosystem services that society also needs to continue growing in a sustainable manner. The management of eucalyptus plantations has to take into account these peculiarities and ecological and hydrological limitations. For precisely the same reason, the management of soybeans, sugarcane, oranges and cattle also carries the same social and environmental responsibilities. There is absolutely no point turning this crucial issue of the survival of all into disputes between ruralists and environmentalists.

**PASTURES CONSUME
LESS WATER, BUT
THEIR INAPPROPRIATE
MANAGEMENT MAY
JEOPARDIZE THE
INTEGRITY OF THE
CATCHMENT AREAS.**

For the same reason, the planning of the urban occupation of the landscape needs to review its actions in regard to the goal of water conservation, since urbanization is also partly to blame. The cities and towns are where the majority of the population lives, but this does not justify them remaining aloof from the needs of catchment conservation. Urbanization is the second factor underlying hydrological degradation, after agriculture. There is even a movement around the world to restore hydrological values in urban areas, with actions aimed at, for instance, “unearthing” channeled streams and integrating them into the urban landscape with all their inherent attributes – such as riparian vegetation, which, besides its hydrological importance, also adds aesthetic value to the urban environment – and this should help to change the perception of the citizens regarding the need to conserve the streams and their catchment areas.





HEADWATERS OF A CATCHMENT AREA, A HYDROLOGICALLY SENSITIVE AREA THAT SHOULD BE PROTECTED. THE CATTLE LOOK BEAUTIFUL AND HEALTHY, BUT THE CATCHMENT AREA SHOWS CLEAR SIGNS THAT IT IS LOSING THE BATTLE.



URBANIZATION IS UNDOUBTEDLY A MAJOR FACTOR IN THE HYDROLOGICAL DEGRADATION OF CATCHMENT AREAS.

SCIENTIFIC EVIDENCE OF THE RELATIONSHIP BETWEEN FOREST PLANTATIONS AND WATER

Worldwide, forest plantations have always been at the center of heated discussions, mainly related to their possible impact on water resources, due to the general perception of their exaggerated water consumption. Such discussions, far from being resolved, have currently attained a new and very significant dimension (JACKSON et al., 2005; FARLEY et al., 2005; VAN DIJK

THE EUCALYPTUS IS A PERFECTLY NORMAL FOREST SPECIES, IN TERMS OF WATER CONSUMPTION, FROM THE PHYSIOLOGICAL POINT OF VIEW.

& KEENAN, 2007). First of all, due to the total planted area, which has reached approximately 50 million hectares in the world's tropical regions, with a rate of new plantings of around 3 million hectares per year (FAO, 2005). Secondly, because it is increasingly obvious that the natural availability of water is one of the most important issues relating to the management of natural resources around the world (ZALEWSKI, 2000; WAGNER et al., 2002). In the light of the evidence, there is a growing demand that the analysis of the potential water impact be systematically incorporated within forest plantation management planning (LIMA, 2005; CALDER, 2007; VANCLAY, 2009).



The literature reveals that the relationship between forest plantations and water is being studied in many countries, using different research methods and approaches, both for isolated trees and stands, but especially in experimental catchment areas (LIMA, 2006). Excellent review papers have been published, focusing on a careful analysis of the information available in the literature regarding particular aspects of the problem. The work of ANDREASSIAN (2004), for instance, provides a very sound and interesting historical perspective on the controversy surrounding the hydrological impact of forests and forest management, from the quaint – even romantic – beginning of these debates, when there was not yet any scientific evidence, up till the present day.

Then there is the work of WHITEHEAD & BEADLE (2004), comprising a very interesting review of all the physiological aspects of eucalyptus water consumption. Within the eucalyptus myth, it is not hard to find allegations that it is a peculiar forest species in relation to water, capable of feats that have never been attributed to any other forest species. Analyzing the available results on physiological aspects, in terms of transpiration rate, stomal dynamics, leaf area, water use efficiency, interception losses and water balance, the authors are categorical in concluding that the eucalyptus is an absolutely normal forest species, which does not consume any more water per unit of produced biomass than any other forest species, and even demonstrates superior water use efficiency.

This greater water use efficiency can be better understood by observing the experimental results presented in Figure 1, which were obtained during the comparative measurement of the components of soil water balance in the Jequitinhonha Valley, in the state of Minas Gerais, Brazil, in adjacent plots of *Eucalyptus grandis* and *Pinus caribaea*, both five years old, as well as in a representative portion of the local cerrado vegetation (Brazilian savannah) (LIMA et al., 1990). The studied depth of the soil profile was 2 meters, meaning that the water balance of this 2-meter soil profile involved the measurement of incoming rainwater (blue downward pointing arrows), net water withdrawal through transpiration (yellow bar), and upward (by capillary action) or downward (deep percolation) movement of soil humidity. In other words, to illustrate the case of the eucalyptus plot: the precipitation that actually reached the soil surface was 986.5 mm per year, due to loss through interception by the forest canopy of part of the gross rainfall, which amounted to an annual average of 1,121 mm. The figure of 784 mm represents the average annual withdrawal by the eucalyptus of water from the soil through transpiration, which contributed to the accumulation of 366 m³ of wood per hectare. By comparison, in the case of the pine, the ratio was 617 mm of transpired water to 210 m³ of wood production, while the estimate for the cerrado indicates a much smaller ratio: 569 mm of transpiration to about 36 m³ of above ground biomass per hectare.

COMPARATIVE STUDY OF SOIL WATER BALANCE BETWEEN CERRADO (BRAZILIAN SAVANNAH) AND 5-YEAR-OLD PLANTATIONS OF PINUS CARIBAE AND EUCALYPTUS GRANDIS.

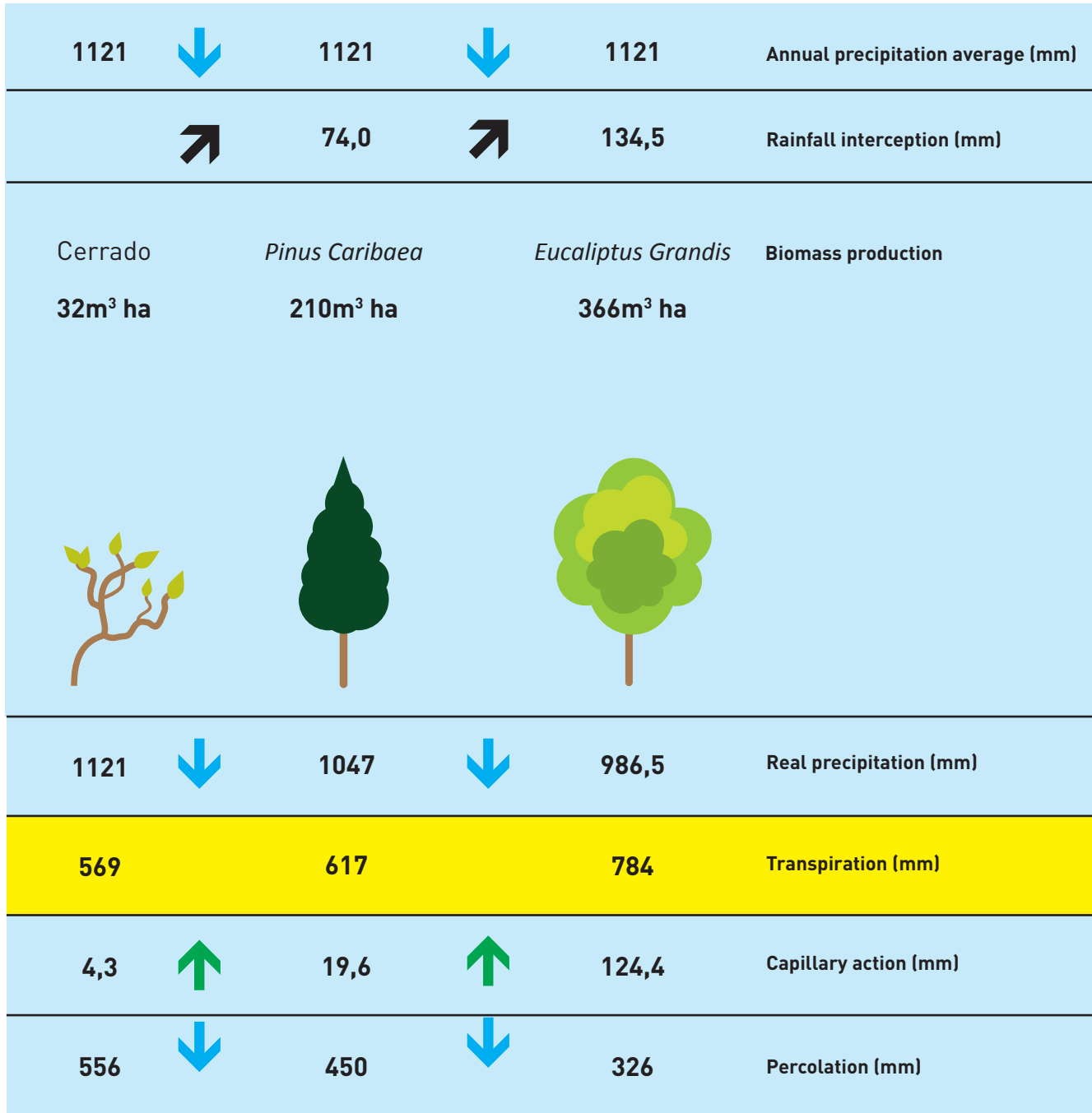


FIGURE 1: RESULTS OF THE COMPARATIVE STUDY OF SOIL WATER BALANCE BETWEEN CERRADO (BRAZILIAN SAVANNAH) AND 5-YEAR-OLD PLANTATIONS OF PINUS CARIBAEA AND EUCALYPTUS GRANDIS, CONDUCTED IN THE JEQUITINHONHA VALLEY, MINAS GERAIS. THE NUMBERS REPRESENT THE AVERAGE OF TWO CONSECUTIVE YEARS OF MEASUREMENTS. SEE TEXT FOR EXPLANATIONS. (LIMA ET AL., 1990).

On the experimental catchment area scale, which is the most reliable scale for the analysis of the possible hydrological impact of forest management, the first classic review was written by HIBBERT (1967) and presented at the International Symposium on Forest Hydrology, which was held in the USA back in 1965. In this work the author clearly stated, based on the evidence he found, that forest cutting increases annual water runoff, while reforestation decreases catchment water runoff.

It may be useful to clarify the term runoff, which is often confused with flow. The abovementioned effect of cutting down trees or reforesting relates to the annual water balance of the catchment area, in other words, calculating the total annual water entering the catchment area as a result of rainfall, less the annual loss due to evaporation, leaving the surface water that feeds the water flow.

Anyway, getting back to the work of Hibbert (1967), the author was also very careful to point out that these effects could vary greatly from place to place, and were in many situations quite unpredictable. Nowadays, it is known that these hydrological effects are the result of interaction with other environment factors, the soil hydrology being one of the most important. In shallow soil, where little water is stored, the differences in water consumption between forests and lower vegetation, such as pasture, would simply be due to the loss of rainfall to interception, which is usually greater in the forest canopy. Another factor would be the climate, particularly the rainfall regime. In regions with high annual precipitation and rainfall regularly distributed throughout the year, evapotranspiration always occurs at the potential rate for a given climatic condition. Under these conditions, a more uneven forest canopy, combined with a greater amount of available advective energy (significant heat gain caused by the interaction of air masses that are warmer

than the forest), may increase water consumption by forests, in comparison with lower vegetation.

In this regard, ZHANG et al. (2001), analyzing data from some 250 experimental catchment areas worldwide, established a very simple, but consistent, relationship between evapotranspiration at the catchment scale and the annual rainfall, which is summarized in Figure 2. As can be seen from this figure, in areas with annual rainfall below 700 mm, the results show that there is not much difference in the evapotranspiration between catchment areas with forest and catchment areas with pasture. In other words, under these conditions the water balance is mainly governed by the weather, regardless of the type of vegetation cover. And when, in regions with higher annual precipitation, forest cover tends to show higher water consumption than lower vegetation, the maximum value of this consumption is nevertheless limited by the climatic constraint of available solar energy. So, it is not a linear relationship, as the figure shows. The model proposed by the authors is referred to in the literature as “Zhang curves”.

SCIENTIFIC RESEARCH IS ESSENTIAL TO GUIDE
METHODOLOGIES FOR THE MANAGEMENT
OF PLANTED FORESTS AIMED AT THE
CONSERVATION OF WATER RESOURCES.



