Tropical forests in a changing world

Prof. dr Pieter A. Zuidema

Inaugural lecture upon taking up the post of Personal Professor of Tropical forest ecology at Wageningen University on 10 September 2015

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Esteemed Rector Magnificus, dear colleagues, family, friends, ladies and gentlemen. Welcome.

How many fields of tropical forest are lost per minute? This is the question I usually get. And this question was asked to me during my first radio interview as a professor in tropical forest ecology. The interview took place during the World Cup in Brazil in 2014 and the occasion was the match played in Manaus, an immense city surrounded by Amazonian forest. So, football fields per minute was not a surprising unit. For those of you who are desperate to hear this number: it's 15-19 football fields per minute (depending on the size of the football field). That means 750 during this lecture, plus 1500 during the reception afterwards if you stay until the end.

This focus on forest loss is illustrative for how we see tropical forests: ancient and mysterious jungles that are demolished by evil powers (Figure 1). We keep telling this story of drama and doom, of loss and extinction. We are seemingly attracted to a pessimistic view on the fate of tropical forests. I think this a typical case of 'somberlust', the desire to be pessimistic. The term somberlust was coined by René Gude, an inspirational and popular Dutch philosopher [1]. He publicly warned against somberlust – using a small bell – a fight that has inspired me.
Let me stress that I am not denying that tropical deforestation is a big and frustrating problem. But we should put less emphasis on the problem and more on possible solutions. Scientists can play an important role by finding out to what extent remaining tropical forests are still able to deliver beautiful products, maintain their biological diversity and contribute to the livelihoods of many millions of people. It is my ambition to contribute to that role.

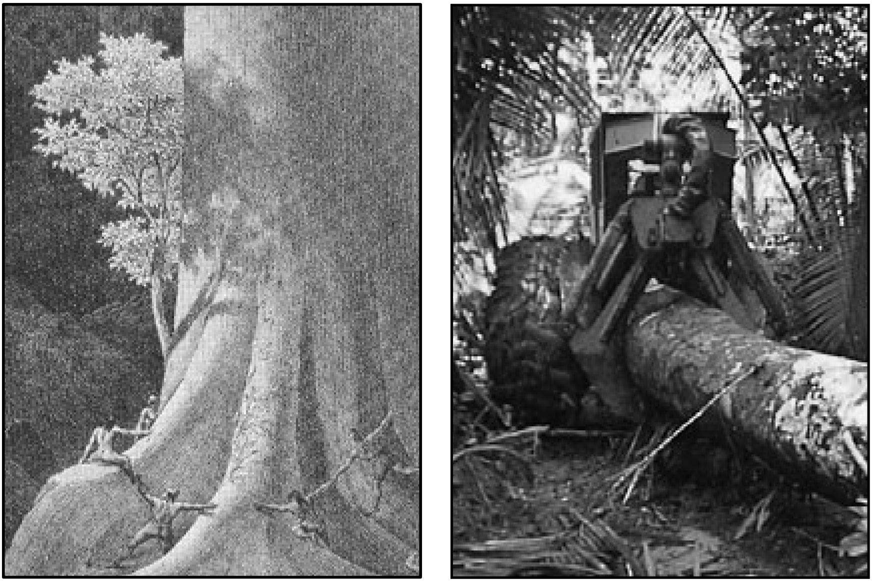

Figure 1. How tropical forests are often seen: ancient and mysterious jungles (left) that are demolished by evil powers (right). Left: detail of picture in Flora Brasiliensis by Karl Friedrich Philipp von Martius (1840); Right: skidder moving the stem of a felled tree in a forest in Guyana (around 2000).

In this lecture, I will basically answer three simple questions: Why? What? And how? Why do I study the effects of global change on tropical forests? What research have I done so far and will I do the coming years? And how do I conduct these studies? Please note that when I talk about "I" in this lecture, this of course means "we": PhD students and post-docs whom I supervise and many colleagues with whom I collaborate.

There are two intermezzi during the lecture, during which I would like to share my thoughts and worries on academic work in general. These intermezzi are moments of reflection, and who knows, perhaps they trigger ideas for discussions during the reception.

Why study the effects of global change on tropical forests?

So, why is it important to study tropical forests? There are plenty of reasons. Let me start with the personal ones. I was a World Wildlife Fund ranger as a kid and collected money to save the Sumatra rhino. At high school, I did a project on tropical rainforests. When leafing through the project report some time ago, I was amazed to see that as a teenager I had already formulated one of my future research questions: how will tropical forests respond to the rise of CO_2 in the atmosphere?

