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«THE BASICS OF THE ECONOMICAL AND SCIENTIFICAL REVOLUTION OF SAHEL»

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THE BASICS OF THE ECONOMICAL AND SCIENTIFICAL GREEN REVOLUTION OF SAHEL

I want express my sincere thanks for inviting me to discuss on this rather difficult subject. I believe I can contribute with somenew information which can be used for both the Sahel and elsewhere in the world.

First, I would like to describe the background which led to the various discoveries that will be the center of my remarks today. These discoveries are linked to the economic and social problems that were lready evident by the early 1970. The environmental crisis brought about the astonishing advances in industrial technology and productivity

Our contribution stem from research on two problems: the degradation of the forest environnement and the pollution attributed to the chemicals to bleach paper pulp, and containing mercury identified as the most dangerous and most harmful residue.

By using wood chipped tree branches, chipped and mixed them with the top few centimeters of the soil increases in agricultural yield were obtained ranging from 30% to 300% depending on the crop and no fertilizers or conditionners were used. Unfortunately no mention was found in the scientific litterature on this material and on its effects. In the early 1980s , additionnal tests in a forest environment, showed significant effects on soil regeneration, soil morphology, physical and chemical reactions, flora, etc., The reason for these changes had to be found. It has been common practice to throw away branches as no value material. However, after studying the various components of branches, it was obvious that they were highly rich in nutrients, one specific substance which is, a slightly polymerized lignin, in the form of monomers is easily decomposed by biological organisms.

When we start our study, the scanda surrounding Minamata disease, caused by mercury poisoning, had convinced researchers, working for major corporations and governments, to come up with new techniques for bleaching paper, since lignin gave paper a fowl colour. Major, studies were undertaken around the world on the enzymatic "breakdown" of lignin, specially comming from coniferous trees. For the first time, a significant effort was devoted to this extremely complex and highly energetic molecule for which the pulp and paper industry had no use.That is why it was evacuated into the environment with other by-products such as organic mercury compounds.

Ten years later we came across a scientific article matter by two European scientists, Dr Leisola of the Finnish Sugar Institute and Dr. Garcia of the *Institut Pasteur*, and dealing with the role played by various enzymes in the production of humic acid from lignin, a key factor in pedogenesis, that is, soil formation and fertility.

For the first time, I had a better understanding of why ramial chipped wood (**RCW**) had such a significant impact on yields, without any supplementation by chemical nutrients such as synthetic fertilizers. For the first time, I left the traditional approach of mineralization and the chemicals associated with it. Then I was found oriented towards the organic approach, but in a forestry perspective, where the advocates of compost and manure, are obessed by the waste disposal so characteristic of our economy as we approach the end of the millenium.

It should be pointed out here that all the research works on lignin have been conducted for its breakdown, its transformation or its elimination. No recent studies were found on upgrading, that is the build-up of the soil energy structure from aromatic rings incorporated in the new environment as far as the organic waste disposal is concerned only. The breakdown is taken into consideration, without any mention of the most important phenomenon, the energetic, biological and structural upgrading of the soil as a living microcosm.

The constituants of lignin material have made possible man's development around the world. At one time or another, all Africa was dominated by deciduous forest. The tropical forest is deciduous and it generates the highest yields, both in agricultural and forestry. According to History the entire Sahel was once covered by forest. Under various types of pressure, for instance economic developments, demographic increases, and climatic change, the native forests were close to disappear.

Since 1926 the theory dealing with lignin as the basis of natural humus has been put forward but little attention was paid to that fact. The mots extensive studies ignore this evolution of lignin. They all try to understand the breakdown of this macromolecule, not its positive evolution. The main change occuring in soil is linked with the process of benzenic rings, the very basis of other complex compounds wich is kept intact or only slightly modified, while the stored energy is increased. On the other hand the mineralization process need energy and reduce the amount of energy stored, **pedogenesis** therefore involves **entropy** increasing energy and by dispersing it in the matter as opposed to where energy as in the case of mineralization is concentrated or expelled. Modern agriculture relies on the second phenomenon, namely mineralization, with all its pertinent consequences: soil degradation and water pollution are two of the best known aspects. The same is true in traditionnal agriculture, were organic residues are burned in order to make available to plants the nutrients, but to the detriment of the formation of trophic web.

WHAT HISTORY AND GEOGRAPHY TEACH US

Based on observations, reflection and deductions, I may conclude that the world's major civilizations rose from the context of the

deciduous forests, By cultivating the soil taken from these forests the best highest crop yields were obtained under all conditions, over time. The increase of wealth became possible with the growth of populations. All attempts to use the soil gained from coniferous forests failed at all latitudes and in all climates. A number of explanations have been put forward but none have really been convincing.

It is different with fertile agricultural soils deriving from formations of Monocotyledons where xeric tendencies are observed, and production of grass and grains in particular is worthwhile. Those large grasslands are found in both the Americas, and Asia and to a lesser extent in Europe and average population densities are generally found there. Intensive uses of the soil lead generally to total, partial or temporary desertification under these precarious climatic conditions.