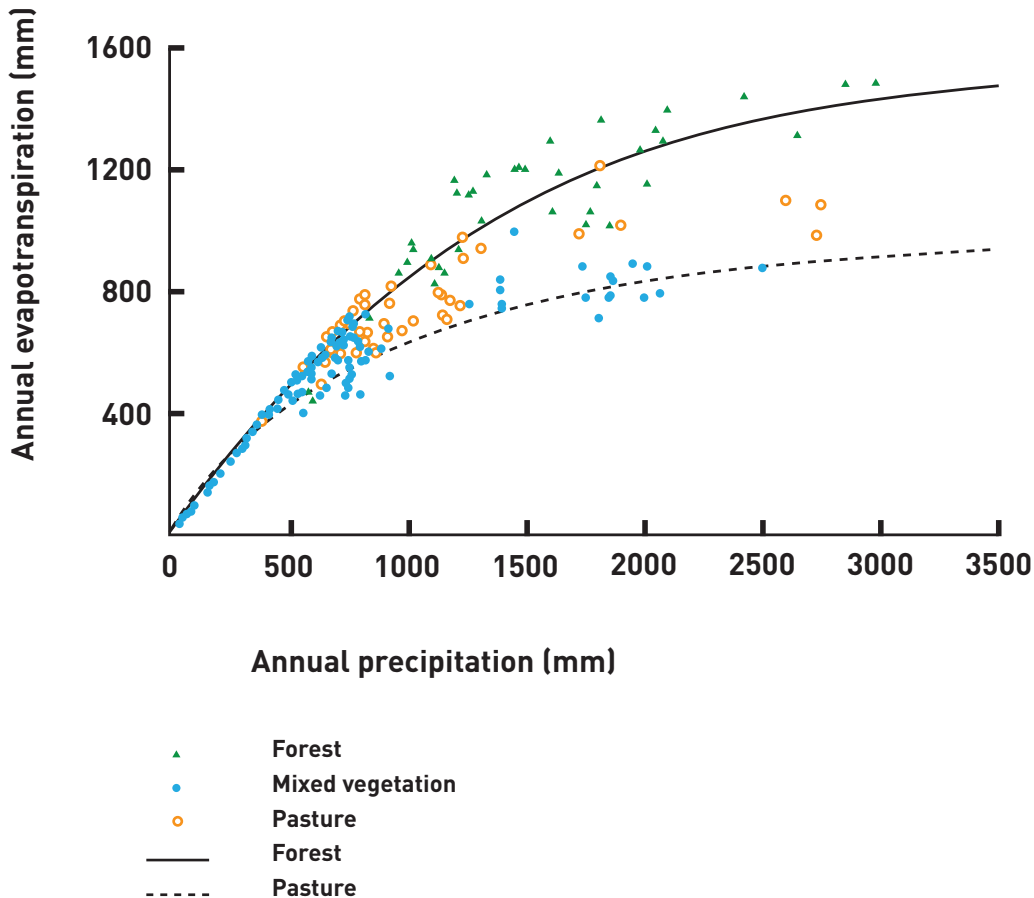


FIGURE 2: CHART SUMMARIZING THE MODEL OF ZHANG ET AL. (2001), SHOWING THE RELATIONSHIP BETWEEN ANNUAL EVAPOTRANSPIRATION (VERTICAL AXIS) AND ANNUAL PRECIPITATION (HORIZONTAL AXIS). THE UPPER LINE CORRESPONDS TO MEASURED RESULTS IN CATCHMENT AREAS WITH FOREST COVER, WHILE THE LOWER DOTTED LINE CORRESPONDS TO RESULTS IN CATCHMENT AREAS WITH PASTURE.

At about the same time as the now classic review by HIBBERT (1967), the work of SWANK & MINER (1968) provided what might be considered the first comparative result for the replacement of natural forest (temperate mixed broadleaf forest) by a forest plantation, in this case eastern white pine (*Pinus strobus*), in an experimental catchment area. The region of the experiment was characterized by average annual precipitation around 1900 mm and a potential rate of evapotranspiration of 1120 mm, giving it an annual water surplus of around 775 mm. The authors demonstrated

that when the pine plantation reached the age of 10 years, the annual catchment water yield had decreased by 94 mm in comparison with the original natural forest conditions.

Other studies illustrating this comparison between natural forests and forest plantations were produced in Australia, in experimental catchment areas supplying the city of Melbourne. The region is characterized by average annual rainfall of around 1600 mm, that is well distributed throughout the year, and a water surplus of around 650 mm per year. The first evidence

was found somewhat fortuitously, as a result of a forest fire that decimated a natural forest of *Eucalyptus regnans* that was more than 200 years old. Natural regeneration after the fire was vigorous, resulting in a new forest with a density of more than 3,000 trees per hectare, all growing uniformly, similar to a forest plantation of fast-growing species. On the experimental catchment scale, when this new regenerated forest had reached an average height of 10 meters and was 38 years old, the annual water yield had reduced by 200 mm from the level before the fire (LANGFORD, 1976). KUCZERA (1987) analyzed the historical sequence of data for this catchment area and produced a theoretical model of the

relationship between catchment water yield and the age of the new forest, which is summarized in Figure 3. Considering that the timescale is not directly applicable to Brazilian conditions, what should be noted in Figure 3 is the fact, already stated herein, that there is a tendency for the annual catchment water yield to return to the original balance as forest plantation advances in age. Within reason, this may mean, in practical terms, that a longer rotation period (cutting age of the forest plantation) than is currently practiced in the forest plantation management for industrial supply in Brazil (around 7 years) could allow sufficient time for a return to the original catchment water balance.

THE CORRECT MANAGEMENT OF FOREST PLANTATIONS AND OTHER ACTIVITIES ON A RURAL PROPERTY IS ESSENTIAL TO MAINTAIN THE QUANTITY AND QUALITY OF THE WATER.

Miriam Prochnow



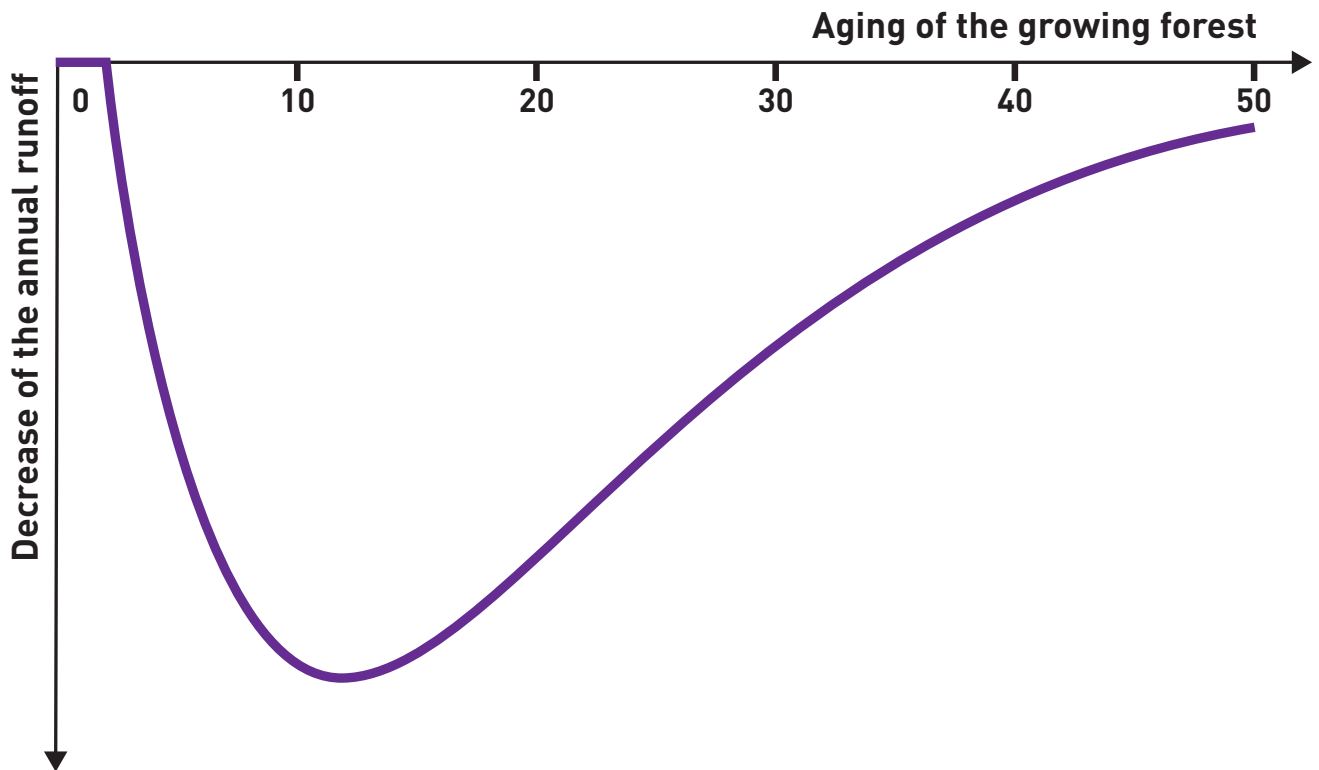


FIGURE 3: CHART SUMMARIZING THE MODEL DEVELOPED BY KUCZERA (1987), WHICH SHOWS THE RELATIONSHIP BETWEEN THE DYNAMICS OF THE ANNUAL CATCHMENT WATER YIELD (VERTICAL AXIS) AND THE AGING OF THE GROWING FOREST (HORIZONTAL AXIS). IT REVEALS THAT, IN THE INITIAL PHASE OF THE GROWTH OF A NEW FOREST, THE ANNUAL CATCHMENT WATER YIELD TENDS TO DECREASE, REACHING A MAXIMUM REDUCTION AT AROUND 12 YEARS (IN THE AUSTRALIAN CONDITIONS WHERE THE RESULTS WERE OBSERVED), THEN IT TENDS TO RETURN TO THE ORIGINAL CONDITIONS PRIOR TO THE PLANTING (IN THIS CASE, AROUND 50 YEARS).

With the objective of obtaining experimental results that would validate the theoretical model, describing the dynamics of the relationship of catchment water yield and forest growth, proposed by KUCZERA (1987) – Figure 3 – VERTESSY et al. (2001) performed a detailed study of the components of the water balance in natural forests of *Eucalyptus regnans* of different ages in Australia, the results of which are summarized in Figure 4. As the figure shows, over the years, the water balance components change, not only because of physiological changes that

control transpiration, but also owing to changes in the very architecture of the canopy. Thus, referring to the schematic illustration in Figure 4, in the initial phase of growth, both transpiration and interception losses are high, leaving very little of the gross precipitation to feed catchment runoff. Over time, these components diminish, resulting in a greater water surplus that gradually increases the annual water yield. This would also explain the acknowledged hydrological stability of catchment areas that are protected by undisturbed natural forests.