My first real-life experience with a tropical forest was at the age of 22, when I did fieldwork in remote areas in the Bolivian Amazon. I was thrilled by the overwhelming diversity of tree species, the complexity of this ecosystem and by the mindboggling question how tiny seedlings could become forest giants of 50 m tall. And I was completely unaware that during this trip the seed of inspiration was planted and I would study the ecology of tropical forests for the next 23 years.

What other reasons to study tropical forests? Well, they harbour 50% of the World's species, on just 10% of the Earth's land surface. A recent study estimated that there are over 50 thousand tree species in tropical forests [2]. Plus all the birds, mammals, other plants and insects. In addition, tropical forests are responsible for a third of the global production of sugars by photosynthesis. And they contain a quarter of the carbon stocks in ecosystems on land – mainly in big trees [3]. This makes these forests an important component of the global carbon cycle. This role is also shown by the fact that tropical deforestation accounts for 10-15% of the global emission of greenhouse gasses [4].

In addition to these natural values, tropical forests also have important productive and supportive functions. They are of direct importance for the wellbeing and income of five hundred million people living in or close to tropical forests [5]. Natural tropical forests yield 240 million m^3 of valuable timber annually worth over 10 billion EUR [6, 7]. We use this timber for window frames, water works, furniture and flooring. And these forests produce an enormous variety of delicious and beautiful non-timber products, including 'emping', açai juice and Brazil nuts that are sold in your local supermarket.

So, what is changing in these forests? I study the effect of three important changes: fragmentation, exploitation and climate change. Fragmentation is the process that reduces large areas of tropical forests to small islands of forest. Conversion of forests to soybean, oil palm and tree plantations and small-scale agricultural fields has caused many tropical landscapes to become mosaics of different land uses, in which forests are left as islands. About half of the remaining tropical forests is fragmented [8].

The second major change in tropical forests is harvesting of timber and other products. In a third of the total area of tropical forests timber exploitation is taking place [9]. An area 100 times that of the Netherlands. Logging in tropical forests implies that only a small fraction of trees are felled. This movie shows how this is done [10]. Felling trees always causes damage to other trees, but this damage can be minimized and the forest still remains afterwards [11]. Exploitation of timber and other products changes tropical forests in complex ways, sometimes visible, sometimes not.

And finally, just like other ecosystems, tropical forests are experiencing the effects of climatic and atmospheric changes. Air temperature in the tropics has risen by 0.1ºC per decade since the 1950s and nutrient deposition has increased substantially [12]. As in all ecosystems worldwide CO_2 levels have increased by 40% since the onset of the Industrial Revolution in 1850. And until the end of this century, tropical forests will likely experience additional warming by 3-6°C and a 50-150% increase in CO_2 concentration [12].

I study the effect of these three changes on tropical forests. In a minute I will tell you about research results and plans, but before that, it's time for our first intermezzo.

Intermezzo 1: The swinging pendulum of scientific practice
During the 20 years that I have worked in the academic world, scientific research has strongly changed (Figure 2). The slow-moving pendulum of scientific practice has made a big swing. But has it swung too far?

At the time I started my PhD study, limited attention was given to delivering study results. Many researchers did not publish the results of their studies. Valuable knowledge was often lost. This has radically changed, and now the number of publications is an important way to evaluate the success of scientists. Science has become production-driven. Publication pressure has caused an increase in the number of co-authors of scientific publications in the field of ecology [13]. It is not uncommon to find ecological publications with more than 100 co-authors these days. But then: what is the maximum number of persons that can call themselves 'author' of a publication? Should scientists who deliver data always be co-author? And how does such data co-authorship relate to the increasing pressure to make data publicly available? It would be wise to reassess what authorship of scientific publications actually entails [13].
Over the past 20 years, individual scientists became more important than the research groups to which they belong. Personal funding, personal scores, personal

Figure 2. The pendulum of scientific practice has made a big swing over the past 20 years. There is an increased focus on production, a larger role for individual scientists and the windows in the ivory tower of science have gradually opened.

professorships. Having profited from this development myself, I tend to see the positive side: personal attention can stimulate development, offer opportunities and increase mobility of scientists between universities. But the risk is that this leads to competition between colleagues instead of collaboration. And another risk is that past successes increase the chances to get funding, making it harder for somewhat less successful or younger scientists to get their research plans funded. Luckily, the important role of research groups at Dutch universities prevents a dominance of individualism and I am very glad with the intensive collaboration within the research group to which I belong.