Throughout the world, human beings and a large number of animal species, including Primates, our closest relatives, are dependant on deciduous forests for their survival. Under these conditions the biological diversity is the greatest to exist. Disappearance of the forest break down the water cycle and leads directly to desertification in the tropics. There are undoubtedly major cycles involving transition from one stage to the other, thereby ensuring the adaptation and appearance of new species namely the human beings as a good example.

As the earth's various geological features are the "*memory*" of its history, it seems obvious that the soil is the memory of the forest for changing very slowly, and maintaining an unequalled gene pool which enables it to reconstitute the conditions needed for the developpement of new biological equilibria. The deciduous forest only exhibits genuine climaxes, in both temperate and tropical regions, and can therefore claim for "self-perpetuation" as a society, as long as the basic parameters are stable.

THE EXPERIMENTS IN CANADA, AFRICA AND THE CARIBBEAN

After poundering the results obtained by incorporating 150 m^3/ha of ramial chipped wood (**RCW**) into the first centimeters of the topsoil, some hypothesis had to be formulated in view of identifying the mechanisms involved. The first hypothesis had to be supported by general rules leading to the formulation of universal fundamental principles. It was then necessary to test this hypothesis under various conditions. In temperate climate, numerous limiting factors, are different from those in tropical's.

By assuming that the basic hypothesis was dealing with a universal phenomenon, namely pedogenesis, numerous experiments were conducted. At first, the hypogeous ecosystem was considered to be related to biological factors, and the type of lignin appeared to be the most basic and central. Once establised, some experiments were conducted in Africa, in the subsahelian region of Senegal, as well as in the Caribbean, using a single trees species, *Casuarina equisetifolia.* The latest results seem to support our earlier ones in every respect, and usually they are in vegetable production higher than the traditional yields by a factor of four to six. In Africa, better results were obtained using local tree and shrub species when grown closer to the equatorial forest.

In Canada, as well as in Africa and the Caribbean, the increases in yield were obtained without any fertilizers. All the biological, physico-chemical and physical parameters tended toward equilibrium, and will be discussed later.

RE-ESTABLISHING THE BIOLOGICAL EQUILIBRIA OF THE FOREST IN AGRICULTURAL ENVIRONMENTS

According to mankind History, man had to prevail in a harsh struggle against the forest. It is obvious that the forest was long before mankind and consequently the ecological complex soil-forest-animal remain undisturbed until very recently. This equilibrium was more or less maintained for millennia in the absence of technology and therefore went through wars and epidemics of all kinds.

Introduction of mechanical power as well as new knowledge in chemistry provided changes and favoured the increase of productivity. Due to the fact that the soil's ***"memory"*** is so large, the soil reacted only under the most favourable conditions. Elsewhere, the result was catastrophic. Technology can be used to remedy the situation, but the economic cost will be high. Unfortunately, numerous factors and conditions may favor tribal wars, famines and massive epidemics.

It must be said that the soil microbial equilibria is resulting from ecological changes in the forest environment. Agriculture practices are related to physical and biological characteristics specific to each region and consequently involved process of degradating the environement, in the name of increased productivity. However, the cost for maintainning technically for this high productivity is reaching levels difficult to be beared by the economy.

By returning the most productive part of trees into the soil the equilibrium could be restored in all the trophic web, where the nutrients are confined, fully shielded from the chemical as well as from physico-chemical cycles that we have been measuring so keenly for more than a century. The biological system only is in charge of all chemical nutrients and consequently of all the rules of the chemistry of the soil, since the cycles and controls are regulated either by groups of living organisms or

simply by chains made of several levels of life form and, finally, by a series of enzymes resulting from this activity.

These equilibria in the soil can be restored after some "agricultural degradation" but, all the mechanisms of ***pedogenesis*** must be in place, including all the mechanisms contributing to soil formation. In temperate climates, low yields have served to maintain a certain equilibrium, especially in the presence of a well-structured clay-humus complex. In tropical climates, often in forest environments, agricultural crops in rotation with forest has succeeded in protecting these equilibria. Tree harvesting and industrial farming can cause catastrophes and the bad effects are now just beginning to be measured.

We now recognize why tropical soils are relatively poor in nutrients. The wide biological diversity of microorganisms and the amount of energy available can prevent the upper vegetation to grow if the nutrients are not stored in their branches rather than only in the soil. Recent studies on the Amazon forest canopy have shown that all levels of microrganisms live also in the canopy, and in equilibrium made of entirely of vegetation: namely the branches and leaves of large trees.

From those observations, it is understood why, the yields are so increased when the chipped branches are returned to the soil. The cycle initiated by nature is then completed. The branches must be prepared for a massive attack by microorganisms, especially by the family of fungi called ***Basidiomycetes.*** **The content of nutrients in ramial chipped wood (RCW) will pass directely into the microbial biomass namely fungi, protozoans, bacteria, algae and others, rather than into the soil solution**. At this point, I would like to recall that fungi are the most important acting agents, in contrast with bacteria in composts making.

