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«RCW TECHNOLOGY AND SOIL FORMATION : A COMPREHENSIVE VISION IN THE AFRICAN CONTEXT»

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FOREWORD

On February 16, 2001, the World Bank, IDRC, CIDA and Laval University held a consultation meeting in Ottawa. Those present felt the need to have a comprehensive vision of RCW [ramial chipped wood] technology and to set the concept clearly in the African context, for which the World Bank specifically created ASFI [African Sustainable Fertility Initiative].

A great deal of effort was devoted to drafting this document. It traces the history of Africa's biophysical framework, broadly outlines the technology, and indicates the results of its application. These considerations lead to academic and professional proposals, and indicate the path to follow in establishing new paradigms. This will involve reconciling agriculture and forestry, and eliminating the conflicts that thousands of years of hunting, gathering and slash and burn, have inflicted on a continent that is so rich and yet now is most often reduced to poverty.

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Introduction

This vision paper is definitely the hardest text we have ever had to write. We must continually make use of basic data that science has neglected or simply obscured. We must also highlight the results we have obtained and their interpretation. We hope our readers will indulge us and make the connection between past and present. We could easily have made far more specific proposals, but we deliberately limited ourselves to the problem, possible solutions, and their social and economic implications.

To make the problem more understandable, we have frequently referred to the Laval-McGill Consortium, why it was formed, and how the various disciplines are interrelated. Finally, in conclusion, we appeal to the private sector and call for the establishment of an international institute responsible for consistently disseminating knowledge among major academic institutions.

This study should actually be approached from a global perspective. For now, we will limit ourselves to the African context, which is so special and unique that it richly deserves our efforts to develop a comprehensive vision.

Historical context

For some unexplained reason, Africa seems to have been the cradle of humanity with its many cultures and characteristics. We must regard Africa as the birthplace of the whole human race. Life is unpredictable, however. The earliest peoples of Africa evolved under conditions that have remained largely unchanged, unlike those that would develop later in Asia, Europe and the Americas.

Geologically, this ancient continent is more regular and even than the rest. It is unique by virtue of its area, its fairly smooth terrain, its continuum of climates, its searing heat and scarcity of water. As far as we can see and understand the history of its plant life, this ancient continent has been marked by forestry rather than agriculture, as we might be inclined to think. This timeless history of the forest has shaped the landscape, but above all animal and human life, with many complex food chains, often fiercely competing with each other.

We have thus postulated that Africa is above all a forest continent. The characteristics that make African soil fertile are not the same as the well-known criteria of soil in the Northern Hemisphere, where agriculture took root. This makes matters even more mysterious and confusing, so that it is difficult to say much more on the subject.

We must rely on our experience of the past 25 years, both in Canada and in Europe or the Caribbean, for possible answers to the questions and issues raised in Africa. In the regions that we have just mentioned, forests have cycles in which softwoods almost always pioneers. In the evolution of trees, softwoods [conifers] (or Gymnosperms) emerged about 300 million years ago, long before hardwoods [Angiosperms], which made their appearance about 60 million years ago. Note that only traces of the softwoods of ancient times subsist in Africa and North Africa, where cedar groves prevail.

We concluded that the lack of softwoods in a forest made it vulnerable to degradation and was not conducive to regeneration after the shock of a natural or human disturbance. In Africa, more than any other continent, forest loss does not give way to regeneration cycles. It gives way to rapid desertification, in tandem with population growth and the introduction of techniques focused on production.

As a consequence of the adaptation of hardwood Angiosperms to the development of the African continent, hardwood fertility was transferred directly from soil to tree tops. Both genetic and trophic evolution thus became dependent on the forest. Several physical factors come to mind, such as water cycles, heat regulation and so on.

The other burning question is, "What mechanisms governed these fertility transfers, and why?" Here we must look back to the Industrial Revolution, which occurred after Europeans colonized the globe. They were once Africans themselves and practiced the same lifestyles: hunting, gathering and fishing. In a troubled Europe, with its seasonal extremes, shortages were common, resulting in war, epidemics and other calamities. Raids and conquests were thus followed by a period of development through the invention of technology and the domestication of plants and animals.