A third development is that the windows of the ivory tower of science have gradually opened. Increasingly, results of scientific research become available to the general public. For instance, I make my publications and research data publicly accessible as much as possible. There is also more influence of society on science. Science funding organizations pay more attention to societal relevance and research questions can even be formulated by the general public, as in the new Science Agenda [14]. But if potential societal relevance or economic gains are an important selection criterion for science funding, it may become hard to fund curiosity-driven research. Curiosity, the wish to understand how things work, is the engine of scientific development and an important motivation for many scientists, including myself. And curiosity-driven research allows chance and serendipity to play a role. Loosing curiosity-driven research would cause tremendous damage.

What do I study and what are my plans?

We get to the 'what' question. What are the results of my research so far on the three themes I mentioned earlier. What are the gaps in knowledge? And what are my plans?

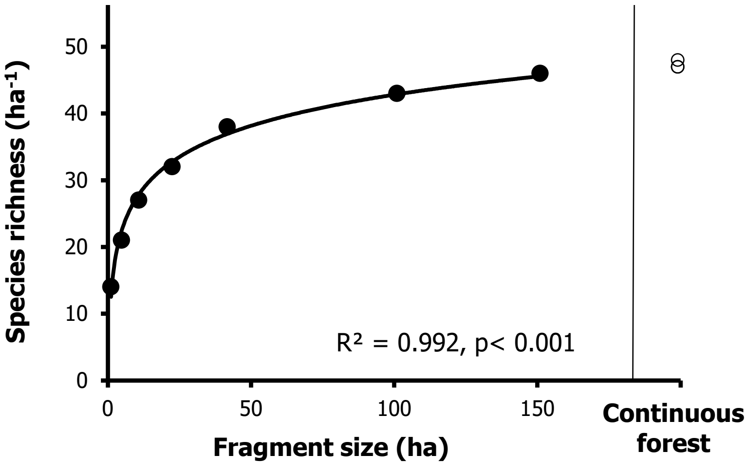

Figure 3. Larger pieces (fragments) of forests in Vietnam contain more tree species per unit area (species richness). The good news is that forest fragments of 100 ha (1 km^2, equivalent to 140 football fields) contain as many tree species as large areas of forest (continuous forest) [16].

Let me start with the topic of my first scientific publication, back in 1996: the effects of **forest fragmentation** [15]. When a large area of forest is cut up in pieces, this increases the proportion of forest that is close to a forest edge. In these forest edges, temperature is higher, more light penetrates and the air is drier [15]. These conditions favour fast-growing tree species, which outcompete tree species that are adapted to shaded conditions. In smaller fragments, the proportion of forest edge is larger, and the number of species is therefore expected to be smaller. This is exactly what my PhD student Ha Van Tiep found in Vietnam and what you can see in Figure 3: fewer tree species in small forest compared to larger patches [16]. But there is also a positive result in this graph. The somewhat larger pieces of forest – of about 100 ha, or 140 football fields – can be as rich as a protected, large forest.

Now, the problem is that part of the species that you can find in fragments at this moment may go extinct because their populations are small. This is called the "extinction debt": species that are present at this moment, but for which extinction is likely [17]. A first analysis for these Vietnamese forest fragments suggests that the problem of extinction debt is likely restricted to the smallest forest fragments [16]. The survival of tree populations in forest fragments also depends on the genetic mixing between populations, so the exchange of pollen or seeds between fragments.

Figure 4. Examples of wildlife in a logging concession in the department of Santa Cruz, Bolivia. Left: a puma; right: a tapir. Pictures made by the trail camera of Peter van der Sleen.

As you can see, the effects of forest fragmentation are very complex [15, 18]. A major research challenge is to find out what part of the rich diversity of tropical forests can be conserved in fragmented landscapes, and under what conditions. This requires a sound understanding of the factors that determine the survival of individual species. With my research group, I plan to generate such knowledge through ecological, genetic and demographic studies in Vietnam, Laos and China.

The second theme, **sustainable exploitation of tropical forests** is very dear to my heart. My first tropical fieldwork was about sustainable harvesting of Brazil nuts. Sustainable forest management is hard to achieve in practice, but luckily there are many encouraging examples through forest certification, timber trade regulations and bans on the import of illegal tropical timber [9].

Big trees that are felled in tropical forests hit the forest floor with brutal force, but what happens afterwards? Can species of animals and plants survive in forests that are selectively logged? Well, the pictures in Figure 4 show that this is the case: the tapir and puma walked in a logged forest in Bolivia where our former PhD student Peter van der Sleen had installed an automatic camera.

A more scientific answer is in the graph in Figure 5a that we assembled based on 100 scientific studies: you see the percentage of species that is retained in logged tropical forests, compared to unlogged forests, for four groups of species. For plants, insects and mammals, there is no statistical difference between the number of species in logged and undisturbed forests, but in birds 15% of the species are lost [9]. The reason that logged forests harbour many species is that the physical structure of the forest is conserved. But when logging operations are unnecessarily damaging to the forest or intensive hunting takes place, this graph looks differently [19].