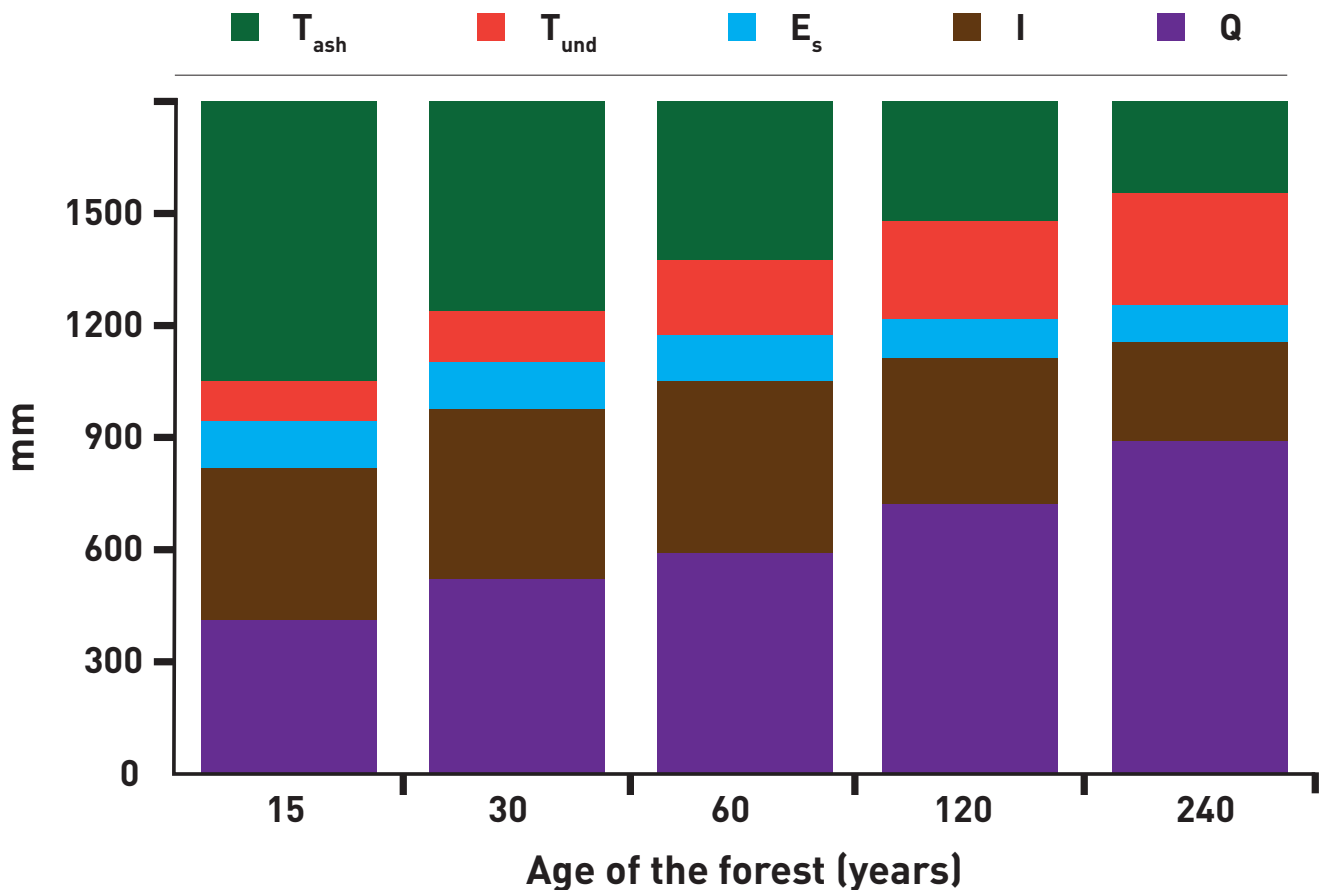


FIGURE 4: SUMMARY OF THE RESULTS OF MEASUREMENTS OF WATER BALANCE COMPONENTS IN *EUCALYPTUS REGNANS* FORESTS OF DIFFERENT AGES IN AUSTRALIA. THE KEY AT THE TOP OF THE FIGURE CORRESPONDS TO: TASH = TRANSPIRATION OF THE FOREST; TUND = TRANSPIRATION OF SECONDARY VEGETATION; ES = DIRECT EVAPORATION FROM THE SOIL; I = INTERCEPTION OF RAIN BY THE CANOPY; Q = CATCHMENT WATER YIELD. THUS, THE QUANTITATIVE CHANGE IN THESE COMPONENTS WITH THE ADVANCING AGE OF THE FOREST RESULTS IN A GRADUAL INCREASE IN THE CATCHMENT WATER YIELD, AS SIMULATED BY THE MODEL IN FIGURE 11 (VERTESSY ET AL., 2001).



UNDER TROPICAL CONDITIONS, IT IS CRUCIAL THAT MANAGEMENT ACTION PROTECTS HYDROLOGICALLY SENSITIVE AREAS AND THE SOIL SURFACE.

More recently, two other similar review papers were published by BOSCH & HEWLETT (1982) and BROWN et al. (2005). They analyzed a larger amount of available information and reached the same conclusions as the pioneering work of HIBBERT (1967). In the latter review, for example, the authors managed to clarify more details of these relationships in terms of tropical conditions, which can be summarized as follows:

- soil infiltration and the evapotranspiration representative of different types of vegetation play an essential role in the hydrology of the catchment area, which experienced change in its forest cover;
- for instance, if the infiltration rate decreases after deforestation, or after forest harvesting, to the point that the increase in direct runoff caused by the reduction of infiltration exceeds the possible gain of aquifer recharge resulting from the decrease in evapotranspiration, then one should expect a gradual decrease in the minimum flow during the dry season;
- on the other hand, if the forest harvesting or deforestation is carried out in a way that does not disturb the soil surface and the infiltration rate, then the decrease in evapotranspiration after the cutting should result in the increasing of aquifer recharge and, consequently, of the minimum flow;
- however, the effects of interaction between changes in infiltration and in evapotranspiration as a result of forest management activities also depend on the soil hydrology, and especially its water storage capacity.

Such information is extremely important for water conservation. There are so many examples of irresponsible land use that do not consider the necessity of protecting the soil surface, which is worn away by erosion, thus reducing infiltration and leading to catchment degradation. It is often not the act of cutting down the forest or harvesting the trees that impacts on the water resources, but the way this is done and the changes in the soil surface resulting from it.



The work of BROWN et al. (2007) is also very interesting from a practical standpoint, for it is a review of experimental results obtained in experimental catchment areas with forest plantation cover, and also because it tried to obtain information on the extrapolation of the results from small catchments to larger river basins. This expectation of downstream propagation of the effects is undoubtedly significant and also widely questioned, although it has not yet been confirmed in experimental studies, because of the obvious difficulties inherent in the enormous number of factors that operate simultaneously in a large river basin, especially the dilution of possible effects, in view of the sheer volume of water in a large river system. The authors conducted the experiment in a river basin of about 84,000 km² in Australia, in which, through simulation using hydrological models, they tried to ascertain what would happen in the main channel of the macrobasin as a result of introducing 30,000 hectares of forest plantations, representing just 0.4% of the total area. Obviously, no effect on the main river was detected. Indeed, other similar studies show that no effect actually occurs if the area of the forest plantations represents less than 20% of the experimental catchment area. However, the model indicated that if the 30,000 hectares were located entirely in one of the smaller sub-basins, a decrease in the water yield of this smaller catchment area would be observed, as has indeed been seen in experimental catchment areas. Moreover, it was also noted that this decrease in water yield would be less significant the further away the plantations were located from the drainage network, in other words, far away from areas where the water table is closer to the surface.

The review of FARLEY et al. (2005), on the other hand, is very enlightening with regard to an understanding of how interactions between forest management and other environmental factors can result in larger or smaller hydrological impacts. Analyzing the results from 26 sets of experimental catchment areas in various parts of the world, with a total of 504 observations, the authors concluded that:

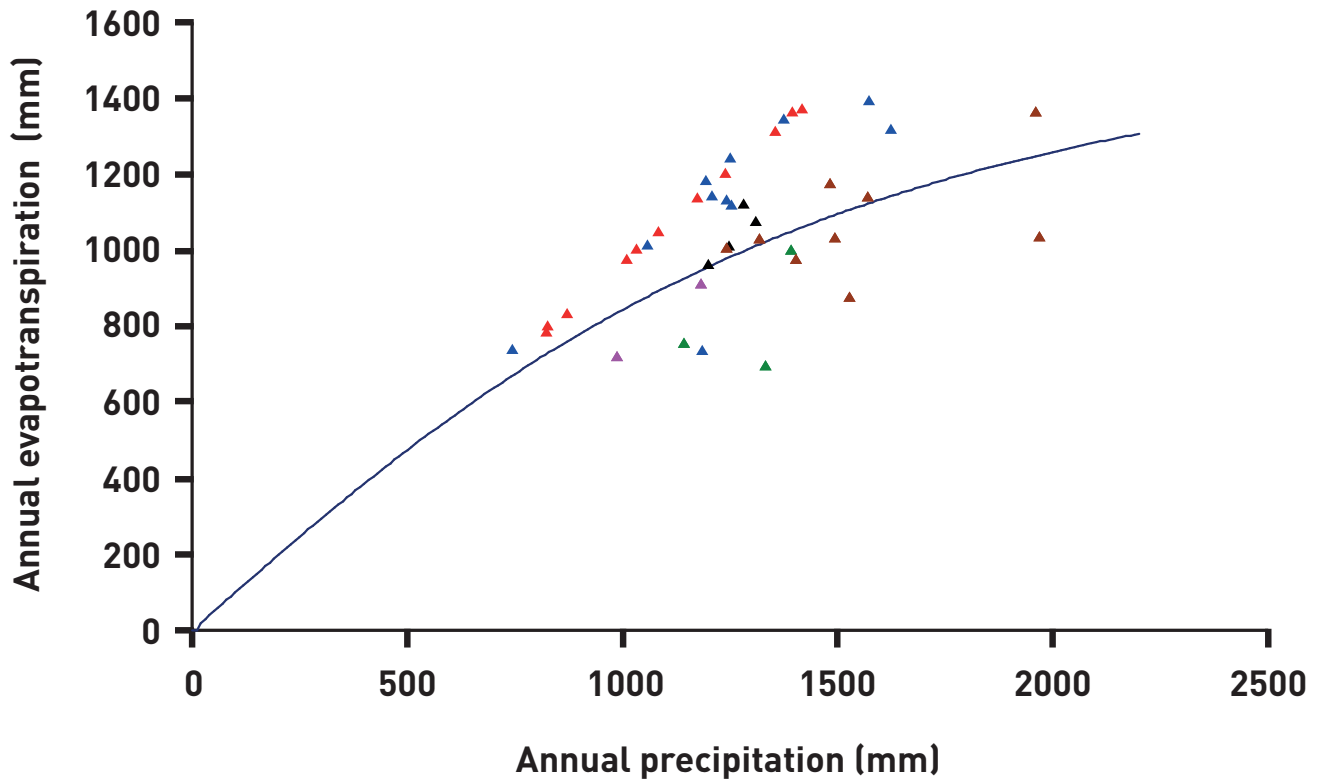
- in areas where the average annual runoff is less than 10% of the annual rainfall, the stream can dry up as a result of reforestation. On the other hand, where the average annual runoff is around 30%

of the annual rainfall, the expected reduction in runoff is about 50%;

- the reduction in runoff increases with the growth of the forest plantation, but the catchment water balance tends to return to the pre-existing balance once the plantation gets beyond a certain age.

Until not so long ago there was still no result for experimental catchments in Brazil, so it was necessary to infer from the results obtained in other countries and in other situations, which often led to the questioning of their validity in our conditions. But the Catchment Area Monitoring Program (PROMAB) of the Forestry Science and Research Institute - IPEF, in partnership with Brazilian forestry companies, has been accumulating water balance results for experimental catchment areas in various locations, some of them with over 10 years of consecutive measurements. In this program there are areas with only one experimental catchment area with forest plantations, but in some cases the work involves a pair of catchment areas: one with forest plantations and the other with natural forest, the latter functioning as a reference for comparing the results. Global analysis of these accumulated results has led to the observation that the results in the world literature, as well as the conclusions one can draw from them, such as those of FARLEY et al. (2005), mentioned above, seem to also occur in Brazilian conditions.

The strong relationship between evapotranspiration and annual precipitation observed by ZHANG et al. (2001), as shown in Figure 2, is also consistent with the accumulated data on annual precipitation and evapotranspiration from the experimental catchment areas of PROMAB, both using the individual annual figures, as shown in Figure 5, and the annual averages for the monitored period, as shown in Figure 6 (LIMA & FONTANA, 2008).



— Zhang ▲ Itatinga-SP ▲ Itatinga_pós ▲ Alagoinhas-BA ▲ Santa Branca-SP ▲ Luís Antônio-SP ▲ Aguaí-SP

FIGURE 5: CORRELATION BETWEEN THE ANNUAL FIGURES FOR EVAPOTRANSPIRATION IN THE EXPERIMENTAL CATCHMENT AREAS OF PROMAB (COLORED SHAPES) AND THE MODEL DEVELOPED BY ZHANG ET AL. (2001) (LINE).

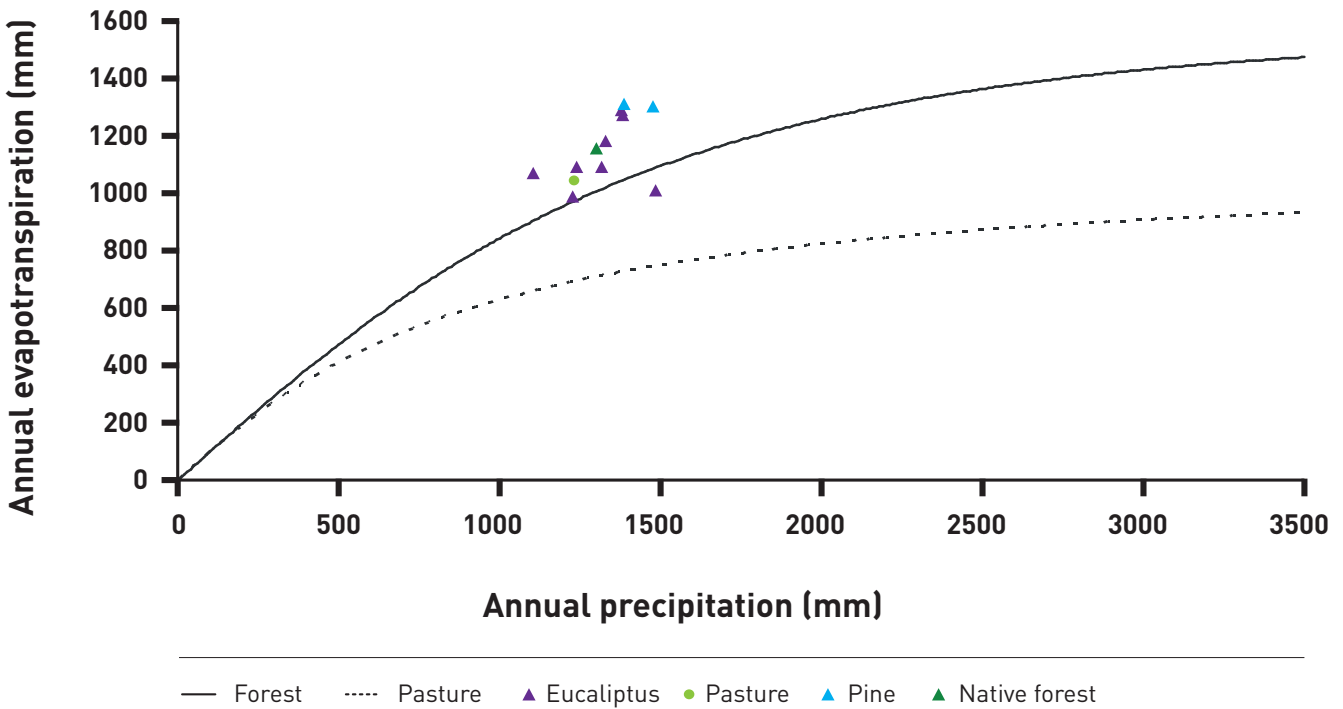


FIGURE 6: CORRELATION BETWEEN THE AVERAGE ANNUAL FIGURES FOR EVAPOTRANSPIRATION IN THE EXPERIMENTAL CATCHMENT AREAS OF PROMAB (COLORED SHAPES) AND THE MODEL PROPOSED BY ZHANG ET AL. (2001) (UNBROKEN LINE FOR FOREST AND DOTTED LINE FOR PASTURE).