The lack of effective technology quickly forced some Europeans to conquer Africa to obtain labour in the form of human trafficking or slavery. Slaves were the forerunners of modern mechanization and mass production, whose effects we now see all over the world and in our respective environments.

Von Liebig's discovery in the mid-nineteenth century proved the importance of nitrogen in crop yield and growth. Productivity would henceforth focus on the chemical fertilizer industry, one of the crowning jewels of global major industry. The discovery was a major one. It propelled agriculture to heights of production that increased population growth while decreasing disease and epidemics, thanks to toxic biocides, the product of industrial technology that was increasingly powerful and increasingly profitable for major industry.

In the forest environment of Africa's biological development, the advent of technology focused on production was initially viewed as rescuing millions of people from an increasingly precarious fate. These techniques are proving to be bankrupt and are threatening the worst calamities, whose advent we can expect within the next fifty years. Africa has thus been transformed from a primitive, arboricultural but healthy economy, to a sophisticated agricultural economy that is nevertheless unhealthy and maladjusted, as shown daily by the food dependency established as early as the nineteenth century by colonial and mercantile powers.

We are betting that the necessary compromises can be made for the emergence of development that reflects both the forest environment and the need to promote diversified and profitable agriculture. This requires innovation in the African context, not in the industrial framework of developed countries, by making compromises between forestry and agriculture that are necessary for the entire biophysical environment. This is what we will try to show.

In closing, we cannot dodge social issues, since the economy largely depends on what we have just described. The premises of the project that we are submitting to the World Bank are above all social. The disappearance of the forest as an environment for life and production has caused insecurity and disturbances that have produced rigidity and distortions in communities that must adapt to age-old constraints. We believe we can outline a comprehensive, ecologically viable framework that is cruelly lacking in societies divided by historic, social and economic divisions. We must suggest new harmonies and solutions to underlying conflicts.

This will be very difficult, but not impossible, although it is a task far too enormous for ourselves alone. We must remember that humanity forms part of long food chains. The advent of new prosperity could mean inviting new stakeholders from the animal kingdom to the table in direct competition with human efforts. We will be forced to make agonizing choices for which we have no collective experience, and there will be much gnashing of teeth. Poor productivity and endemic poverty have spared us the need for such choices. Things will be very different in a wealthier, more technologically advanced society.

Soil, soil science and soil formation, or how fertility is transferred to trees

We cannot hold expressing our astonishment at the initial results obtained in the early 1980s. We noted and described wide variations among various experimental plots on the same site. These variations affected plant composition and forest regeneration, in the absence of other nutrients and on particularly poor sites. Moreover, this increase in fertility emerged from the second year after soil treatment. Even more intriguing was the difference in fertility produced by spreading chipped hardwood twigs on the ground in the soil test experiment instead of softwoods.

We thus quickly turned to the scientific literature of the past 25 years and realized some very surprising things:

- a) All of that literature was based on agricultural premises, described with a focus on production, based on the availability of nutrients.
- b) The term "pedogenesis" was unknown in most major scientific databases.
- c) Soil science focused strictly on production or mapping.
- d) Soil biology was also neglected and even unknown to science.
- e) Only bacteria generated some interest.
- f) *Basidiomycetes* fungi were known only for their role in cuisine or as pathogens.
- g) Lignin and polyphenol polymer soil biology was virtually unknown.
- h) Finally, the biological dynamics of soil were virtually unknown. Everyone saw organic matter, compost, industrial waste and the fecal pharmacopeia as the saviours of agriculture and the staff of life of humanity.

Such a state of ignorance was enough to frustrate even the most clever and determined. We quickly realized there were so many inconsistencies that the entire soil paradigm required a closer look. By scrutinizing the approach to soil and fertility in Africa, in the absence of specific knowledge and a refined understanding of the growth process, we realized what was really happening.

Most of the work done in the past 20 years shows that the biological richness characteristic of forest soil in temperate zones has been transferred from soil to tree tops over millions of years. The reasons are fairly simple if you understand the role of polyphenols, and especially condensed lignins and tannins, in producing and managing biodiversity. This is how we now conceive the role of trees in producing and conserving wealth. It pains us to see peasants use branches that are incredibly rich in protein to cook food.