The first step involved will be the formation of the trophic or food web, while the second will be the depolymerization of lignin into two main components: humic acid and fulvic acid. These are not

mechanisms of breakdown as mentioned by many authors, dealing with **mineralization**. Humic acid deriving from lignin is therefore the primary component of soil aggregates which in the presence of clay results in the clay-humus complex and reponsible for soil stability and fertility. In tropical climates, the aggregates in turn are quickly metabolized forming the concentration of nutrients in the green parts of plants.

It is through the fungi *Basidiomycetes* and the depolymerization of the lignin, not its breakdown, that the RCW can innitiate the basic mechanisms toward ***pedogenesis,*** that is, the formation and maintenance of fertile soil, and to increase its energy content as well as and the content of nutrients used by plants. This is the ***entropic process*** of forest origin which has nothing in common with ***current enthalpic techniques*** wich are specific to agriculture and to some extent to new trends in forestry.

Essentially, the transformation of lignin is the central point in all pedogenesis process. Its chemical structure will stimulate other ancillary mechanisms such as the chelation of iron and the production of polyphenols, as well as mechanisms of formation of podzols or laterites as an example.

With the RCW technique it is possible to establish and maintain an agricultural soil similar to forest soil and to control its fertility and structure over long period of time. This **type of a reconstituted soil similar to forest soil** or **"true agroforestry"** appear to be the very basis of the **sustainable developpement.**

THE INTERPRETATION OF THE EFFECT OF RCW ON SOIL CALLS FOR FUNDAMENTAL CHANGES

Since the nutrient management is rather well understood in temperate climate it seems different in tropical climates, where successive failures and the endemic poverty are known facts for years.

In temperate climates, and only in presence of fine clays or alluvial deposits, the nutrient regime involves the clay-humus complex. Even under the most favourable climatic conditions, the absence of this complex has major effects on the local population and economy. Even when the previous forest was productive agricultural productivity is declining. This is not logical and the bad results should be attributed to ignorance and technical deficiencies.

It is obvious that increases in yields, changes in soils structure, use of water and reduction of parasites and diseases over years and climatic conditions must be of great significance. In tropical climates, it is known that soils formed under forest cover are of poor quality for agricultural uses. Therefore when the forest productivity is good, it means the nutrients are located in the trees themselves, particularly in the top branches, the immediate site of photosynthesis.

This hypothesis was supported by the experimental works conducted in Notto (Senegal) and initiated in 1993, and resulting in a spectacular increase in the fruit production of the Ethiopian nightshade *(Solanum æthiopicum)* and total disappearance of nematode fauna at the root level. The second year, the yields were multiplied by two, implying the recirculation of RCW nutrients from *Casuarina equisetifolia.* The same kind of experiment was conducted in Ivory Coast with RCW from various deciduous species and the dry matter yields were of the same magnitude, indeed even greater with maize.

There is a problem which can be related to an error of interpretation of the mechanisms and implying the lignin from deciduous trees and the microbial biomass. Modern agriculture is based

mainly on mineralization. That interpretation is associated the role of compost and manure. With RCW, another and more important and omnipresent reality, is introduced, it is **pedogenesis,** which recycles all the biological and nutrient mechanisms. This step is essential to prime the pump of self-regulated recovery, so important for meeting human needs.

Humification and induced trophic web are the basis factor for short-, medium- and long-term fertility. Based on the stable ***humus-microbial biomass*** the nutrients are available as well as their adequate concentration for the development of vegetation. In tropical climates, this role seems to be assumed by the ***arboreal ligneous vegetation microbial biomass*** complex.

The lignin from deciduous trees is the most suitable element for structuring soils and adding the energy required to ***build up the trophic web acting for regulating the flow of nutrients, in quality and quantity***. In the microbial biomass, the Basidiomycetes is the most important acting agents by depolymerizing lignin into humic and fulvic acids which are the basis of the chemical and physical structuring of the humus, the primary source of soil energy.

Eventually, agriculture could depend on forest soils, cultivated only for the production of RCW. This is a new statement impossible to be formulated some years ago.

It seems possible to draw a universal law which applies equally to agriculture and forestry: **the nutrient regime system is asumed by the microbial biomass and under control of lignin and its derivatives.**

As a corollary for this law, it may be added that **agricultural soils are under the same fundamental forest mechanisms, in which lignin and its derivatives are the central factors.**

CONCRETE PROPOSALS

From the standpoint of sustainable development, the term ***ecoviability,*** we believe to be more convenient but the time has come to arrise to more appropriate techniques, based on the ***biodiversity***. The mechanisms already outlined are very basic of ***ecoviability*** and ***biodiversity,*** while until now the emphasis has been put on productivity at any cost and also on uniformity and volume. There should not be any incompatibility between ***ecoviability*** and productivity, provided the processes involved are well known.