Therefore, Figures 5 and 6 show that water consumption by forest plantations tends to be greater in regions with higher annual rainfall, a relationship that is evidently not linear.

Furthermore, the model proposed by KUCZERA (1987), showing that water consumption tends to decrease with the advancing of age of the plantations (Figure 3), also seems to be confirmed by the catchment area monitoring results for the

Itatinga Experimental Station (ESALQ/USP), located in the center of the state of São Paulo, Brazil, which is also part of PROMAB. Under the conditions of that region, the hydrological monitoring data collected throughout 12 consecutive years showed similar results (Figure 7). In this study, during the period prior to the clearcutting indicated in the figure, the catchment area was covered with 50-year-old sprouting from an old plantation of *Eucalyptus saligna*.

Note the annual water yield during this phase appeared to be balanced and in harmony with the annual rainfall variations. The clearcutting of this old forest produced an increase of about 100 mm in water yield in the first year (CAMERA & LIMA, 1999), compared with the average annual runoff for

the entire period prior to cutting. Immediately following the cutting, the catchment area was replanted with *Eucalyptus saligna*, and the figure shows a gradual decrease in runoff during the initial period of rapid growth of the new plantation, very similar to the curve in the model developed by KUCZERA (1987).

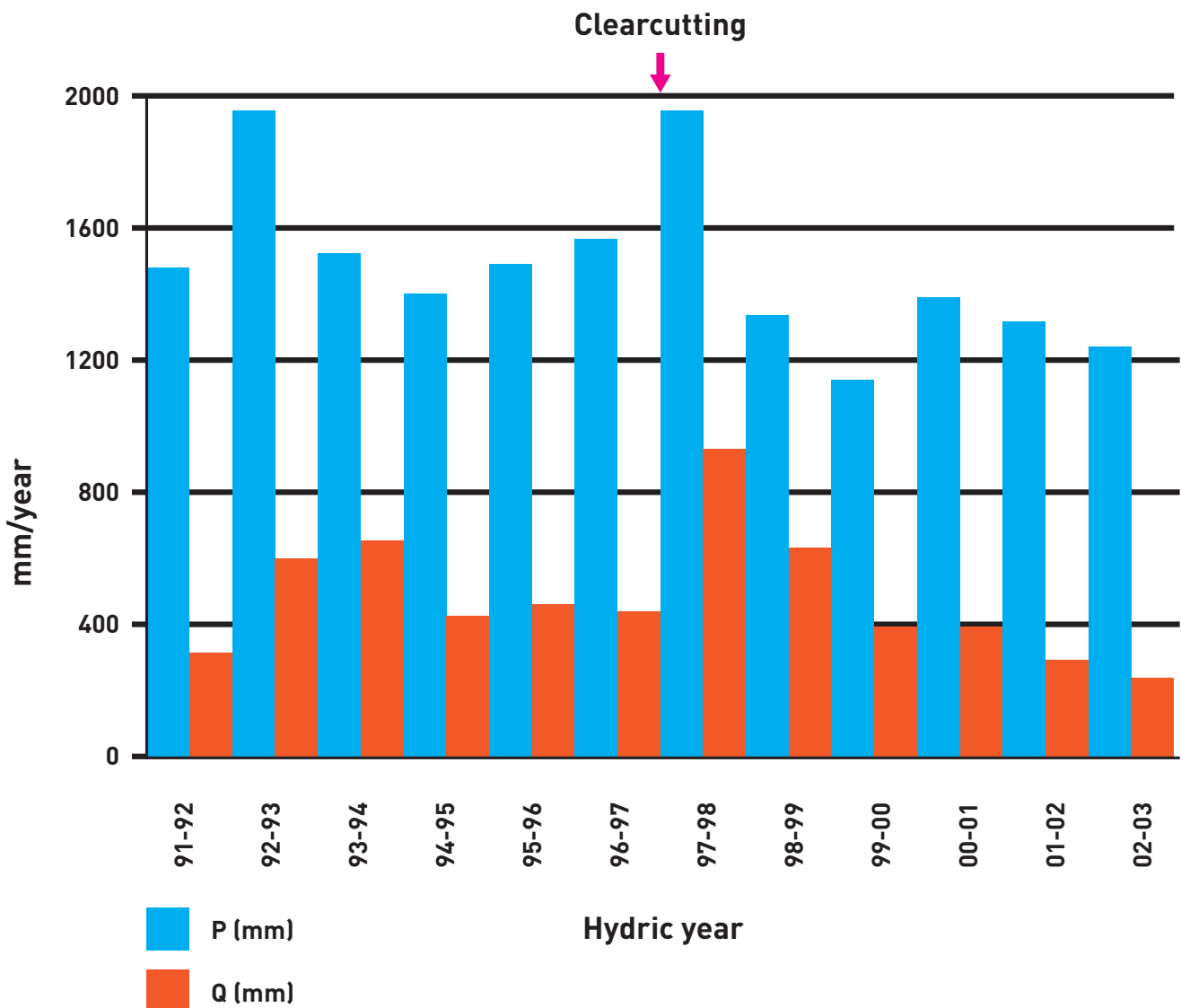


FIGURE 7: HISTORICAL SEQUENCE SHOWING THE RELATIONSHIP BETWEEN THE ANNUAL RUNOFF (Q) AND THE ANNUAL PRECIPITATION (P) OBSERVED IN THE ESALQ/USP EXPERIMENTAL CATCHMENT AREA OF ITATINGA. IN THE PERIOD PRIOR TO THE CLEARCUTTING, THE CATCHMENT AREA WAS COVERED BY A FOREST FORMED BY THE SPROUTING OF AN OLD *EUCALYPTUS SALIGNA* PLANTATION THAT WAS MORE THAN 50 YEARS OLD. SOON AFTER THE CLEARCUTTING THE CATCHMENT AREA WAS REPLANTED WITH *EUCALYPTUS SALIGNA*, WITH A CORRESPONDING IMPACT ON THE PRECIPITATION TO RUNOFF RATIO DURING THE INITIAL GROWTH PHASE OF THE NEW FOREST.

Additionally, global analysis of the accumulated results of the PROMAB experimental catchment areas enabled the preparation of Table 1, in which the monitoring results have been grouped according to the differences between the climatic water surplus of the regions where they are located, as shown in the column on the left. The column on the right shows the results

obtained in the monitoring catchments, in terms of average annual precipitation, runoff and the difference between precipitation and runoff (P-Q), which corresponds to the catchment scale evapotranspiration.

The analysis of Table 1 reveals, first of all, that the impact of forest plantations on water consumption (evapotranspiration)

TABLE 1: COMPARISON OF THE AVERAGE ANNUAL WATER BALANCE RESULTS FOR THE PROMAB EXPERIMENTAL CATCHMENT AREAS, SHOWING THE AVERAGE VALUES OF THE CLIMATIC WATER BALANCE IN THE RESPECTIVE REGIONS WHERE THEY ARE LOCATED, GROUPED ACCORDING TO THE AVERAGE FIGURE FOR THE CLIMATIC WATER SURPLUS IN EACH REGION.

Location	Regional Climate			Experimental Catchment Areas					ΔAV
	P	ETR	EXC	P	Q	(P-Q)	Sp	N	
	(mm/year)								
Eunápolis - BA	1252	1132	120	1379	90	1289	E	3	157
Alagoinhas - BA	1233	1081	151	1104	32	1072	E	11	0
Santa Branca - SP	1239	986	252	1329	145	1184	E	7	198
Capão Bonito - SP	1210	938	271	1237	145	1092	E	2	154
Aguaí - SP	1346	946	399	1317	224	1093	E	5	147
Luiz Antônio - SP	1348	949	399	1226	235	991	E	3	42
Itatinga - SP	1308	918	389	1485	476	1009	E	12	91
Arapoti - PR	1500	1000	500	1475	170	1305	P	2	305
Telêmaco Borba - PR	1500	1000	500	1386	76	1310	P	3	310
Telêmaco Borba - PR	1500	1000	500	1300	145	1155	Na	3	155

P= PRECIPITATION;

ETR = ACTUAL CLIMATIC EVAPOTRANSPIRATION;

EXC = CLIMATIC WATER SURPLUS

(P_Q) = EVAPOTRANSPIRATION OF THE EXPERIMENTAL CATCHMENT AREA

SP = FOREST COVER E = EUCALYPTUS / P = PINE / NA = NATIVE VEGETATION

N = NUMBER OF YEARS OF MONITORING

ΔAV: INCREASE IN "GREEN WATER" FLOW = [(P_Q) - ETR]

ΔAV AVERAGE: BAHIA : 78 / SÃO PAULO :126 / PARANÁ: 257

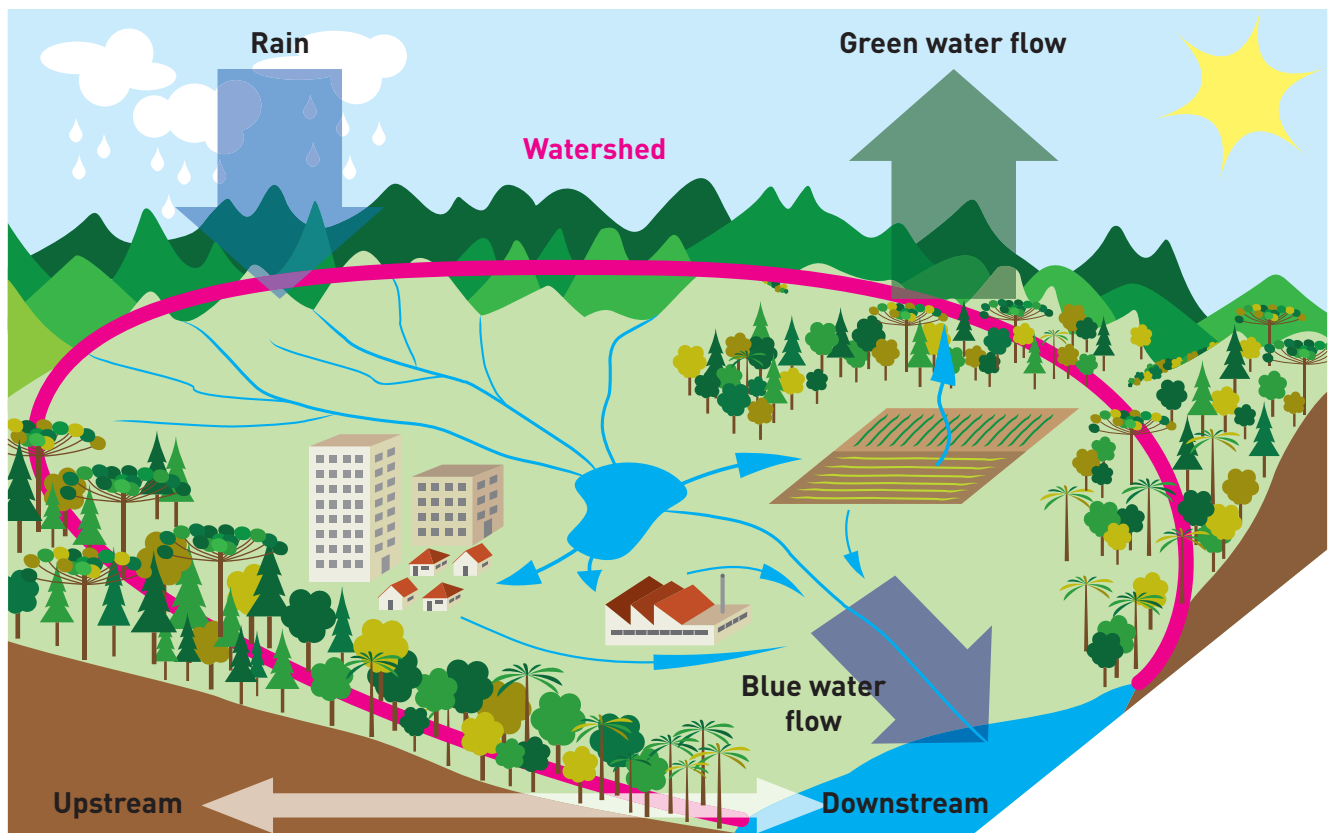
NOTE: REGIONAL CLIMATE DATA WAS OBTAINED FROM THE CLIMATIC WATER BALANCE OF THE RESPECTIVE REGIONS WHERE THE CATCHMENT AREAS ARE LOCATED AND REPRESENTS AN AVERAGE OF 30 YEARS. FOR THE CATCHMENT AREAS IN THE STATE OF PARANÁ (PR), THE CLIMATE DATA WAS EXTRACTED FROM THE CLIMATOLOGICAL MAPS OF IAPAR, 2008.

is not the same in all situations, something that has been emphasized in various publications in world literature reviewing the subject. Indeed, as the table shows, the increase in evapotranspiration in catchment areas containing eucalyptus and pine forest plantations, compared to the actual regional climatic rate of evapotranspiration, is quite variable, ranging from catchment areas where there is hardly any difference to others where this difference can reach about 300 mm per year. These differences, in turn, seem to be related to the climatic condition of natural availability of water. Where the annual precipitation is practically equal to the evapotranspiration rate, there is usually very little water surplus, which prevents the forest plantation from generating a significant increase in evapotranspiration, compared to the

region's average climatic rate, since there is not usually an abundance of available water.