Research on biodiversity in the rain forests of Panama recently showed that 90% of insects living in the canopy were unknown to science. This is obvious for the claim we are making here. These findings were supported by numerous studies of the canopy in Brazil, French Guyana and Indonesia. As the savanna develops and desertification begins, fertility is not transferred downward from tree tops to soil. In most cases, it remains unavailable, except for very brief periods.

Once again, we must look at polyphenol biochemistry to understand the very strong resistance of trees to the drought. This biochemistry enables trees to store all of the resources of the environment during dry spells. Desertification, which damages crops and other types of vegetation, can sometimes be reversed in its early stages.

We know that, without trees, the phenomenon of desertification becomes permanent and irreversible. This is an extreme disaster, but human beings may survive as a result of their intelligence, and if there is no competition along the food chain. Poverty thus becomes a means of resistance.

I hope those comments will enable readers to grasp the importance of the forest in regulating fertility. Most experts continually state that tropical soil is poor, since no phenomenon (such as glaciation) allows soil to be renewed and enriched with allochtonous (or non-native) material, as in volcanic activity. We must instead look at forest biology to understand that biodiversity is controlled by timely application of nutrients to the soil. This is important to avoid a proliferation of plant and animal species that would quickly reduce the forest to a desert where water would no longer be available.

Sources of RCW technology

The new knowledge provided by the literature since 1980 has provided several interesting paths. We had noted a regular absence of knowledge of the soil beyond chemical fertilization, a plethora of insects, and diseases caused by viruses, bacteria and fungi. We could say a great deal about our philosophy and the warlike mindset of our world, but let us put aside these considerations of a different kind.

We thus implicitly witnessed the emergence of the structure of lignins, the array of polyphenols and their relationships with the biological elements of soil dynamics, mainly with reference to forest soil. Oddly enough, it was from biological research by scientists on paper bleaching that made us aware of the relationship between *Basidiomycetes* fungi and lignins. Major industry paid enormous amount of money for damaging to the environment. The use of mercury in the chemical process of paper bleaching was the way to go.

We thus understood that soil formation was involved, with its many effects on all aspects of the regeneration of life, and the dynamics of biological, biochemical, chemical and water balances.

Ramial wood

Much has been said and written about the wood of tree trunks in general, but not about tree branches. Nothing was said or written about the characteristics of ramial wood (which did not even have a name until 1986), even though billions of tons were produced annually around the world. Unlike trunk wood, or caulinary wood, where the bark comprises only an insignificant volume of the wood, ramial wood is largely made up of bark. Among other things, this bark contains condensed and often hydrolyzable tannin, a polyphenol polymer, as well as gayacyl and syringyl lignin, another polyphenol polymer. It seems increasingly clear to us that the linkage of these two groups of polymers constitutes the basis for soil structuring, especially when they are associated with numerous proteins (often more than 20% of ramial wood), and when we find other polymers that are responsible for sustaining life on a short-term basis, such as cellulose, which is associated with sugar.

Tannins, lignins and terpenes combined

From all of these assumptions and findings we conclude that these products of photosynthesis are responsible for medium- and long-term fertility. They trigger nitrogen, often from sources that are deemed inaccessible but whose availability can be timed with the needs of plants in their various stages of growth.

We thus believe we have found what drives soil stability and fertility, the two main ingredients of sustainable agricultural development. According to the scientific literature the presence of those polyphenol polymers, incomparably rich fungal flora, largely dominated by *Basidiomycetes*, are able of producing the enzymes needed to partially transform aromatic rings into humic and fulvic acids, by-products of primary importance in the soil formation process.

Much remains to be done from a biochemical standpoint to understand and identify the by-products of lignins and tannins, which vary depending on the type of tree. Science is virtually silent in this area. We need to make substantial investments and establish laboratories specializing in this field. In this regard, our German colleagues, with whom we enjoy good relations help in the field of lignin chemistry, and our Italian colleagues, who have developed considerable expertise in humic substances.

Tropical soil and the energy needed for trophic chains

It seems increasingly clear to us that the greatest tropical disaster is the lack of available energy to operate this complex "biological machine" that is soil. This "machine" needs thousands of species, from viruses to mammals, that interact and create their own niches. Communication occurs largely through enzyme systems that are simple or complex, but ad hoc and fleeting.