Since climax forests appear to be eternal and high yielding, it seems possible that agriculture could behave the same way by using practices based on ***controled humification,*** instead to uncontrolled mineralization, as is currently accepted throughtout the world.

This implies that modern agriculture and forestry, in both tropical and temperate environements, are driven by the mechanisms of humification based on the formation and maintenance of trophic web, for which lignin and its derivatives are responsible.

The priority should then be given to production of ramial wood, instead of the traditional wood production. In the tropical Subsahelian climate, RCW production should be very rapid and in large amount within a few years, if not a few months. The simple chipping or grinding techniques, associated with spectacular increases in yields, will spread among the population like wildfire. This phenomenon will have to be channelled so that a large part of the RCW produced be directed toward the forest sector to foster the development of a stable and productive forest as quickly as possible. This could be the task of the aid-providing nations, by donating or later lending the necessary funds and expertise.

With such ***winning techniques,*** there should be very significant changes within the next 20 years. Farther to the south, where rainfalls are higher, the use of local species as a source of RCW should contribute

to efficiently stabilizing populations which otherwise remain transhumant.

The forest plantations should be favored because production of RCW; **this is only way of breaking the vicious cycle, implying desertification, poverty physical and social instability.** To do so, many criteria should be revised in the selection of the projects in allowing the funds.

One major step is to change the actual choice of species. They are still selected on account of their behaviour on degraded soil and because they are still good wood productive. The arguments for starting plantations using Australian species such as *Eucalyptus spp., Casuarina equisetifolia, Acacia mangium,* etc. must be different since those species are at their best on poor sites but do not improve the soil over the medium and long term. More judicious choices must be made according to the experiments conducted by **Aman and Despatie** in Bouaké (Ivory Coast) The specific value of RCW must be determined by testing different species according to the expected purposes **A classification of the native and foreign dendrological flora is definitely required for each region.**

All efforts must be made to promote the fact that the development is based on improved soils by introducing source of energy and by remaking the trophic web.

PLAN THE GRADUAL RESTORATION OF THE FOREST AND OF AN ANCILLARY AGRICULTURE

I want to underline the absolute necessity of persuing the goal for restoring the forest with the native species, whose "**experience**" or memory has been formed over million of years. Like any forests, all are very fragile and incredibly robust, a paradox which applies to all life form on this earth. Once rehabilitated a fertile soil should permit a rapid and stable return.

Going back to ***biodiversity,*** in Sahelian countries should be considered a return to nature, since the actual phenomenon is part of the history of Africa. Such efforts could be consistent with orientation followed by the biological history in that part of the world. The techniques associated with RCW are likely to be the only feasible scientific and economic solutions where needed for a medium and long term period. That promotion must be undertaken and carried out by Africans themselves, with available resources in the first place provided by the wealthy nations of the world.

The recovery of this region of the world can only take place by restoring the vanished forest, but not by single-species plantations. History teaches us the painful lesson how the agricultural techniques used in temperate climates are not suitable for tropical countries, particularly in the Sahel. Knowledge and techniques must be reexamined in order to understand why that happens. The RCW simple technique is proposed, but scientific ramifications are extremely complex and very attractive for researchers.

The **enthalpic** trends must be reversed in this corner of the globe by introducing, through technical and by voluntary means, **entropic** trends, related to law of physics which have supported the growth of the industrial world. The investments coming from the developed countries must be reoriented toward unprecedented innovations, but driven by a sound logic. The basic knowledge specific to Sahel must be increased as well as for other countries since pedogenesis is one of the most important biological phenomena on this planet.

The need of establishing an embryonic international organization, must be recognized with only one goal which is to collect both the scientific and traditional soil techniques in relation with the chemical, microbiological, and anthropogenic mechanisms, with regard to their influence on climate and on human and animal diseases.

This set of proposals is the main key to change. This key could be easily lost in the sands of a desert unless rapid changes happen. When I think about the future of my own children in this world built by our rules, I find myself more often inclined to cry than to smile, but turning to this universal treasure, the soil, I realize everything is possible. After the darkness comes the light!. Thank you.

GLOSSARY

agregates: particules linked to one another by a biological cement, the basis of soil structure. It also provide basic food for the microbiological life of soil.

agroforestry: agricultural production techniques in relation with forest canopy, and with soils upgraded by RCWs.

arboreal: what is concerned with trees.