On the other hand, when the annual rainfall is much higher than the average evapotranspiration rate, and also uniformly distributed throughout the year, the climatic water surplus is much greater, resulting in a greater difference between catchment evapotranspiration and the actual average climatic rate of evapotranspiration. And then there are catchment areas situated between these two climatic extremes.

The expression used in Table 1, namely " ΔAV = increase in "green water" flow", was taken from the work of FALKENMARK & FOLKE (2002), whose summary is illustrated in Figure 8.



Júlia Pitti Palácios

FIGURE 8: THE ESSENCE OF INTEGRATED CATCHMENT AREA MANAGEMENT, AS DEVELOPED BY FALKENMARK & FOLKE (2002). WITHIN A GIVEN CATCHMENT AREA, THE DISTRIBUTION OF THE INCOMING RAINFALL CAN OCCUR BY EVAPOTRANSPIRATION ("GREEN WATER" FLOW) OR BY RUNOFF ("BLUE WATER" FLOW). DEPENDING ON THE MANAGEMENT STRATEGY, THE "GREEN WATER" FLOW CAN DRAMATICALLY INCREASES AT THE EXPENSE OF THE "BLUE WATER" FLOW. PLANNING LAND USE TO MAINTAIN A BALANCE BETWEEN THESE TWO FLOWS REPRESENTS A SUSTAINABLE STRATEGY FOR THE CONSERVATION OF WATER RESOURCES.



Considering the catchment area as a strategic unit of forest management planning that incorporates water conservation means that the goal is always to have “blue water”, since this is the surface water that meets not only the human demands but also those of the environment itself, especially in terms of preserving the ecological flow that ensures the quality of the aquatic ecosystem. Therefore, determining strategies for the sustainable management of forest plantations includes, among other things, finding a sustainable balance between the flows of “green water” (water consumption by forest growth) and “blue water” (catchment runoff). Returning to Table 1, as already stated, the increasing in “green water” flow (increased evapotranspiration caused by forest plantations) varies from region to

region. It is imperative, therefore, that a preliminary analysis of the prevailing climatic conditions be taken into account when preparing the forest management plan, in order to define consistent strategies for each situation, with a view to maintaining a balance in the redistribution of incoming rainfall. What is more, the same Table 1 shows that, with the increase in the “green water” flow caused by forest plantations, there is a corresponding reduction in the “blue water” flow, in other words, in the catchment annual water yield. In turn, this reduction seems to occur in different ways, according to what has been found by FARLEY et al. (2005), that is, it varies according to the prevailing percentage relationship between rainfall and runoff. However, considering the results available so far, as

shown in Table 1, there may be a decrease in runoff without it actually disappearing, although this may indeed happen, depending on the combination of inappropriate management strategies, and soil and climate conditions, which reinforces the need for preliminary analysis of the climatic conditions of the water balance when determining the management plan.

This search for a strategy for forest plantation management that maintains a balance of “green water” and “blue water” flows on the catchment area scale has been beautifully summarized in the title of the paper by FALKENMARK & FOLKE (2002), which reads: “The

ethics of socio-hydrological catchment management: towards hydrosolidarity”. This is the keyword to define what the water crisis will increasingly require from all of us: hydrosolidarity, that is, never to eliminate the flow of “blue water” and seeking management strategies that not only keep this flow in balance, but also to try to increase downstream water flow.

This information is of unquestionable practical value, warning us that, ultimately, the control of possible hydrological impacts depends on the application of a sustainable management strategy that takes into account the interactions found in experimental studies.

CONSIDERING THE ENTIRE CATCHMENT AREA, A SUSTAINABLE MANAGEMENT STRATEGY MUST ALWAYS SEEK A BALANCE BETWEEN THE FLOWS OF “GREEN WATER” AND “BLUE WATER” IN STRIVING FOR HYDROSOLIDARITY.



INCORPORATING THE WATER CONSERVATION GOAL INTO MANAGEMENT PRACTICES

AS ALREADY MENTIONED, THE RELATIONSHIP BETWEEN SILVICULTURE AND WATER IS A CONTROVERSIAL AND RECURRENT ISSUE THAT MERITS THE ATTENTION AND CONCERN OF ALL PARTIES: THOSE WHO PLANT AND MANAGE THE FORESTS, RESEARCHERS, SPECIALISTS, ENVIRONMENTALISTS AND SOCIETY IN GENERAL.

Clearly, in view of the accumulated information and research findings worldwide on the subject, this is an issue that involves many other aspects, not merely the question of whether forest plantations dry the soil or not. In fact, this is an environmental problem whose solution or handling should indeed pass the scrutiny of scientific experimentation, but must also take into account all the complexity involved in environmental issues, including the uncertainties inherent in the relationship between the use of natural resources and environmental impacts, the social and cultural aspects involved in the transformation of the landscape and the expansion of forest plantations, the adequate planning of this expansion, especially in terms of preserving the remnants of natural vegetation, the hydrologically sensitive parts of the catchment areas, the structural and functional biodiversity throughout the landscape, the health of the soil and the quality and quantity of the water.

What this controversy calls for, in fact, is not the need to do more research showing that the water consumption by forest plantations differs little or nothing from the consumption by natural forests. This information already exists, although it has not put an end to the controversy. What is really required is a change in the approach of the studies on the relationship between silviculture and water. As shown in Figure 8, water consumption (the "green water" flow) is only part of a bigger problem: what is really happening to our "blue water"? Progress in the study of this problem, for instance, would be to break the question of water consumption down into two factors: HOW MUCH and HOW. How much water is consumed by forest plantations? We have seen that the

WATER CONSERVATION IS A COMPLEX ENVIRONMENTAL PROBLEM, WHICH ENCOMPASSES SOCIAL AND CULTURAL ASPECTS OF THE TRANSFORMATION OF THE LANDSCAPE.

answer to this question already exists – it does not differ very much from the consumption by natural forests – but this is not a satisfactory answer. Now, when we try to find the answer to HOW, the question could be formulated as follows: "Is the water consumption by forest plantations within the capacity of the environment?" In other words, is there enough water to meet this consumption and still ensure the other demands for this precious liquid are met? Or, put it another way, is there enough water to meet the increasing "green water" flow while still maintaining the "blue water" flow? Thus we move forward, not only in the sense of including the social and the cultural aspects of water demand, but also the ecological aspects, because in this way we are also taking into account the need for water to supply the natural processes; what is called the environmental water demand. When a stream dries up it is not only the flow of "blue water" that disappears, but a whole series of related natural processes and ecosystem services, perhaps for ever.

The work of FALKENMARK & FOLKE (2002) indicates an excellent term to define this necessary change in approach to the relationship between silviculture and water: hydrosolidarity. There is nothing wrong in establishing forest plantations, nor in the fact that they





PLANTATION MANAGEMENT PLANNING MUST ENSURE THAT THE REQUIRED WATER DEMAND FOR FOREST GROWTH DOES NOT ELIMINATE THE “BLUE WATER” FLOW, WHICH IS THE FLOW THAT MEETS ALL THE OTHER DEMANDS FOR WATER, INCLUDING THE HUMAN ONES.

need plenty of water. What should be examined, however, is whether this water consumption to supply the forest production is showing hydrosolidary with the other demands for water. Two other expressions used by these authors are very instructive for a better understanding of this issue: the concepts of “green water” and “blue water”, as illustrated in Figure 8. This figure clearly shows, first of all, that the catchment area is the natural scale for the appropriate evaluation of the relationship between silviculture and water. It also shows that rainfall is the natural process of water inflow into the catchment area to meet the demands of society. However, the rainwater may be allocated in two ways: the “green water” flow, representing all the losses by evaporation and plant transpiration, and the “blue water” flow,

representing the surface water. The authors even explain that the expression “catchment management”, in this respect, effectively means rainwater management, not in the sense of controlling this natural process, obviously, but in controlling how we manage this natural inflow of water into the catchment area. We can, for example, direct it only to the “green water” flow, by increasing the water consumed by forest plantations, at the expense of the “blue water” flow. On the other hand, we can plan the management so that the demand for “green water” (which supplies forest production and growth) does not eliminate the “blue water” flow (which meets all other demands for water, including the human ones). This is the great challenge of hydrological sustainability in the management of forest plantations.

Is that not a wonderful suggestion to resolve the apparent paradox surrounding the controversy over water consumption by forest plantations? Studies that are focused only on measurement of the water consumption by eucalyptus or forest plantations deal only with the “green water” flow. But, as previously mentioned, this is only part of the problem. It is also imperative to consider and determine the impact on the “blue water” flow, because that is the water that society and the environment itself depend on. That is why the controversy doesn’t go away, despite the large number of experimental results. Hence the most suitable indicator is the catchment water balance, and not just the evapotranspiration.

Basically, this concern is embedded in the concept of sustainable forest management, especially after the UNCED (United Nations Conference on Environment and Development) meeting held in Rio de Janeiro in 1992. It is a concept that is characterized by certain features that are crucial to resolving this controversy: a) it is a meta-concept, that is, it necessarily involves a change in the approach, in the paradigm; b) as a concept, it seems useless, nebulous and lacking in practicality; c) it must necessarily be evaluated in all its dimensions: economic, ecological, social, cultural, political, etc.; d) it must also necessarily involve different scales of evaluation; and, finally, e) it must be considered not as a criterion, or a set of criteria that define what sustainable management is, but as a goal, a target. This target, in turn, is not a fixed one, but a moving one, since the concept of sustainability is itself dynamic, necessarily reflecting the currently available knowledge of the functioning of biological systems. Interestingly enough, seen from this perspective, the concept turns out to be crystal clear, as it gives a direction to follow, that is, indicates a goal, an objective. So, it can be said that sustainable forest management will always be a process of

perpetual learning, a quest, involving the continual improvement of management practices, both in terms of increasing forest productivity – which is, after all, the ultimate goal of large-scale forest plantations – but particularly in terms of ensuring, at the same time, the permanence of landscape values, which are essential to conserving water and other elements of the environment. In short, forest management, viewed from the point of view of sustainability, has become complex, meaning that we must learn to live with inevitable changes caused by this management and prevent these changes from leading to the degradation of the catchment area.

Consequently, a key factor in the quest for sustainable forest management is monitoring, which should be understood in this context as the process of getting information about the effects of management actions on the environment, so as to be able to make the necessary corrections to the management plan, with a view to its continual improvement. In other words, monitoring must be understood as an essential part of sustainable forest management, as a tool for the ongoing improvement of management practices, as well as to assess whether these management practices are, over time, gradually degrading the soil, altering the nutrient cycle and therefore the productive potential of the soil, or degrading the hydrological functioning of the catchment area. There is also another factor, derived from the natural diversity of the landscape, in terms of climate, soil, geology, geomorphology, vegetation, etc. In each region, all these features and local characteristics will be different, making it necessary to recognize that there will never be a universally applicable prescription.