The best known example in this regard is definitely nitrogen fixing in all of its forms. Another example is phosphorus, which can be recovered from complex, inert forms by special enzymes, such as phosphatases. From those phosphatases, phosphorus can be stored in mycorrhiza tissues in the form of phospholipids, and made available to plants, regardless of soil conditions at the time of growth.

All of these transfers require energy, often unavailable from sugars or other polysaccharides broken down by bacterial flora. However, polyphenols act in various ways, given their ability to form complex compounds by modifying carbon or other chains. We know more than four million different compounds.

The intensity of UV [ultraviolet] radiation, high surface temperatures, and rapid evaporation of water in the absence of a forest cover: these are factors virtually ruling out biological activity and fertility that should be transferred to tree tops with its biological components.

Without trees, the soil is in a nutrient-poor physical medium. A special niche is thus created. This niche is invaded by forms of life that are often allochtonous (or non-native), such as nematodes and certain viruses (in some cases, human pathogens). In semiarid zones, this niche may also promote the development of locusts that invade entire continents. In this case, we believe that life must be regulated by polyphenols, especially in tropical regions. Food chains cannot develop or become more complex without equally complex and flexible regulators.

Polyphenol polymers, complex molecules that are branded as industrial waste and nuisances of all kinds, thus actually appear to be the biochemical medium required by soil to exist. Moreover, than the biodiversity of terrestrial ecosystems need to exist the contribution of the forest.

Trophic chains

Much has been said and written about trophic chains, but mainly in an agricultural context, that is, an environment of limited in biodiversity, and often in advanced degradation, to satisfy industrial needs. Thus, over the years, the forest has been seen as an agricultural variant of the food industry. All the aspects described above have been overshadowed by the chemical industry, which is more convinient to economy and industry. The phytopharmacological and multiple-biocide industries subsequently have developed products incompatible with tropical environments, and causing visible deterioration of their agriculture and its failure to meet their most basic needs.

Basidiomycetes

All biological management of soil occurs as a result of fungi known as cap mushrooms because of their carpophores (or caps). As we have just seen, they are able to produce a large number of different enzyme systems, forming a differential digestive system that attacks dead tissue to recreate living tissue, this time simpler life forms with functions that seem insignificant to us at first glance.

Arthropods

These tiny animals, which bring about many changes, depend on the mycelium of *Basidiomycetes* for their food. They help to store nutrients in their biomass, just like the metabolism of nitrogen in soil, through their characteristic fixing mechanisms.

Earthworms

Earthworms are particularly interesting because of their ability to separate polyphenols from proteins. They thus free large quantities of nitrogen that would otherwise be trapped in the polyphenol-protein complex. This phenomenon is characteristic of soils rich in humic substances.

Organic matter

As you can see, we have made no reference to "organic matter", a term found *ad nauseam* throughout the literature on agriculture and forestry. This term does not cover any biochemical or biological reality. It is a catchall term that has shaped agriculture for over 150 years, without being based on any knowledge whatsoever of the origin of humic substances or polyphenol polymers. Our thinking, and the resulting technology, have pointed our attention on this term which has produced all kinds of fantastic notions. We have concluded that agriculture and forestry developed within a paradigm focused on production, based on economic reasoning limited to cycles lasting no more than 20 years. This is another source of deterioration that occurs in all countries and is particularly significant in the tropics, with Africa unquestionably suffering the most.

RCW technology

Traditional agriculture, both in Africa and in the tropical Americas, is largely based on burn-beating and fallowing. We have thus developed technology that would combine the benefits of the forest and of agricultural productivity. Rather than burning tree branches, why not use them to restore soil fertility? Chipped wood is produced using a specialized machine that is increasingly found in urban areas. We spread wood chips on the ground (as mulch) and then mixe them into the first few centimeters of topsoil.