The other positive finding is that selectively logged tropical forests retain a large share of their original biomass and carbon, as you can see in Figure 5b. They also regain biomass quickly after logging and logged tropical forests may limit the speed of global warming by sequestering CO_2 [11, 20]. How much selectively logged forests can contribute to this, depends on the pace of forest recovery after exploitation, but also on the lifetime of the wooden products obtained from the forest [21]. This is the research topic of my PhD student Federico Alice, and it is a very timely topic. Sustainable management of tropical forests will likely be included in a new climate treaty that is hopefully reached at the international conference in Paris in December 2015 [22].

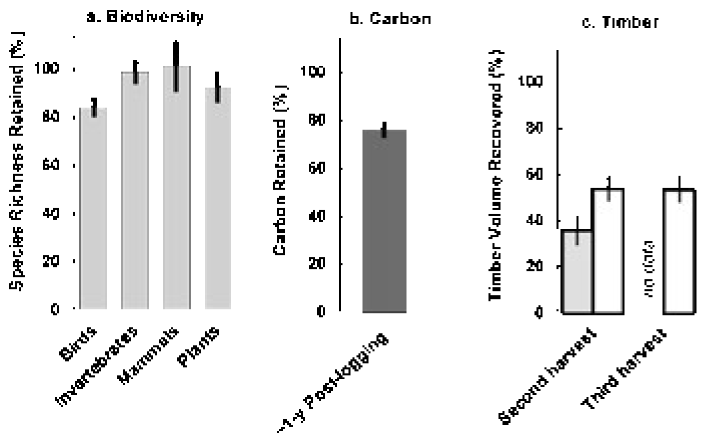

Figure 5. What is retained in tropical forests where timber exploitation has taken place? These graphs show the percentage of species retained compared to undisturbed forest (a), the percentage of carbon retained just after logging, compared to pre-logging (b) and the percentage of timber volume that has regrown at the time of second or third harvest (c). In graph c, the gray bars show the timber recovery if the same species are exploited and the white bars show the recovery if a different mix of species is exploited at second and third harvest [9].

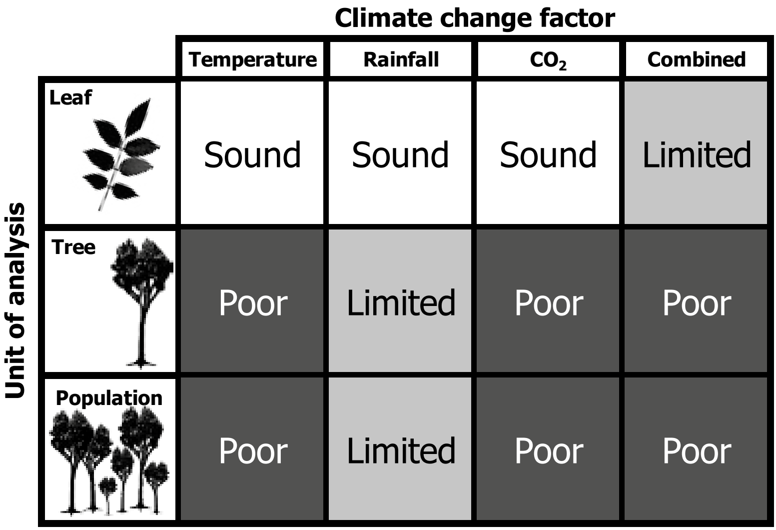

Figure 6. What is known about the effects of climatic changes on leaves, trees and populations of trees in tropical forests? This scheme shows that effects on individual leaves are well understood, but this is not the case for entire trees or populations of trees. Figure adapted from reference [29].

The not so good news is that the exploitation of timber and other forest products is often not sustainable. That is: the current levels of harvesting cannot be maintained in the future [9]. For timber, the loggers returning to the forest after 20-30 years for the second harvest will only find 30-60% of the timber volume ready for felling compared to the first round, as is shown in Figure 5c. For the so called non-timber forest products, the sustainability varies a lot. For frankincense, the resin that is harvested from trees in the dry forests of Ethiopia and used in churches and perfumes, only 10% of the current production is available in 2060 [23]. And the amount of palm heart available in 2060 in Colombia is 20% of what can be harvested now [24]. Brazil nuts are a hopeful case, as I expect their productivity to be fully maintained for the next 50 years [25].

For scientists, foresters and conservationists, the challenge is to identify conditions that allow sustained production of timber and other products. The coming years, I will continue to study these conditions for a variety of products in various countries.