A fundamental principle embedded in the concept of sustainable forest management, taking into account the concern over soil and water conservation, is the need to

consider the catchment area as the physical basis for the management plan, with a view to implementing sustainable management practices. Therein, such practices must necessarily consider the integration, interconnections and effects of management practices on the soil – in terms of maintaining its productive potential – and water, both in regard to quantity, quality and flow regime, and to maintaining the quality of the aquatic ecosystem, that is, the “blue water”. This objective

of incorporating the water and soil values into the management plan depends on the definition of criteria for the protection of ecosystem services on the catchment scale. These ecosystem services are summarized by FALKENMARK & FOLKE (2002), as: a) physical: protection of the soil surface and infiltration rate. It sounds simple, but is actually essential to water conservation; b) chemical: denitrification, oxygen production, CO₂ absorption, etc.; c) biological: seed dispersal, pollination,



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PROTECTION OF THE SOIL SURFACE IS A KEY PHYSICAL FACTOR IN MAINTAINING THE ECOSYSTEM SERVICES THAT CONSERVE WATER, AS DEMONSTRATED BY THIS IMPRESSIVE PHOTO SHOWING HOW A SIMPLE TWIG WAS ABLE TO PROTECT THE SOIL AGAINST WATER EROSION.



Walter de Paula Lima

A COMMON PRACTICE, THAT OUGHT TO BE ABOLISHED, IS THE OPENING UP OF A TRAIL BORDERING A PERMANENT PRESERVATION AREA (ON THE RIGHT OF THE PICTURE). IN ADDITION TO HINDERING THE CONSERVATION OF THE APP, SINCE THE CONSERVATION OF AN ECOSYSTEM IS NOT FURTHERED BY PHYSICALLY SEPARATING IT FROM ITS SURROUNDINGS, IT ALSO TENDS TO CAUSE THE SILTING OF STREAMS.

biological control of pests and diseases, etc. They are essential to the permanence of processes and conditions that ensure “blue water” stability and quality.

Besides these criteria for the protection of ecosystem services, the plan must also determine a strategy for the protection of landscape elements and spaces that are important to maintaining the resilience of the catchment

area, defined here as its ability to absorb disturbances without losing the stability of its biodiversity, riparian areas, and the integrity of the riparian ecosystem. These landscape elements and spaces not only serve aesthetic and ethical purposes, but especially a functional purpose. That is, their loss would impair the very functionality of the catchment area and the landscape (FALKENMARK & FOLKE, 2002).

Another important principle, which derives naturally when the forest management plan is based on the catchment area, is the matter of the different scales of hydrological sustainability, as illustrated in Figure 9. As you can see, forest management operations normally occur at the Forest Management Unit (FMU). A good forest manager devotes all his knowledge and professional ability to implementing “First Class Silviculture” at each management unit, aimed at increasing forest productivity while minimizing the environmental impacts. This is part of the quest for sustainable management. However, as the figure

shows, environmental impacts may be occurring on other scales, and the “First Class Silviculture” will take the blame. Therefore, this change in the approach also requires a holistic view of management, evolving from a “tunnel vision” that only focuses on the stand to a broader and more systemic view that takes into account and analyzes mesoscale factors that are primarily related to preserving the stability of the catchment area, as well as on a larger scale, which informs about the potential and natural limitations of the environment, especially regarding the natural availability of water.

SCALES OF SUSTAINABILITY

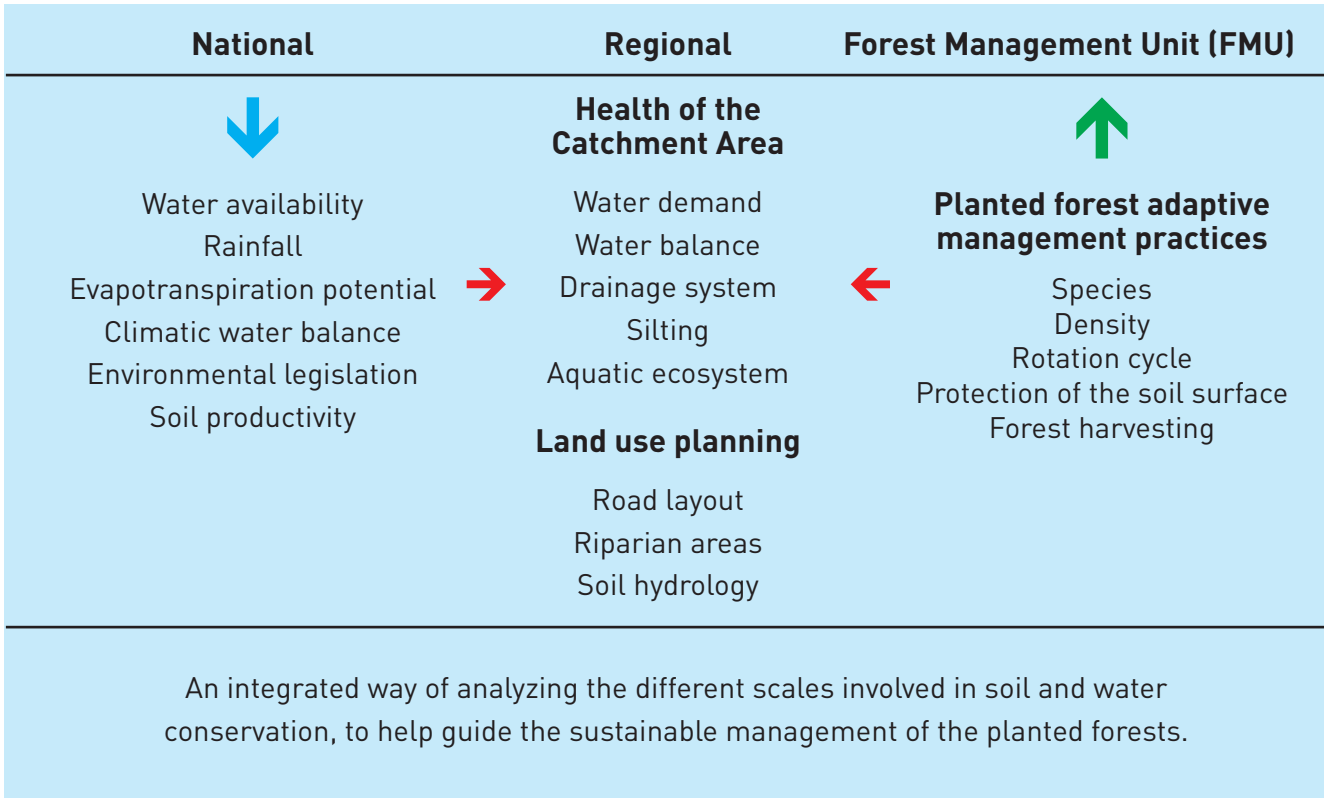


FIGURE 9: AN ILLUSTRATIVE DIAGRAM OF THE DIFFERENT SCALES OF HYDROLOGICAL SUSTAINABILITY. THE IMPLEMENTATION OF MANAGEMENT PRACTICES AT THE FOREST MANAGEMENT UNIT REPRESENTS THE SCALE OF HUMAN ACTIONS AIMED AT FOREST PRODUCTION. THESE ACTIONS MAY EVENTUALLY AFFECT THE WATER RESOURCES. HOWEVER, AS ONE CAN SEE, THERE ARE ALSO NATURAL AND LEGAL IMPOSITIONS INDICATING THE ENVIRONMENTAL LIMITATIONS, ESPECIALLY THE CLIMATIC AVAILABILITY OF WATER. THE SCALE IN THE CENTER, IN TURN, IS THAT OF THE CATCHMENT AREA, WHOSE CONDITIONS, ON THE ONE HAND, REFLECT THE SAME NATURAL CLIMATIC IMPOSITIONS, BUT ON THE OTHER HAND, ALSO REFLECT THE CHANGES IN THE LANDSCAPE CAUSED BY MAN.

CALDER (2007), in his work entitled “Forests and water: ensuring forest benefits outweigh water costs”, used the concept of “green water” and “blue water” borrowed from FALKENMARK & FOLKE (2002) and summarizes very well the need to consistently examine the macroscale of natural water availability, as shown in Figure 10.

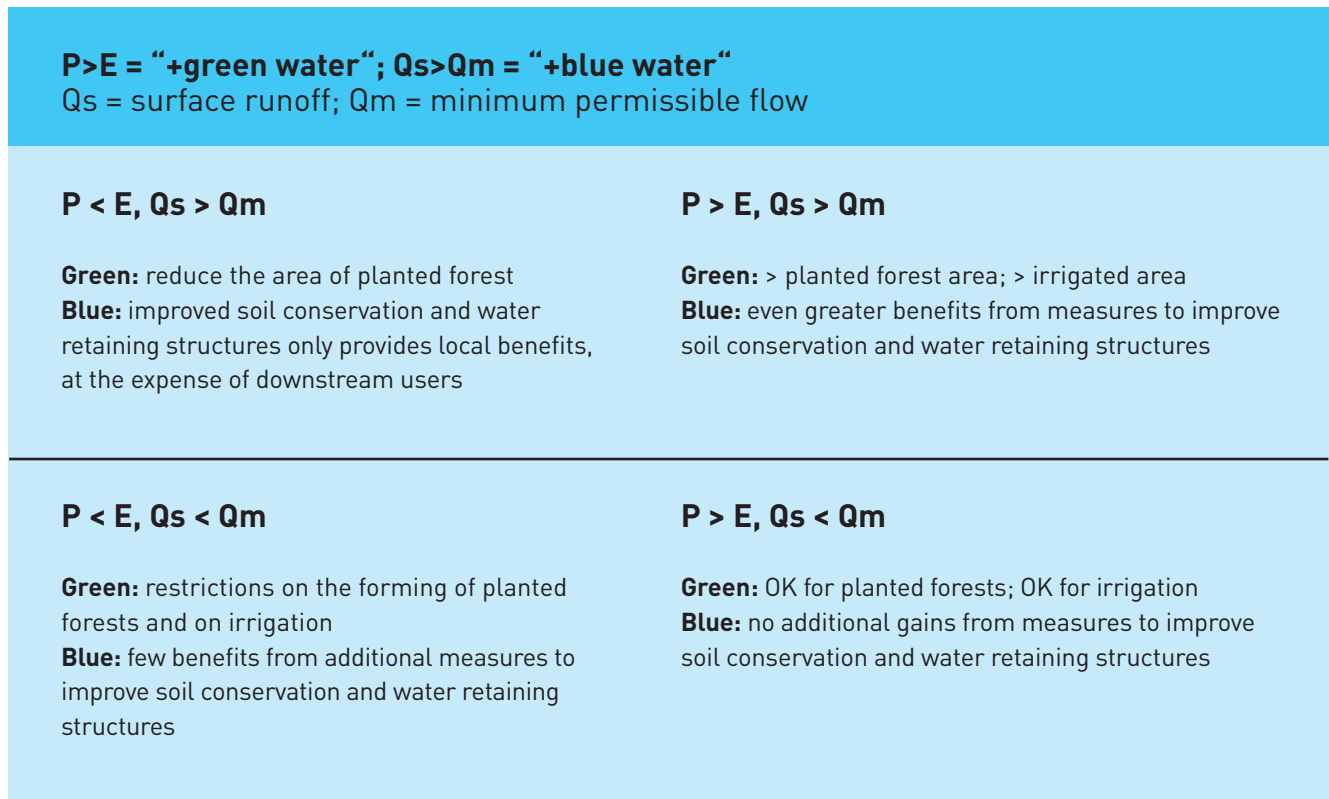


FIGURE 10: QUADRANTS SUGGESTED BY CALDER (2007) FOR THE CONSISTENT ANALYSIS OF NATURAL AVAILABILITY AND LIMITATIONS OF WATER, THAT IDENTIFY FOUR CONDITIONS FOR THESE WATER LIMITATIONS AND POTENTIALITIES WITHIN THE ENVIRONMENT, ON ACCOUNT OF THE RELATIONSHIP BETWEEN PRECIPITATION AND EVAPOTRANSPIRATION, AS WELL AS THAT BETWEEN THE SURFACE FLOW (AVERAGE FLOW) AND THE MINIMUM FLOW ALLOWED. DEPENDING ON THE INTERACTION OF THESE TWO RELATIONSHIPS, THE REGION MAY BE MORE OR LESS RESTRICTIVE FOR FOREST DEVELOPMENT OR ANY OTHER LAND USE ACTIVITY THAT REQUIRES A LARGE AMOUNT OF WATER.

With the purpose of giving an essentially applied character to this concept of monitoring on all the different scales of hydrological sustainability, Table 2 illustrates some already recognized relationships between management practices and the impact on water, based on results and information available in the literature, especially owing to some basic characteristics of a good indicator, with special regard to: cost, easy comprehension by experts and laymen, transparency, cause-and-effect relationship with the management practices.

The criterion that takes into account the cause and effect relationship between forest management practices and water should be emphasized. First, as already stated, it is not expected that forest management activities will affect all chemical, physical and biological water quality parameters. Hence, there is no point in monitoring them all. For the same reason, it is even more important to understand that the purpose of monitoring is not necessarily to know whether the water quality is being changed as a result of management practices. Instead, the monitoring is based on the fact that some management practices can result in changes to certain parameters, which, in this context, function as indicators not of water quality but of the quality of the management practices. And this connotation has a very important practical significance, since it works as a tool for the continual improvement of management practices (adaptive management). On the other hand, it must obviously be taken into account that any increase in the concentration of sediments, nutrients and organic residues in the streams draining the forest management unit may jeopardize the water quality for downstream users, and this social responsibility is also part of the quest for sustainable management.