Various types of results were obtained in temperate zones by using these wood chips, which we called **"ramial chipped wood" or RCW**:

a) Although rich in nutrients (particularly gayacyl lignin), RCW from gymnosperms [softwoods] was not very effective in promoting soil fertility.

b) Although less rich in nutrients, RCW from hardwood angiosperms produced good fertility, especially in the second year. From a forest perspective, they almost exclusively allowed the sprouting of seedlings from hardwood trees.

c) Productivity did not increase very much in the first year, which was devoted to establishing *Basidiomycetes* and arthropods, but rather in the second year.

d) Increased yields were shown in several ways, especially by a 30% increase in solid content matter in potatoes or a 300% in volume yield in strawberries.

We then understood that RCW did not influence the flow of nutrients, but rather the overall physical, chemical and biological factors, as seen from the fact that soil changed in texture and colour, turning reddish-brown. No deficiencies or diseases were observed. The entire dynamic was designed to achieve a series of balances that subsequently never failed.

Talking to a brick wall

For a number of years, with the results obtained instead of a total absence of any reference in the scientific literature questions were asked on the value of these results, which did not arouse any coments among our colleagues. In several countries visited, in Europe, Africa, and the Caribbean, no one raising the slightest question about this technology. In 1993, paper presented to FAO executives in Rome. A few months later, we were told no one believed such a "tale". The 12 countries of the Club du Sahel were a less hostile though unenthusiastic reception in 1995, except for one person from IDRC.

In the tropics

Keenly aware of the value of our measurements and findings, and with the support of CIDA and the cooperation of Mamadou Seck, an assistant professor at Cheikh Anta Diop University in Dakar, Senegal, we began a series of tests with Australian pine *(Casuarina equisetifolia)* RCW in the Les Niayes region east of

Thiès. The results obtained were immediately very impressive, especially for eggplant, tomatoes and Ethiopian nightshade, with yields four to ten times greater than those of control plots. In Côte d'Ivoire and the Dominican Republic, tests with maize, using RCW from dicotyledonous angiosperms, produced yields four times greater than those of control plots.

I will limit any comments to these facts, but many other parameters were improved. Water consumption decreased, salinity was reduced, pH balance tended to become neutral, several weeds were eliminated, and so on. Similar results were achieved in the Ukraine, but to a lesser extent, because of the harshness of that country's continental climate.

This led us to state that:

• a) RCW technology has universal applications to agriculture and forestry.

• b) We are intervening in a positive manner by restoring biologically derived soil formation mechanisms, but in a specific biochemical framework, that of polyphenol polymers.

• c) Sustainable fertility comes from tree tops and not from nutrients, which depend on biological activity to be available (nitrogen and phosphorus).

A change in Africa's basic agricultural paradigm

In proposing this technology, we are perfectly aware that we are proposing a full-fledged "agricultural revolution", but we believe that scientific integrity requires us to propose this technology, based on forest balances in soil formation. The past 20 years have highlighted the difficulty of changing such a paradigm in industrial and developing countries. The promise of success is such that we have spared no sacrifice in publicizing the benefits of going against tradition by seeing the forest as agriculture's main ally and not its adversary.

We thus feel warranted in claiming to offer **the key to sustainable agriculture and forestry**, so that both are closely involved in maintaining chemical and biological soil balances, while restoring the water cycles characteristic of all forest systems. As degradation is increasingly extensive and severe, technology alone cannot succeed. We must talk to people directly, through their current or ancestral social, economic or ethical problems.

The RCW Senegal project

It was not until 1997 that the Coordination Group on Ramial Wood, Department of Wood and Forest Sciences, Laval University, Quebec, Canada, saw the necessity for a more broad-based association with another Canadian academic institution. At the same time, the social issue had been raised, and we saw the need to call on the resources of anthropology, a science that is too often neglected in agriculture and forestry. However, biochemistry, as it refers to polyphenols and more specifically condensed tannins and lignins, lies at the core of scientific and technological innovation. Biochemistry is followed by agronomy, forestry, economics and administration.

Anthropology

The paradigm shift that we propose cannot be effected haphazardly and single-handedly. Activities before, during and after initial field experiments must be properly assessed and keenly perceived to identify social failures and successes, and to monitor their intricacies among farmers, politicians and intellectuals. Professor Serge Genest, Department of Anthropology, Laval University, is responsible for this task.