Basidiomycetes: a family of fungi konwn as mushrooms mostly growing in forests They are mainly responsible for depolymerizing lignin without breaking benzenic rings

benzenic (rings): a basic molecule highly energetic related to benzene. The term aromatic is also commonly used.

biodiversity: concept where life forms are numerous, diverse and living in harmony. Example: the deciduous forest and its fauna and flora.

chelation: natural or artificial phenomenon in which a molecucle become static, being locked in a complex inhebiting system.

chipping: cutting into chips, twigs of various sizes.

climax: term relative to self-perpetuating plant societies in equilibria with all environmental factors

clay-humus: complex of both clay and humus giving birth to soil aggregates, the very basis for soil fertility.

compost: organic matter of various origin transformed mainly by bacterial breakdowns with heath production, making nutrients available to plant growth.

deciduous: Phanerogam Dicotyledon trees shedding or not their leaves and and found in forest areas.

degradation: the loss of integrity of a substance and energy content applied to soil constituencies.

depolymerization: where organic molecules split in their basic elements.

desertification: natural or man made interactions on plant ecosystems leading to and stopping evolution by one of its basic factors namely a shortage of water availability.

ecosystem: biological system allowing different life forms living more or less in harmony within cycles or in full continuity.

ecoviability: concept meaning that harmony is an absolute necessity in order to complete cycles with or without reference to productivity.

enthalpy: term issued from the thermodynamic related to the entire energy of a system with no reference to its dispersion.

entropy: term issued from the thermodynamic related to a disorder state toward an other system.

enzymes: complex structure protein molecule which favor, increase or allow difficult biological reactions, otherwise impossible.

fertilizers: chemical or organic nutrients applied to increase soil fertility and consequently crop yields.

flora: plants characteristic of a region or a topographic feature of a region or a country. Example: the Québec flora, the tidal zone flora of the Saint-Laurent river, etc..

fulvic (acid): low weight molecule issued from the lignin depolymerization, one of the basic element of the pedogenesis. It is one of the two molecules produced by the Basidiomycetes lignoperoxidase manganese dependant or laccase from bacterial origin.

humification: natural processus where organic debris are changed into humus.

hypogeous: indicating that is below the surface. Example: the hypogeous flora of a forest.

laterite: tropical red colored soil where iron alluminium and silicium are not linked to one antoher and where biological agents play an important role.

microbial biomass: the whole amount of microscopic living organisms in the soil.

Minamata (disease): Japaneese city which has given its name to a central nervous system disease due to organo-mercuric polluted food.

mineralization: natural soil degrading process making available the nutrients found in organic debris and transformed by microorganisms.

monomers: simple organic molecule enable to give birth to other complex ones through the polymerization processus. where new links may contribute to form additionnal groups of the same nature.

morphology (soil): the form and colour of soil due to its structure and texture giving specific physical and biological properties to the soil.

nematodes:small worms, mostly microscopic, belonging to the class *Nematoidea* living as parasites on plants and animals.

nutrients: chemical and organic elements used by the plants

organic (matter) a most ambiguous term in reference to organic debris in soil but not to humus or humification processus.

organo-mercuric: compound where mercury is tied to an organic molecule becoming a powerful poison for the central nervous system.

pedogenesis: natural processus by which soil exist and maintain throughout dynamic phenomenons. It implies nutrient flow regulation for plant growth as well as epigeous and hypogeous equilibrium in ecosystems.

physico-chemistry: science relevant to both chemistry and physic sciences with specific properties and consequences. Example: pH measure dissociation in between hydrogen ions.

podzol: issued from the russian terminology and refering to soil with aa ashy and eluvial horizons and characteristic of conifer forests. Numerous specific chemical, biochemical and biological mechanisms are responsible for.

polyphenols: derivative phenolic compounds based on benzenic rings

RCW: **R**amial **C**hipped **W**ood. Branches of less than 7 cm in diameter with a high nutrient content. It has little polymerized young lignin linked to highly complex biochemical systems and in a transitory status toward stemwood.

regeneration: natural processus in which forest can regenerate three seeging,regrowth and in close connection to flora and fauna.

sustainable: term used by international agencies with reference to continuous productivity. Example: sustainable development, sustainable agriculture, etc.

upgrading: processus evolving toward a higher complexity and energy content.

web (food or trophic): plants and animals acting directely on the transformation of plant and animal tissues into nutrients and soil energy from the soil to the plants.

xeric: environments with a water deficit in regard of an optimum life. It can be caused by climate, or topographic and soil charateristics.

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THE BASICS OF THE ECONOMICAL AND SCIENTIFICAL GREEN REVOLUTION OF SAHEL