We now turn to **climate change**. The two most important climatic and atmospheric changes that tropical forests will experience are increased temperature and CO_2 rise [12]. If trees respond positively to these changes by growing faster, forests will

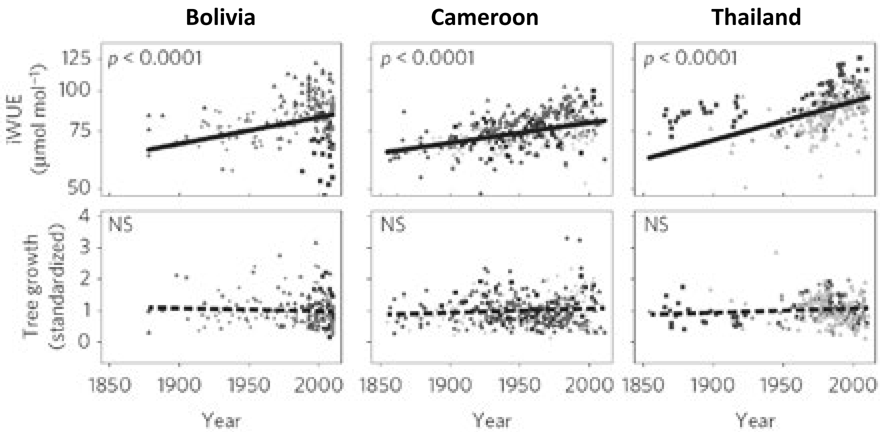

Figure 7. What is the effect of the historical CO_2 rise on tropical trees? Upper graphs: CO_2 rise increased the efficiency of water use (iWUE, intrinsic water use efficiency) of large tropical trees in Bolivia, Cameroon and Thailand. So, for every drop of water that these trees transpired, the rate of photosynthesis was higher in recent years than 150 years ago. Lower graphs: CO_2 rise did not lead to a significant stimulation of the growth of large tropical trees in Bolivia, Cameroon and Thailand. Figure from reference [30].

become 'heavier' and sequester CO_2. As a result, CO_2 rise will be somewhat dampened and the pace of warming may be reduced [26]. But if these climatic changes lead to extra tree death and forest dieback, the reverse happens [26]. And this response may speed up climate change, as a lot of CO_2 is released [27].

Extra CO_2 stimulates tree photosynthesis, reduces water loss and may thus enhance tree growth [28]. This is the so called 'CO_2 fertilization' effect. Warming stimulates tree photosynthesis up to some level but also increases water use and increases the costs of maintaining a functioning tree, respiration costs. So, what is known about the effects of CO_2 and temperature on tropical forests? With my research team, we tried to summarize graphically (Figure 6). The conclusion is that we know quite well how CO_2 and temperature influence the activity of the leaves of trees. But effects on entire trees or their populations are poorly understood [29].

So, there is a lot to do, and with my team we did a little bit during the last years. We made use of the man-made, worldwide experiment of gradual CO_2 rise since the start of the Industrial Revolution. To this end, PhD students Peter Groenendijk, Mart Vlam and Peter van der Sleen measured 100,000 tree rings and did 2,500 chemical analyses of wood samples. We studied these trees in Bolivia, Cameroon and Thailand. We found that CO_2 rise led to a strong increase in the efficiency of water use, as you can see in the upper graphs in Figure 7 [30]. This means that for every drop of water that trees transpire, the rate of photosynthesis was higher in recent years than 150 years ago. This effect of CO_2 rise was expected as extra CO_2 stimulates photosynthesis and reduces water loss of trees.

We then expected that these changes in the physiology of trees would have led to a stimulation of tree growth. So, higher growth rates now compared to 150 years ago. To our surprise we found no significant increase in growth, as you can see in the lower graphs in Figure 7 [30, 31]. This result contrasts findings of increased growth from studies using different methods [32, 33]. Explaining these differences is difficult because the methods are so different, but still, the discrepancy is puzzling.

So, why did 150 years of gradual CO_2 rise not stimulate tree growth in this study? This is an unresolved but important issue. One possible explanation is that our idea of what determines tree growth should be partially redefined. Perhaps tree growth is not only limited by the supply of sugars from photosynthesis but also partially by conditions that allow wood growth to occur [34, 35]. Let me give an example to illustrate this. Imagine that you own a cookie factory. The amount of cookies you produce is not determined by the amount of sugar you buy from sugar refineries, but mostly by the demand from consumers. Of course, the amount of sugar can limit your cookie production – without sugar no cookies. But clearly, it would not be wise to make the cookie production only dependent on sugar supply. You would end up with piles of cookies that are not sold.