Polyphenol biochemistry

Needless to say, the greatest innovation is the introduction of a scientific field that has almost always been excluded from the biological sciences in favour of industrial innovations. Through RCW technology, this field of research — polyphenol chemistry — is interested in the wine industry, the drug industry and pollution control. This is a new development that, even recently, no one expected. This scientific field has been entrusted to Professor Tatjana Stevanovic-Janezic, a world-renowned lignin specialist. She is a full professor in wood chemistry in the Department of Wood and Forest Sciences at Laval University. She is responsible for all biochemical links with ramial wood in the soil formation process. She plays a key role and will help to determine the soundness of recommendations. Above all, she will help to explain, through biochemistry, the effects of polyphenol polymers in all trophic chains. We believe this will represent a major contribution to science, agriculture and economics.

Forestry

Although it is central to any future development, forestry plays a very modest role in the RCW Senegal project. This will not be the case in the future. The RCW Senegal project will almost exclusively use branches and twigs from the necessary development of Australian pine along the shoreline from Dakar to Saint-Louis. Since UCAD [Cheikh Anta Diop University] in Les Niayes has conducted preliminary tests, we know the quality of RCW that we will obtain. Professor Gilles Lemieux will handle this aspect and ensure the coordination of all scientific and technical aspects of the RCW Senegal project.

Later, we shall see the importance of the forest and its regeneration in agricultural development through RCW agroforestry technology. This aspect will be far more important in the overall development of technology throughout Africa.

Economics

This aspect is causing implementation problems at the present stage. Preliminary tests, done in Canada, have shown us that technology has impacts on several levels that must be measured, and long-term funding for this purpose is never available. This is also the case here, where we will have access only to harvest yield in terms of yield, sales and economic rates. However, such a project is not designed or funded to measure the positive effects of water quality adjustment, soil stability, or the decreased impact of a given insect. We will try to do what we can in a given project.

Administration

The administrative aspect of such a project is of crucial importance in establishing new rules and making them acceptable to national or international institutions that provide the necessary capital for such a project. Professor Michel

Dessureault, head of Department of Wood and Forest Science, Faculty of Forestry and Geomatics, Laval University, is responsible for this aspect. François Carrier, International Research Office, McGill University, and Jacques Parent, Director, International Bureau, Laval University, are also involved in this area.

Suggestions for ASFI

ASFI [African Soil Fertility Initiative] has filled a void in the World Bank's African project to promote fertility. We identified this void several years ago, but the time was not yet right. We think the current structure of the Laval-McGill Consortium would form an excellent basis for ASFI in its mission.

We thus suggest focusing on the following aspects:

a) Sociology-anthropology
b) Polyphenol biochemistry
c) Soil biology (viruses, bacteria, mushrooms - mycorrhiza, algae, arthropods - mites and so on)
d) Farming (subsistence and factory)
e) Forestry (silviculture, plantation, RCW production management and so on)
f) Economics (forest and agricultural)
g) Involvement of the private sector
h) Administration (national, international and academic institutions)

Essential involvement of the private sector

While it is important to involve major national and international institutions, the academic sector makes an equally important contribution, as shown by the development of new global technologies. No matter how honourable, however, none of these institutions can implement and manage a technology such as RCW in every African country. The private sector must become involved in all ramifications of such a technology, such as production and distribution of wood chippers specifically to produce RCW; training for farmers, technicians and professionals in managing production surpluses and conservation techniques; and so on.

The whole area of producing RCW through systematic planting and reforestation must also be managed. Once again, neither national nor international organizations can claim to act in this field of competence. Only a commercial or industrial institution can claim to assume such a task and to obtain positive results. This requires core funding, which the World Bank can provide with the support of countries such as Canada, Germany and Japan. In Canada, such a firm has just been established, with the support of the academic sector, to transfer this technology to countries in need.

This firm's experience already promises largely positive impacts, based on field experiments in Madagascar, where local initiatives by farmers quickly led to planting trees to produce RCW, with significant effects in producing rice, vanilla and tea. Initial tests on locust larvae clearly show RCW's lethal effect on their development. The same applies to managing surplus market garden production, which is dried and then rehydrated for use during shortages.