The monitoring indicators listed in Table 2 should not be mistaken as a guarantee of sustainable management, since sustainable management is only a concept. However, they may contribute to ensure the preservation of environmental quality, taking into account the related environmental factors. And this environmental quality is one of the pillars of the concept of sustainable management. Similarly, the column "Adaptive Management" in this table should not be understood as a prescription for good management practices, but only as conceptual criteria, based on which it is possible to identify mitigating measures aimed at reducing or eliminating the listed potential impacts. Obviously, these criteria must be put into practice in management activities that take into account the peculiarities of each site.

TABLE 2 - CAUSE-AND-EFFECT RELATIONSHIP BETWEEN THE PLANTED FOREST MANAGEMENT AND THE POTENTIAL HYDROLOGICAL IMPACTS, CONSIDERING THE DIFFERENT SCALES, OR LEVELS OF PLANNING, IN WHICH THIS RELATIONSHIP CAN MANIFEST ITSELF, ALONG WITH THE MONITORING INDICATORS AND CONCEPTUAL CRITERIA FOR ADAPTIVE MANAGEMENT, AIMED AT MINIMIZING THESE IMPACTS.

WATER IMPACT	PROBABLE CAUSES	MONITORING INDICATORS	ADAPTIVE MANAGEMENT
Water availability	Deforestation / Reforestation	Regional water balance	<ul style="list-style-type: none"> • Analysis of physical environment conditions; • Spacing; • Clone physiology; • Design of the stands and catchment occupancy rates.
Attributes of the landscape and biodiversity	Large tracts of forest plantations	Ecological zoning	
Catchment degradation	Destruction of riparian ecosystems	Condition of riparian areas	<ul style="list-style-type: none"> • Increase the resilience of the riparian ecosystem: <ul style="list-style-type: none"> - Permanent Preservation Areas vs Riparian areas; - Minimize the crossing of water courses; - Eliminate forest trails bordering Permanent Preservation Areas; - Minimum distance between roads and channels; - Conservationist planting systems; - Low-impact harvesting; - Design of the road network.
	Unsuitable roads	Road system design	
	Soil compaction	Permeation	
	Erosion	Soil conservation practices	
Catchment water balance and flow regime	Forest plantations	Stream flow, precipitation, and water table level	<ul style="list-style-type: none"> • Plantation density per catchment; • Rotation period; • Fertilization timing and methods; • Precision silviculture; • Minimum cultivation; • Clearcutting rate per catchment; • Cycling of nutrients; • Biodiversity; • Soil compaction; • Agroforestry systems; • Forest fires.
Eutrophication	Fertilization, erosion, lack of riparian forest	Concentration of N and P in the stream water	
Silting of water courses	Erosion and sedimentation	Turbidity, suspended sediments	
Loss of nutrients	Erosion and forest clearcutting	Electrical conductivity, catchment biogeochemistry: N, P, K, Ca and Mg	
Organic material	Decomposition of plant residues in water courses	Dissolved oxygen, water color	

The column “Adaptive Management”, in Table 2, can be understood as a suggestion on how to take the catchment area into account (that is, maintaining the health of a catchment area affected by forest management) in the management plan. Some of the measures have already been mentioned in this document. Figure 3, for example, which shows the link between water consumption and the age of the plantation, suggests that working with the issue of rotation age can be a sound line of research, aimed at achieving hydrosolidarity, since harvesting at more advanced ages, within economically sustainable criteria, can help to improve the availability of “blue water” in the catchment areas.

Another measure refers to plantation density. As shown in Figure 11, produced in the work of WHITEHEAD & KELLIHER (1991), the lower density of remaining trees after the thinning of a forest plantation of *Pinus radiata* led to a 200 mm increase in net precipitation, which effectively recharges the soil, indicating that spacing control is a management measure that could be used both as an immediate solution to some established conflict or to establish appropriate strategies in response to natural water limitations that may arise.

As can be deduced, “considering the catchment area in the management plan” involves much more than just drawing up a map of the area identifying the

VARIATION OF THE COMPONENTS OF THE WATER BALANCE IN AN 11-YEAR-OLD PINUS RADIATA STAND IN NEW ZEALAND BEFORE AND AFTER THINNING (WHITEHEAD & KELLIHER, 1991)

Component of the water balance	Before	After
Precipitation (P)	1623 mm (100%)	1623 mm (100%)
Transpiration (Et)	636 mm (39%)	410 mm (25%)
Interceptation (Ei)	268 mm (17%)	195 mm (12%)
Direct evaporation from the soil (Eo)	93 mm (6%)	191 mm (12%)
Real precipitation (PE)	626 mm (38%)	827 mm (51%)
Water balance: $PE = (P - Et - Ei - Eo) \Delta t$		
	Before thinning 754 trees/ha H = 17m IAF = 15.5	After thinning 334 trees/ha H = 21m IAF = 9.0 Canopy = 46%

FIGURE 11: POSSIBILITIES FOR INSERTING SPACING CONTROL AS A HYDROSOLIDARITY BASED FOREST PLANTATION MANAGEMENT STRATEGY IN SITUATIONS OF POSSIBLE WATER USE CONFLICTS (WHITEHEAD & KELLIHER, 1991).

catchment areas, or even trying to turn the stand into a catchment area. On the other hand, neither is it an overly complex task. On the contrary, if a complexity exists, it is only because of the human difficulty of embedding these environmental variables in conventional economic decision-making models in forest management. Nevertheless, it is a difficulty that has to be resolved, sooner or later. As stated by NARASIMHAN (2008), perhaps the most important finding from the accumulated knowledge on the

functioning of the biosphere and the biological systems is that the Earth is finite and its ability to sustain life is critically dependent on the delicate interrelationship between biological systems. Absorbing this lesson and developing sustainable strategies for the management of natural resources and the conservation of water resources is a question of survival – not just one more allowed expense for the purpose of eliminating the hydrological footprint of the management practices.

**FOR THE EFFECTIVE CONSERVATION OF WATER RESOURCES,
RURAL LANDOWNERS MUST HAVE ACCESS TO INFORMATION
TO ENABLE THE IMPLEMENTATION OF SUSTAINABLE
PRACTICES ON THEIR PROPERTY.**

Miriam Prochnow



CONCLUSION



Edlaine Dick

This study sought to make a critical analysis of the relationship between silviculture and water, taking into account what science has already clarified and the inconsistencies involved in this controversy, as well as the lessons that the available information can provide for improving the management practices aimed at water conservation.

From the standpoint of available scientific information, there is evidence that forest cutting increases and reforestation decreases the annual water yield on the catchment area scale. The results are highly variable, however, because these effects derive from the interaction of other factors, especially rainfall regimes and soil conditions. In other words, the relationship between forests and water is sufficiently complex to impede the development of a general theory.

Regarding the hydrological aspects of forest plantations, it seems clear that the issue of water consumption is only a part of a bigger problem, which should be analyzed not only in respect to the quantity of

THE RELATIONSHIP BETWEEN FOREST AND WATER IS TOO COMPLEX FOR A GENERAL THEORY TO BE APPLIED. WE NEED TO ADOPT MANAGEMENT MEASURES TO ENSURE THE CONTINUITY OF ENVIRONMENTAL SERVICES.

consumption, per se, but also in respect to the level of such consumption in relation to the natural availability of water in the region. What is more, in the quest for water conservation, the forest plantations themselves are also only part of the problem. A more systemic approach points towards the implementing of sustainable management strategies that are consistent with the preservation of ecosystem services.

Understanding the hydrological effects of changes in land use and forest management practices is part of the quest for sustainable forest management. In this sense, the catchment area provides a fuller

IN ORDER TO MAINTAIN THE ENVIRONMENTAL SERVICES, IT IS NECESSARY TO CHANGE THE APPROACH OF THE PLANTED FOREST MANAGEMENT, FROM "STAND MANAGEMENT" TO "ECOSYSTEM MANAGEMENT", WHICH DEFINITELY INCORPORATES WATER CONSERVATION INTO THE MANAGEMENT PLANS.

Jean François



CONCLUSION

approach to the problem, emphasizing the need to analyze the distribution of incoming rainwater, both as “green water” flows, representing the losses to evapotranspiration, and the “blue water” flows, representing the concern over the perpetuation of catchment stream flows.

Applying this knowledge to the management of forest plantations represents a change in approach, from the conventional management of the stand to a more holistic ecosystem management, involving a strategic innovation that definitively incorporates water conservation within the management plan, thereby emphasizing the importance of maintaining the hydrological stability of the catchment

areas, as well as the need to analyze the potential hydrological impacts at all scales of sustainability.

Society, in turn, must understand that the water crisis seems to be here to stay, not in the sense that water will run out some day, but because it may be about to become the cause of conflicts. this crisis is by no means simply the result of the expansion of forest plantations, but is due to many alterations in the landscape caused by man. the solution depends not only on science, but on the involvement of the whole of society, which means that there must also be a cultural change, involving an evolution from a democracy based only on individual rights to a democracy embracing environmental responsibilities as well.



Miriam Prochnow

ENVIRONMENTAL CONSERVATION IS THE RESPONSIBILITY OF THE WHOLE OF SOCIETY. ALL SECTORS NEED TO CONTRIBUTE EFFECTIVELY TOWARDS GENUINE SUSTAINABLE DEVELOPMENT.

DOGMAS, IDEOLOGIES AND POINTLESS ARGUMENTS ARE NOT PART OF THE SOLUTION, BUT MERELY RESPONSIBLE FOR THE FALSE NOTION THAT FOREST PLANTATIONS ARE NECESSARILY HARMFUL TO WATER RESOURCES AND FOR PERPETUATING THE MYTH SURROUNDING THE EUCALYPTUS. THEY CAN ALSO LEAD TO MEASURES THAT OFTEN ATTACK THE SYMPTOMS, RATHER THAN THE CAUSES OF WATER RESOURCE DEGRADATION.



IT IS BOTH FEASIBLE AND VIABLE TO INTEGRATE NATIVE FORESTS WITH PLANTED FORESTS AND AGRICULTURAL PRODUCTION IN A SUSTAINABLE MANNER.

REFERENCES

- ANDREASSIAN, Nvart. **Water and forests: from historical controversy to scientific debate.** 2004. *Journal of Hydrology*, 291: 1-27.
- BOSCH, J.M. & HEWLETT, J.D. **A review of catchment experiments to determine the effect of vegetation changes on water yield and evapotranspiration.** 1982. *Journal of Hydrology*, 55: 3-23.
- BROWN, A.E.; ZHANG, L.; MCMAHON, T.A.; WESTERN, A.W.; VERTESSY, R.A. **A review of paired catchment studies for determining changes in water yield resulting from alterations in vegetation.** 2005. *Journal of Hydrology*, 310: 28-61.
- BROWN, A.E.; PODGER, G.M.; DAVIDSON, A.J.; DOWLING, T.I.; ZHANG, L. **Predicting the impact of plantation forestry on water users at local and regional scales. An example for the Murrumbidgee River Basin, Australia.** 2007. *Forest Ecology and Management*, 251: 82-93.
- CALDER, Ian R. **Forests and water: ensuring forest benefits outweigh water costs.** 2007. *Forest Ecology and Management*, 251: 110-120.
- CÂMARA, C.D. & LIMA, W.P. **Corte raso de uma plantação de *Eucalyptus saligna* de 50 anos: impactos sobre o balanço hídrico e a qualidade da água em uma microbacia experimental.** 1999. *Scientia Forestalis*, 56: 41-58.
- FALKENMARK, M. & FOLKE, C. **The ethics of socio-hydrological catchment management: towards hydrosolidarity.** 2002. *Hydrology & Earth System Sciences*, 6 (1): 1-9.
- FARLEY, K.A.; JOBBAGY, E.G.; JACKSON, R.B. **Effects of afforestation on water yield: a global synthesis with implications for policy.** 2005. *Global Change Biology*, 11: 1565-1576.
- HIBBERT, A.R. **Forest treatment effects on water yield.** In: Sopper & Lull (Ed.). *International Symposium on Forest Hydrology.* 1967. Pergamon Press: 527-543.
- JACKSON, R.B.; JOBBAGY, E.G.; AVISSAR, R.; ROY, S.B.; BARRET, D.J.; COOK, C.W.; FARLEY, D.A.; MAITRE, D.C.; MURRAY, B.C. **Trading water for carbon with biological carbon sequestration.** 2005. *Science*, 310: 1944-1947.
- KUCZERA, George. **Prediction of water yield reductions following a bushfire in ash-mixed species eucalypt forest.** 1987. *Journal of Hydrology*, 94: 215-236.
- LANGFORD, K.J. **Changes in yield of water following a bushfire in a forest of *Eucalyptus regnans*.** 1976. *Journal of Hydrology*, 29: 87-114.
- LIMA, W.P.; ZAKIA, M.J.B.; LIBARDI, P.L.; SOUZA FILHO, A.P. **Comparative evapotranspiration of eucalyptus, pine and cerrado vegetation measured by the soil water balance method.** 1990. *IPEF International*, 1: 5-11.
- LIMA, Walter de P. **O eucalipto seca o solo?** 2004. *Boletim Informativo da Sociedade Brasileira de Ciência do Solo*, 29: 13-17.