The vegetation models used by scientists and the IPCC to predict the effect of climate change on global vegetation depart from the supply model of cookie production. This is called 'source-limited growth', as is shown in the left scheme in Figure 8. But as with real-life cookie factories, tree growth may actually be limited by the 'demand' from the parts of the tree that are growing, so the tissues in leaves, roots and wood. This is called sink-limited growth and is shown in the right scheme of Figure 8. Now, the difference between the left and right scheme is not trivial. In the source-based system (left), tree growth would be strongly stimulated by CO_2; in the sink-based system (right), tree growth is much less sensitive to CO_2 rise.

I plan to perform detailed studies on tropical wood formation to find out to what extent tree growth is sink- and source-driven. We can then get more realistic predictions of the effects of future CO_2 rise and warming on tropical forests. If sink-limited growth – the right scheme – is important, CO_2 rise will not be able to compensate for the negative effects of warming. In that case, tropical forests are more vulnerable to climate change than currently assumed [27, 36].
It is high time for a second intermezzo, on creativity in science.

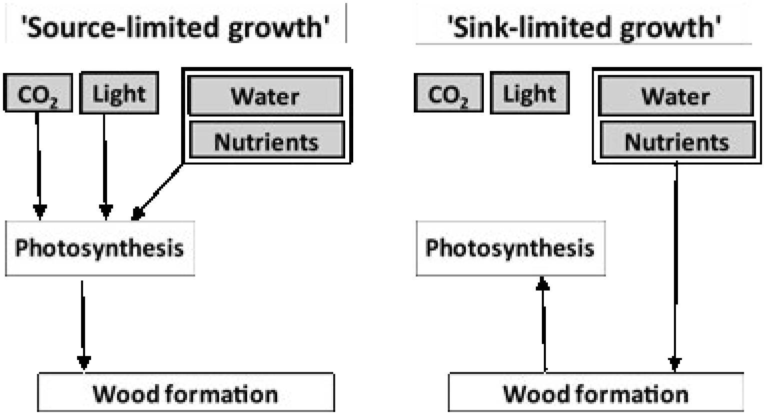

Figure 8. Is tree growth more limited by photosynthesis (and thus CO_2) or by the availability of water and nutrients? In the first case, 'Source-limited growth' (Left scheme), the rise of CO_2 in the atmosphere may strongly stimulate tree growth, as it increases the efficiency of photosynthesis. In the second case, 'Sink-limited growth' (Right scheme), the development and growth of wood tissue is directly limited by the availability of water or nutrients; not by photosynthesis. In this case, CO_2 rise will have little effect on tree growth. Arrows represent positive effects of one component on another. Figure after reference [35].

Intermezzo 2: On creativity in science

On television, scientists are usually interviewed in well-organized settings: in front of book shelves or in labs. The impression then is that scientists are rational and planned persons. But science is far more than controlled measurements and replicated experiments. Designing new studies and writing publications requires a lot of creativity. And creativity is undervalued in science. Just look at the way our universities are furnished and organized. Offices and desks are certainly not the best places for creative outbursts. And a compulsory time writing system does not help either.

So, how can we stimulate creativity in scientific practice? What are the conditions to be creative? Is solitude required, or does it work better in groups? Is a hammock better, or a walk in the forest? Very little attention is given to stimulating creativity in science (Figure 9). Personally, I've found ways to help creating creative moments. Some ideas pop up while playing piano or double bass, others when hiking or biking [37]. Early morning cappuccinos in a cafe in Melbourne greatly stimulated writing. And I very much enjoy doing science while travelling by train. Actually, most of this lecture was conceived and written somewhere between Amsterdam and Wageningen, Amsterdam and Groningen or Amsterdam and Maastricht. For me, creativity also *thrives in interaction with others. With members of my research team we had inspiring retreats in a cottage in the dunes. We'll never know if most scientific progress was made during the endless discussions in the living room or while playing frisbee at the beach. Field work visits to remote places and camping out in the forest also offers splendid conditions for new ideas to pop up.*

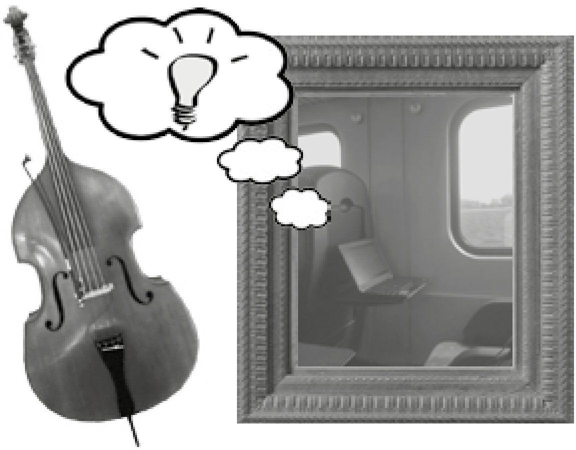

Figure 9. Creativity is an undervalued component of scientific practice. What are the ideal conditions for scientific creativity? For me, some ideas pop up while playing the double bass or travelling by train. Actually, most of this inaugural address was conceived in the train.