For the last quarter century the boom of knowledge has led to many to frightening conclusions but has also brought hope as never before. A cropping activity at first, agriculture rushed into the high production fields lead by chemistry, physics and physico-chemistry at the end of the last century. The results achieved must be seen as the most important since man has existed on earth. However, the last ten years has shown a threshold from which the economic profitability of techniques is deeply questioned. This is underlined by a decrease in industrial productivity, money value and basic real productivity. Our social and economic problems seem to reflect this reality. We have taken sustainable development as a goal to achieve with regard to renewable resources. By the same token we guess about rules we know very little about while using current models as to make long term predictions. We all agreed upon the fact that this economic collapse was limited to the Third World, since our knolwge and skills was so high, afforded an unbeatable shelter against predictable catastrophies, even if they were taking place in various forms. At the end of the seventies we have explored fields where poverty was flourishing in the face of abundance and wealth. Most of the time one's wealth is seen as abundant precious metals or material of industrial value such as wood and agricultural products. Management of such a common wealth has led us to forget the most important wealth of all: life and all its components. While we thought that scientists were taking care of oceans in order to maintain fertility and productivity, we paid little attention to what we thought to be the best known and humble: the soil. We were striken by the fact that its biological aspects, in other words the life in all its complexity, were never seriously taken into account; only nutrient and mineralization mecanisms were seriously studied. Our curiousity motivated us to examine more closely the humification process; the universal model for this process is found in forest ecosystems. As time went by, we recognized the relation existing between the canopy and the underlying soil. The scientific discoveries of the last decade have shown the importance of lignin and more spcifically the less polymerized lignin, that generates fertility in forest soils. Twigs and branches having this "young", lignin also contain more than 70% of all the nutrients necessary for plant growth. In addition to chemical nutrients, these branches also contain sugars in many forms, celluloses, hemicelluloses and lignin, with all amino acids, a high number of protein, vitamins, hormones and a large number of enzymes. We have chipped those branches in small pieces those branches, material that was always perceived through the centuries as a symbol of poverty, and mixed the material with agricultural soil or forest litter. Rapidly, yield increases were achieved in agriculture and remarkable effects were noted on germination and regeneration in forestry. We then put forward the hypothesis that this process was universal and established scientific experiments in Africa and the Caribbean Islands. Results achieved were much more important than those under our climatic conditions, giving access to a potential green revolution. It is by the integration of nutrients and energy to the soil and mecanisms allowing food web installation and maintenance that agricultural soils are falling under a "forested" regime.. This puts the "biological production machine" back on its feet with the proper management of water, and nutrient availability, and when necessary, by stopping pollution. The most economical solution with regards to Sahelian Africa is to favour economical production and utilization of Ramial Chipped Wood **(RCW)** from plantations instead of burning or leaving this precious material to rot. Arguments put forward are important and must be taken into account from the social and economical standpoint, for biological, scientific and historic reasons.

RÉSUMÉ

LES GERMES ÉCONOMIQUES ET SCIENTIFIQUES DE LA RÉVOLUTION VERTE AU SAHEL

L'évolution rapide des connaissances au cours du dernier quart de siècle a conduit à des constatations qui en effraient plus d'un, mais qui apportent des espoirs sans pareil. L'agriculture, d'abord activité de récolte, puis de production, s'est engouffrée dans les sentiers tracés par la chimie, la physique et la physico-chimie au siècle dernier. Les résultats obtenus peuvent être considérés comme les plus importants depuis que notre civilisation existe. Au cours des dernières décennies, les faits nous incitent à comprendre que nous avons atteint un seuil à partir duquel la rentabilité des techniques est mise en cause avec des répercussions sur l'industrie, la valeur des monnaies et la productivité réelle. Les difficultés économiques et sociales que nous subissons en sont la preuve. Nous avons opté pour un développement durable en ce qui regarde les ressources renouvelables, mais nous nous épuisons en conjectures en prenant les tendances actuelles comme modèle à long terme.Tous ont cru au début que cet effondrement était le lot des pays du sud et que nos connaissances préservaient ceux du nord des catastrophes annoncées, bien que celles-ci prennent forme sous les aspects les plus divers. Ainsi, dès la fin des années 70, n'avons-nous pas exploré des domaines où la pauvreté semble se plaire et se développer, mais en présence de richesses de toutes sortes? Plusieurs ne voient la richesse que sous forme de métaux, précieux ou abondants, d'importance industrielle, tout comme pour les bois et les productions agricoles. La gestion de ces richesses nous a fait collectivement oublier la plus grande de toutes: la vie avec toutes ses composantes. Alors que nous pensions que les scientifiques s'occupaient de la mer pour en maintenir la fertilité et la productivité, nous nous sommes penchés sur ce que nous croyions de plus humble et de mieux connu: le sol. Notre surprise fut totale en constatant que tous les aspects biologiques, c'est-à-dire la vie, même dans toute sa complexité et sa signification, n'avait été prise en considération que d'une manière bien timide, sauf en ce qui regarde la minéralisation et les nutriments. Ceci nous a