- **Planted forests and water impacts: cross-scale analysis through hydrological indicators.** 2005. *The International Forestry Review*, 7: 758-764.
- **Efeitos hidrológicos do manejo de florestas plantadas.** In: Lima e Zakia (Ed.). *As Florestas Plantadas e a Água: implementando o conceito da microbacia hidrográfica como unidade de planejamento.* 2006. RiMa Editora and CNPq: 9-28.
- LIMA, W.P. & FONTANA, C.R. **Microbacias Hidrográficas.** 2008. IPEF Annual Report: 13- 17.
- NARASIMHAN, T.N. **Water, law, science.** 2008. *Journal of Hydrology*, 349: 125-138.
- SWANK, W.T. & MINER, N.H. **Conversion of hardwood-covered watersheds to White Pine reduces water yield.** 1968. *Water Resources Research*, 4: 947-954.
- UNITED NATIONS. **Forest and Agriculture Organization (FAO) Global Forest Resources Assessment.** FAO – Food and Forestry Paper 147. Rome(.): 2005.
- VANCLAY, Jerry K. **Managing water use from forest plantations.** 2009. *Forest Ecology and Management*, 257: 385-389.
- VAN DIJK, I.J.M. & KEENAN, R.J. **Planted forests and water in perspective.** 2007. *Forest Ecology and Management*, 251: 1-9.
- VERTESSY, R.A.; WATSON, F.G.R.; O´SULLIVAN, S.K. **Factors determining relations between stand age and catchment water balance in mountain ash forests.** 2001. *Forest Ecology and Management*, 143: 13-26.
- WAGNER, W.; GAWEL, J.; FURUMAI, H.; SOUZA, M.P.; TEIXEIRA, D.; RIOS, L.; OHGAKI, S.; ZEHENDER, J.B.; HEMOND, H.F. **Sustainable watershed management: an international multi-watershed case study.** 2002. *Ambio*, 31: 2-13.
- WHITEHEAD, D. & BEADLE, C.L. **Physiological regulation of productivity and water use in Eucalyptus: a review.** 2004. *Forest Ecology and Management*, 193: 113-140.
- WHITEHEAD, D. & KELLIHER, F.M. **A canopy water balance model for a Pinus radiata stand before and after thinning.** 1991. *Agricultural and Forest Meteorology*, 55: 109-126.
- ZALEWSKI, Maciej. **Ecohydrology – the scientific background to use ecosystem properties as management tools toward sustainability of water resources.** 2000. *Ecological Engineering*, 16: 1-8.
- ZHANG, L.; DAWES, W.R.; WALKER, G.R. **Response of mean annual evapotranspiration to vegetation changes at catchment scale.** 2001. *Water Resources Research*, 37: 701-708.





THE BRAZILIAN FORESTS DIALOGUE

The Brazilian Forests Dialogue is an independent initiative that facilitates the interaction between representatives from forest-based companies and socio-environmental organizations. Established in Brazil in 2005, it aims to develop a common vision and agenda between these sectors so as to promote effective actions associated to forests production, widening the scale of efforts for conservation and restoration of the environment, generating benefits to the participants of the Dialogue and to society in general.

Initially created focusing on the Atlantic Forest, one of the most biodiverse and threatened biomes on the planet, the initiative has expanded to incorporate, more recently, regions from the Pampa and Cerrado biomes.

Priority topics:

- Tree farming programs, as a development and environmental conservation vector.
- Territorial planning, as an opportunity to agree land use and occupation on the landscape scale.
- The relation between intensive managed planted forests (IMPF), water and biodiversity.
- Private protected areas, as an essential factor for the conservation.

The Brazilian Forests Dialogue seeks to: maintain and consolidate a space for proactive dialogue between the nonprofit sector and the forest-based companies; generate tangible large-scale field results for the conservation of natural resources; contribute to the improvement and quality of human life, through better relations between society and natural resources; and propose and influence the adoption of public policies that promote the protection and sustainability of natural resources.

Currently, there are approximately 360 participants in the Brazilian Forests Dialogue, including a National Forum, a Coordination Council, an Executive Secretariat and seven Regional Forums.

National Forum

Celulose Nipo-Brasileira - Cenibra • Fibria • Klabin • Masisa • Norske Skog PISA • Rigesa Celulose Papel e Embalagens • Stora Enso • Suzano Papel e Celulose • Veracel Celulose • Laboratório de Ecologia e Restauração Florestal - LERF • Embrapa Florestas • Instituto de Pesquisas e Estudos Florestais - IPEF • Associação Brasileira de Celulose e Papel - Bracelpa • Sociedade Brasileira de Silvicultura - SBS • Sociedade Brasileira de Engenheiros Florestais - SBEF.

Associação Mineira de Defesa do Ambiente - Amda • Associação em Defesa do Rio Paraná, Afluentes e Mata Ciliar - Apoena • Associação de Preservação do Meio Ambiente e da Vida - Apremavi • CI-Brasil • Instituto Ecoal para a Cidadania • Associação Flora Brasil • Instituto Floresta Viva • Fundação Biodiversitas • Fundação SOS Mata Atlântica • Instituto de Manejo e Certificação Florestal e Agrícola - Imaflo • Instituto BioAtlântica - IBio • Instituto Ecofuturo • Instituto de Pesquisas Ecológicas - Ipê • Instituto de Pesquisas da Mata Atlântica - Ipema • Rede de ONGs da Mata Atlântica - RMA • Reserva da Biosfera da Mata Atlântica - RBMA • Sociedade de Pesquisa em Vida Selvagem e Educação Ambiental - SPVS • The Nature Conservancy - TNC • WWF-Brasil.

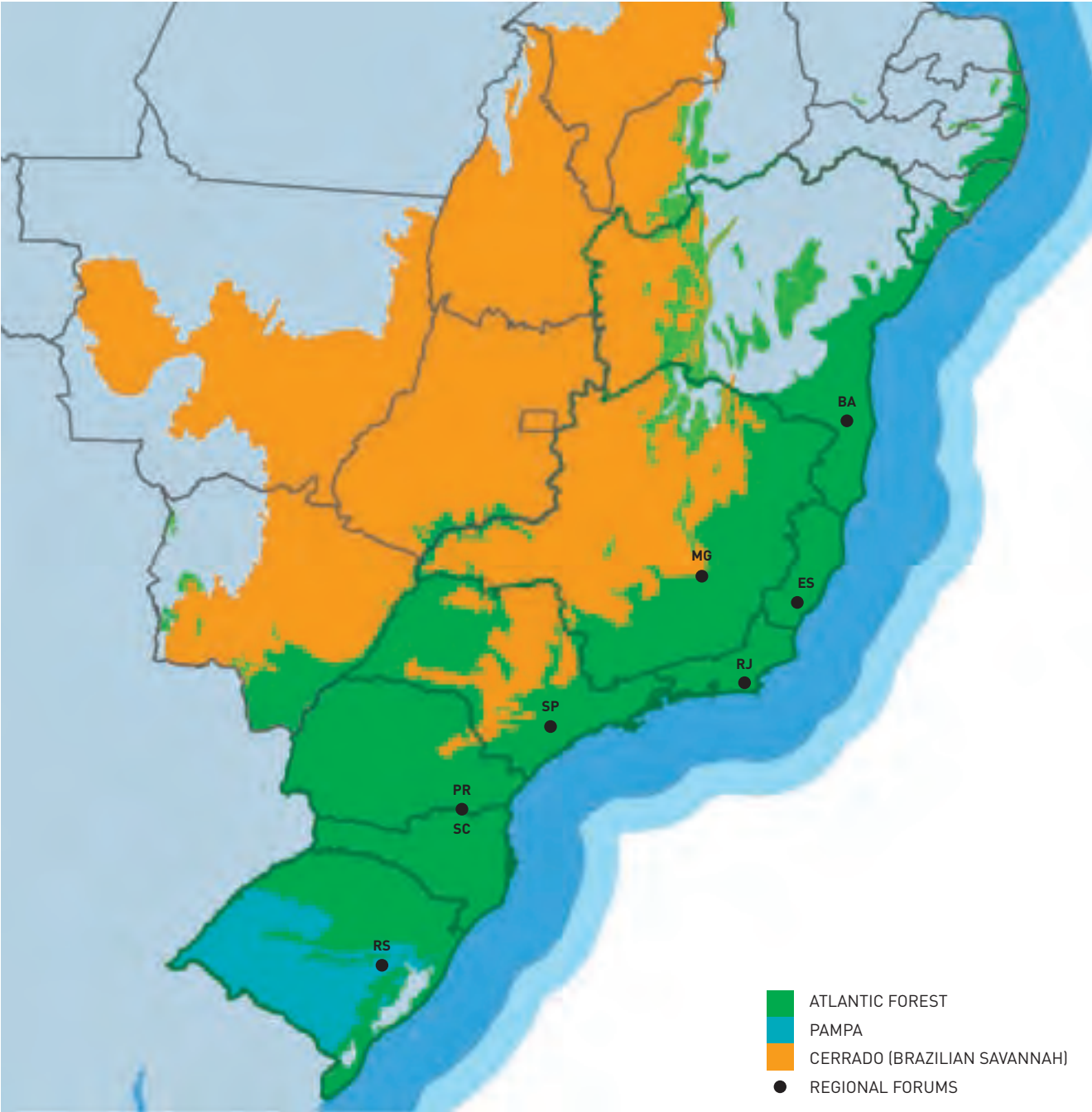
Coordination Council

Cenibra • Fibria • Klabin • Rigesa • Suzano • Amda • Apremavi • Ecosolidário • IBio • TNC

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THE REGIONAL FORUMS

Each Regional Forum has a specific discussion agenda, considering local specificities and needs.

SOUTH AND EXTREME SOUTH OF BAHIA FORESTS FORUM

FORUMBA@DIALOGOFLORESTAL.ORG.BR

Created in 2005, it has developed guidelines for the tree farming programs developed by the participating companies. Subsequently also adopted by the National Forum, these guidelines serve as reference for other forums. The compliance with them by tree farmers and companies that operate in the region was assessed by an independent audit, concluded in 2010. The forum also gives priority to two other topics: territorial planning and independent monitoring of socio-environmental impacts from forestry.

RIO GRANDE DO SUL FORESTS FORUM

FORUMRS@DIALOGOFLORESTAL.ORG.BR

Established in 2007, its primary challenge is to discuss the expansion of IMPF in the Pampa biome under rules and zoning that comply with the law, and promote biodiversity conservation. Its priority theme is the relation between water and planted forests. It also works with protected areas.

SÃO PAULO FORESTS FORUM

FORUMSP@DIALOGOFLORESTAL.ORG.BR

Operating since 2008, its priorities are: landscape planning; socio-environmental management; tree farming programs; conservation in private areas; water, forest and biodiversity; and public policies. It is currently discussing how to effectively support the implementation of the Biodiversity Corridor of the the Paraíba do Sul Valley Project.

ESPÍRITO SANTO FORESTS FORUM

FORUMES@DIALOGOFLORESTAL.ORG.BR

Its first meeting was held in September 2008, and it has defined that one of the chief themes in the State is the tree farming programs developed by the companies. The

forum will start a diagnosis on forest plantations in two communities in the municipality of Santa Teresa. The formation of corridors in the North of the State is also being discussed.

MINAS GERAIS FORESTS FORUM

FORUMMG@DIALOGOFLORESTAL.ORG.BR

The first meetings were held in 2008, with the drafting of the Manifesto in Support of the Production and Use of Planted Forests, with Environmental, Social and Economic Responsibility. Its main action points are being discussed involving wood and firewood use and the supply of coal to metallurgical and pig iron plants, and biodiversity conservation in forest mosaics. Its work is centered in the Atlantic Forest and Cerrado (savannah).

RIO DE JANEIRO FORESTS FORUM

FORUMRJ@DIALOGOFLORESTAL.ORG.BR

Operating since 2008, it was created in anticipation of the impending expansion of forestry in the state of Rio de Janeiro. It has been a privileged forum for the exchange of information between the private initiative, public sector, academia, and civil society. Among its results figures the State Decree that regulates forestry in small and medium-sized properties in the State. The forum currently works to support the state government in establishing a program to enforce the implementation of private protected areas and the forest restoration required by law.

PARANÁ AND SANTA CATARINA FORESTS FORUM

FORUMPRSC@DIALOGOFLORESTAL.ORG.BR

This forum is operating since 2008. It has established two working groups. The Pilot Project group focuses on landscape planning and the Tree Farming Programs group gives priority to the adoption of criteria for sustainable development by companies. The forum has already selected a geographic area to develop a landscape planning pilot project, and has initiated debates on effective actions to be implemented in the region.





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