We really need to give more attention to creativity in science and much less attention to efficiency. The theme "Disruptive thinking" of the opening of the Academic Year 2015-2016 was a good start. A next step could be to exchange creative experiences among colleagues.

How do I perform these studies?

We get to the 'how' question: how do I perform the studies I talked about. Scientists are as proud of the contents of their methodological toolbox as the average hobbyist. They really love talking about this. I am not any different in this respect. So I brought a toolbox with me, with three tools (Figure 10). Let me get the first tool from the box.

The first method is that of tree-ring analysis. Scientists have long thought that tropical trees do not form annual rings because of tropical climates tend to be a-seasonal in terms of temperature. Luckily, this proved to be wrong in many cases [38]. The occurrence of a dry season invokes conditions that induces the formation of ring boundaries in many tropical trees. We now know that over 230 tropical tree species form annual rings [39, 40]. This movie shows how an 'increment core' is taken from a tree in Thailand [41]. It is hard work, but rewarding. This tree core contains an archive of the lifelong growth rates of this tree. Measuring tropical tree rings is often not easy and results should be interpreted with care. Ring-forming

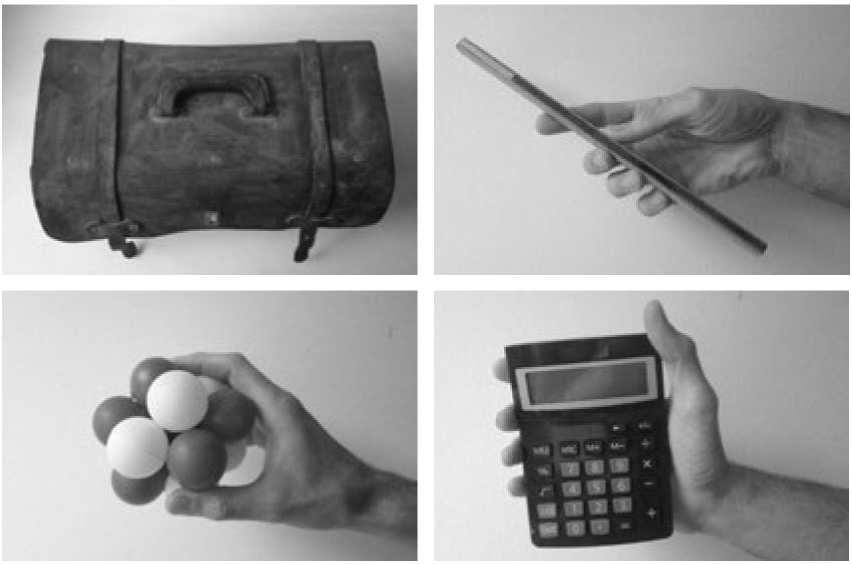

Figure 10. Three items from my methodological toolbox. The piece of wood is an increment core from a tree in Thailand; it contains information on the growth history of the tree. The atom model represents a stable isotope, in this case ^{13}C, a heavier version of carbon. Stable isotopes can be measured in tree rings and provide information about past growing conditions of trees and about their responses to changes in these conditions. The calculator represents a mathematical model. Simulation models of tree growth, population dynamics or forest dynamics are important tools to quantify effects of future climate change, exploitation and other human disturbances.

species are a non-random subset of all tree species and the trees that you sample are a non-random subset of all the trees that have lived [42]. I feel privileged to work in a group that has a great 'dendro'-facilities and 'dendro'-expertise.

The second tool I took with me is a stable isotope, in this case of Carbon. This is not a normal ^{12}C carbon atom, but a ^{13}C atom. Don't worry it is not radio-active, it is stable, and this is why it is so useful in ecological research. The fraction of CO_2 that contains the heavier ^{13}C atom is treated in a different way by plants. It gets into the leaves at a lower speed and it is not preferred by the enzyme in the leaves that binds CO_2 as part of the photosynthesis process [43]. By measuring the fraction of ^{13}C in the wood we can determine the efficiency of water use by trees. This was the basis for the graphs in Figure 7 about effects of CO_2 rise. Other stable isotopes: ^{18}O and ^{15}N again provide information about the amount of rainfall and the nitrogen cycle [44, 45]. So, the chemical composition of tree rings contains information about the growing conditions of trees and thus its geographic origin. With PhD student Kathelyn Paredes and post-doc Mart Vlam, we are applying this tool to verify the legal origin of tropical timber. We call this CSI-Wageningen, at times, and received attention in the national newspaper *Trouw* [46] on our Timtrace project [47].