Urgent need to establish an international institution on pedogenesis

We believe we have clearly shown innovative aspects and scientific weaknesses of such enormous scope that they make us wonder about the impact of RCW technology. Our tour of several countries leaves no doubt that people do not know the importance of polyphenol polymer biochemistry in regulating life and soil fertility.

International institutions, supported by donor countries, must thus ensure the establishment of an ***International Institute of Pedogenesis***, which would have impacts both in tropical countries and in temperate zones, as shown by our research in the Ukraine. This would strengthen the 180° turn we must make away from traditional agriculture that cannot be sustainably adapted to the tropics, and significantly contributes to air and water pollution in industrialized countries.

We must engage our major academic and research institutions in disseminating this concept of soil formation from the forest, without any trees in the immediate vicinity, to regenerate the flow of biodiversity and deliberately to control its parameters. In today's world, where so many scientific innovations have emerged, we still depend on agriculture that degrades the soil, when we could do so much better for future generations. We could eliminate food insecurity and water shortages that increase the toll of death and disease.

We must apply what science teaches, what technology tells us, and what capital investment can achieve to change the present worn-out and outmoded agricultural paradigm. Modern industrial parameters scarcely offer much more hope, since they often stem from a philosophy of war and confrontation, rather than peace and cooperation.

What can we conclude?

In the face of such evidence, we have an obligation to study the matter further, to learn lessons and to make proposals for the future. How did we end up with food and water shortages by thinking solely in agricultural terms, based on technology unsuited to Africa, without batting an eye or shedding a tear over the loss of millions of human lives? The answer lies, not in moaning and groaning about the past, but in looking ahead to the future.

Inventing environmentally friendly bioengineering

It is almost unbelievable that, after such collective vicissitudes that have lasted for over a century, we are still extolling the virtues of professions that are focused entirely on production in an environment of confrontation. This model was exported to Africa at the same time as similar technologies arrived from temperate climates. We are inclined to think that burn-beating and agriculture developed in temperate zones are the source of the absolute poverty that is developing at a virtually unimaginable pace under African skies. Some object to such a statement, but then why is productivity in Africa only 30% of what it is in temperate countries?

Major industry suggests that GMOs [genetically modified organisms] are the wave of the future. We think this is the height of the ridiculous, but it is consistent with the warlike philosophy of building strength to fight "enemies". But how can we be strong in a barren wasteland without knowing and using the mechanisms responsible? This is where the agricultural paradigm fails in Africa. We must view the situation from the perspective of the forest. This means setting aside professional and industrial rivalries between agriculture and forestry, for the reasons suggested by RCW technology.

Promoting training for environmental engineers

People must be trained in accordance with the demands of the African environment. They must be trained very differently than they are currently in every country of the world. We must redraw the circle of life by changing our traditional perceptions of agriculture, livestock breeding and forestry. **SCIENCE NOW CHALLENGES US TO FORGE PRODUCTIVE TIES BETWEEN THE LAND AND THE TREES, BETWEEN AGRICULTURE AND FORESTRY, BY RESTORING WATER CYCLES INSTEAD OF WATCHING WATER DISAPPEAR.**

This task does not belong to the major international institutions, but rather to universities, which must be supported and encouraged in one of the world's greatest professions: ***shaping people through knowledge***. The United Nations, FAO, UNESCO and the World Bank must play a positive role in this regard. The challenge is enormous, but the technology is now available to generate and maintain balances whose absence is leading to absolute chaos in the intimately associated processes of water and food.

A Marshall Plan to reforest Africa

Although all of the major international organizations are beating their breasts publicly about the gigantic problems developing in Africa, proposals are only occasionally advanced. These proposals are half-baked and frequently unsuited to the African environment. Nevertheless, we acknowledge the daily expression of willingness to provide solutions to desperate situations.

We sincerely believe that, in a few years, the systematic use of RCW technology could sow the seeds of positive productivity using African resources. However, we must fight resignation to poverty and shortage, and we must promote a new culture of wealth and productivity. We believe the challenge is just as great in terms of culture and economics as in agriculture and forestry. Such an approach will produce, not only new agricultural paradigms, but also new economic and cultural paradigms unknown to Africa and many of the peoples living in tropical regions of the world.

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