amené à examiner de plus près le processus d'humification, dont le modèle universel est celui de la forêt. C'est ainsi que nous en sommes venus, au fil des ans, à reconnaître la relation qui existe entre la cime des arbres et le sol sous-jacent. Les découvertes des dix dernières années ont montré l'importance de la lignine, et plus particulièrement celle qui est peu polymérisée, dans la genèse et la fertilité des sols forestiers. En plus d'une forte concentration de nutriments, les rameaux contiennent une énergie considérable sous formes de sucres, celluloses, hémicelluloses et lignines, auxquels s'ajoutent tous les acides aminés et un grand nombre de protéines, vitamines, hormones et enzymes. Nous avons donc imaginé de fragmenter ces rameaux qui, sous toutes les latitudes et de tous les temps, ont été perçus comme le symbole même de la pauvreté et de la déchéance, et de les incorporer au sol ou à la litière, selon que nous sommes en agriculture ou en foresterie. Très rapidement, les résultats se sont manifestés par des augmentations de rendement importantes des produits agricoles et maraîchers, ainsi que par des effets remarquables sur la germination et la régénération en forêt. Ayant émis l'hypothèse que les processus que nous observions devaient être universels, nous entreprîmes des expériences agricoles en Afrique et aux Antilles. Les résultats furent supérieurs à ceux obtenus sous climat tempéré, ouvrant ainsi la porte à une révolution verte que nous n'avions pas prévue au départ. C'est en intégrant au sol l'ensemble des nutriments et les mécanismes impliqués dans la création et le maintien des chaînes trophiques que les sols agricoles passent à un régime «forestier». Ceci remet en activité la «machine biologique de production» en assurant la gestion à la fois des sols, de l'eau et la disponibilité des nutriments, lorsqu'ils sont nécessaires, évitant ainsi le gaspillage et la pollution qui peuvent en découler. La solution la plus économique, en ce qui a trait à l'Afrique sahélienne, nous semble liée à la production économique de bois raméal fragmenté (**BRF**) à partir de plantations, plutôt que de réserver les rameaux au bois de feu ou à l'abandon. Les arguments que nous apporterons sont importants et méritent qu'on s'y attarde du point du vue social et économique, pour des raisons biologiques, scientifiques et historiques.

RESUMEN

ORIGENES ECONOMICOS Y CIENTIFICOS DE LA REVOLUCION VERDE EN SAHEL

La rapidá evolución de los conocimientos a lo largo de este último cuarto de siglo ha conducido a ciertas constataciones que asustan a más de uno, pero que son portadoras de una gran esperanza. La agricultura, en un principio actividad cosechera y después de producción, se ha adentrado por senderos marcados por la química, la física y la físico-química durante el siglo pasado. Los resultados obtenidos pueden considerarse como los más importrantes desde que nuestra civilización existe. En el transcurso de las últimas décadas, los hechos nos incitan a pensar que hemos alcanzado un nivel, a partir del cual la rentabilidad de las técnicas es puesta en tela de juicio, con repercusiones sobre la industria, el valor de la moneda y la productividad real. Las dificultades económicas y sociales de las que somos testigos hoy son la prueba. Hemos optado por desarrollo sostenible en lo que respecta los recursos renovables, pero nos perdemos en conjeturas al tomar las tendencias actuales como un modelo a largo plazo.Todo el mundo creyó que este hundimiento era exclusivo de los países del sur y que nuestros conocimientos preservarían a los del norte de las catastrofes anunciadas, aunque éstas se materializan bajo los más diversos aspectos. Así pues, desde el final de los años 70, ino hemos explorado sectores en los que la pobreza parece complacerse y desarrollarse, pero en presencia de todo género de riquezas? Mucha gente ve la riqueza solamente bajo la forma de metales, preciosos o abundantes, con importancia industrial y lo mismo para el bosque y la produccion agrícola. La gestíon de esta riqueza nos ha hecho olvidar colectivamente la mayor de todas: la vida, con todos sus componentes. Mientras pensábamos que los científicos se ocupaban del mar para mantener su fertilidad y productividad, nosotros hemos vuelto los ojos a lo que creiamos lo más humilde y mejor conocido: el suelo. Nuestra sorpresa fue total al constatar que todos los aspectos biológicos, es decir, la vida misma, con toda su complejidad y significación había sido considerada muy someramente, excepto en lo concerniente a la mineralización de los elementos nutritivos. Esto nos ha conducido a examinar con más detalle los procesos de humificación, cuyo modelo universal es el bosque.Fue así como llegamos, en el correr de los años, a reconocer la relación existente entre la cima de los árboles y el suelo que los soporta. Los descubrimientos realizados en estos últimos diez años han puesto de relieve la importancia de la lignina y, más específicamente, aquélla que está poco polimerizada, en la génesis y la fertilidad de los suelos forestales. Ademas de una alta concentracion en elementos nutritivos, las ramas contienen una considerable energía bajo la forma de azúcares, celulosas, hemicelulosas y ligninas a lo que hay que anadir todos los aminoácidos y un gran numero de proteínas, vitaminas, hormonas y enzimas. Hemos pensado, pues, en fragmentar estas ramas que, en todas las latitudes y en todos los tiempos, fueron considereadas como el símbolo mismo de la pobreza y de la decadencia, e incorporarlas al suelo o a los residuos vegetales superficiales, segun se trate de la agricultura o de las ciencias forestales. Rapídamente los resultados se han traducido en importantes aumentos del rendimiento tanto en cultivos agrícolas extensivos como hortícolas así como en notables efectos sobre la germinación en el bosque.