The last item I took with me is a calculator. This stands for the models that calculate what happens to trees or populations in the future. Models that describe the growth of individual trees provide detailed insights into the effects of CO_2 rise, warming and rainfall on tree growth. The tree-growth model (IBTREE) built by post-doc Peter Schippers is a nice example [48, 49]. Models simulating the dynamics of populations are essential tools to calculate extinction risks or future harvests [23, 50, 51]. Nowadays, population modellers are getting more interested in the differences between individuals. They call this 'individual heterogeneity' [52]. If you look around, you will notice that your neighbours are quite different from you. Even if they are of the same sex and age class. Until recently, population modellers did not care about these individual differences. This is not so smart: just look at the large differences in the growth of individual palms in Figure 11 [53]. Some super-individuals grow rapidly throughout their lives, while others take their time. The super-individuals are much more important for the survival of the population and for the amount of products that can be harvested from a population. With PhD student Merel Jansen, we use these individual differences to improve predictions of sustainable harvesting.

Much more important than the fanciness of these tools are the people I work with. All plans and results I presented are based on collaboration with many colleagues and students, both close by and far away. Research and teaching are team efforts.

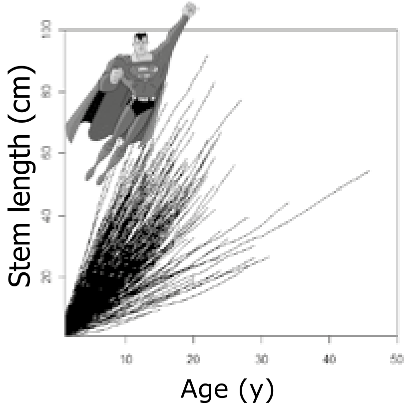

Figure 11. Modellers are getting more interested in the differences between individuals within a population. This graph shows that these differences can be very large: some individuals of this Mexican palm are so called 'super performers'. They reach a six-fold larger size at the age of 20 years compared to the slowest growers. Simulation models that include these differences between individuals will provide better predictions of the effects of palm leaf harvesting. Figure after reference [53].

To conserve and manage tropical forests in a changing world, we need bright and skilled problem solvers. Future professionals need to be able to think independently, interpret large amounts of information and easily liaise with people with different backgrounds. Our teaching should therefore help students to develop skills to solve problems in an innovative way. The Wageningen honours programme is a nice example of such an approach and I feel privileged to coach honours students.
As lecturers, we need to be aware that the population of enrolling students is increasingly diverse in educational background, capacities and aims. Our study programme should cater for this 'individual heterogeneity' in the student population. Just like the growth trajectories of palms I showed earlier, the developmental trajectories of students are very different. I would be in favour to give students more freedom to design their own personal MSc programme depending on goals and needs. This could entail doing two instead of one research thesis or increasing the length of the internship. I am also in favour of reducing the number of courses that needs to be followed by MSc students, and gradually reverse the trend of 'coursification' of MSc programmes.

I am deeply motivated to contribute to capacity building at institutes and universities in various tropical countries. And I am glad to work at Wageningen University, which is a great place for international students. Supervising foreign students and collaborating with 'tropical scientists' has greatly enriched my research, teaching and my life. I will continue to collaborate with 'tropical' universities and institutes, and support their curricula and research. One of my moments of great professional pride was when a project on curriculum development in forestry that I led, was featured on the Cambodian news. There are probably just two words you will understand .... [54].

Concluding words

Let me try to summarize the main message of this lecture. In my view, the real conservation challenges in tropical forests are not about what is lost, but about what can be sustained, about the potential. To meet these challenges, we need creative and innovative solutions. Is this too optimistic? Perhaps it is, but on the other hand, this may come quite close to the ideal that philospher René Gude called the disillusioned pessimist [55]. This is a person that tries to be pessimistic all the time, but fails, becomes disillusioned and then gets more optimistic. Whatever typification of my optimistic nature is appropriate, it is my aim to contribute to the wise use and conservation of tropical forests by research, teaching and capacity building.

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Prof. dr Pieter A. Zuidema

'Tropical forests harbour half of the world's biodiversity and a large share of the carbon stored in ecosystems. These forests have changed dramatically over the past decades and will continue to be affected by global change. The direct and indirect effects of human disturbances may reduce the biodiversity, viability and productivity of tropical forests. My research focuses on forest responses to disturbances, exploitation and climate change. Results of these studies help to improve the management and conservation of tropical forests.'

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