Habiendo aceptado la hipótesis de que los procesos que observamos debían tener ambito universal, emprendimos una serie de experiencias en Africa y Las Antillas. Los resultados fueron superiores a los obtenidos en climas templados, abriendo, con ello, la puerta a una revolución verde que no habíamos previsto en un principio. Es, precisamente, al integrar al suelo el conjunto de los elementos nutritivos y los mecanismos implicados en la creación y el mantenimiento de las cadenas tróficas como los suelos agrícolas pasan a un régimen "forestal". Todo esto activa la "maquína biológica de producción" asegurando, a la vez, la gestión de los suelos, del agua y la disponibilidad de los nutrientes, cuando éstos son necesarios, evitando así el consumo inútil y la contaminación que esto trae

consigo.La solucion más económica, en lo que respecta al Africa saheliana, nos parece que va ligada a la producción de madera rameal fragmentada **(MRF)**, a partir de plantaciones mejor que destinar estas ramas a la combustión o al abandono. Los argumentos que aportaremos son importantes y merecen ser tomados en consideración desde el punto de vista social y económico, por razones biológicas, científicas e históricas.

RESUMO

OS PRINCÍPIOS ECONÓMICOS E CIENTÍFICOS DA REVOLUÇÃO VERDE NO SAHEL

A evolução rápida dos conhecimentos no decurso do último quarto de século conduziu a resultados que perturbam algumas pessoas mas que auguram esperanças sem paralelo. A agricultura, antes do mais uma actividade de colheita após a produção, tem sido submersa pelos ditames traçados pela química, pela física e pela físico-química durante o último século. Os resultados obtidos podem ser considerados como os mais importantes desde o início da nossa civilização. No decurso dos últimos decénios, os factos levam-nos a compreender que atingimos um limiar a partir do qual a rendibilidade das técnicas é posta em causa com repercussões sobre a indústria, o valor das moedas e a produtividade real. As dificultades económicas e sociais que suportamos são a prova disso. Temos optado por um desenvolvimento sustentável no que respeita aos recursos renováveis, mas esgotamo-nos em conjecturas ao tomarmos as tendências actuais como modelo a longo prazo. Inicialmente, todos pensaram que a derrocada apenas afectava os países do sul e que os nossos conhecimentos preservariam os do norte contra as catástrofes anunciadas, ainda que estas se apresentassem sob as formas mais diversas. Assim, desde o final dos anos 70, não explorámos nós os domínios onde a pobreza medra e se desenvolve, apesar das riquezas de vária ordem? Muitos não vêem a riqueza senão sob a forma de metais preciosos ou abundantes, de importância industrial, o mesmo se passando em relação às produções florestais e agrícolas. A gestão destas riquezas levou-nos colectivamente a esquecer a maior de todas: a vida com todas as suas componentes. Ainda que pensássemos que os cientistas se ocupavam de tudo para manter a fertitidade e a produtividade, nós estamos inclinados para o que pensávamos ser mais simples e melhor conhecido: o solo. A nossa surpresa foi total ao constatarmos que todos os aspectos biológicos, isto é, a vida, mesmo em toda a sua complexidade e significado, não tinha sido tomada em consideração a não ser de uma forma tímida, salvo no que respeita à mineralização e aos nutrientes. Tal facto levou-nos a examinar com mais cuidado o processo de humificação, cujo modelo universal é o da floresta. É assim que, com o decorrer dos anos, chegámos a reconhecer a relação que existe entre a parte aérea das árvores e o solo subjacente. As descobertas dos dez últimos anos mostraram a importância da lenhina, e mais particularmente da que é pouco polimerizada, na génese e fertilidade dos solos florestais. Além de uma forte cencentração de nutrientes, os ramos contêm uma energia considerável sob a forma de açúcares, celuloses, hemiceluloses e lenhinas, aos quais se juntam todos os ácidos aminados e um grande número de proteínas, vitaminas, hormonas e enzimas. Em face disso, resolvemos proceder à fragmentação destes ramos, conhecidos, em todas as latitudes e em todas as épocas, como símbolos da pobreza e da degradação, incorporando os fragmentos correspondentes no solo ou utilizando-os em cobertura, consoante as actividades se desenvolvem no domínio da agricultura ou da floresta. Muito rapidamente, os resultados têm-se manifestado através de importantes aumentos de rendimento em cultutras arvenses e hortícolas, bem como de efeitos assinaláveis sobre a germinação de sementes e regeneração da floresta. Tendo formulado a hipótese de que os processos observados deveriam ser universais, procedemos ao estabelecimento de experiências agrícolas em Africa e nas Antilhas. Os resultados foram superiores aos obtidos em climas temperados, abrindo-se assim a porta a uma revolução verde que não havíamos previsto no início. É através da incorporação no solo do conjunto de nutrientes e através dos mecanismos implicados na criação e na manutenção das cadeias tróficas que os solos agrícolas passam a um regime "florestal", Deste modo, torna-se a pôr em actividade a "máquina biológica da produção", asseguarando a gestão simultânea dos solos, da água e da disponibilidade de nutrientes sempre que sejam necessários, evitando-se assim o desperdício e a poluição que poderiam resultar. A solução mais económica, no que respeita à África do Sahel, parece-nos estar ligada à produção económica de aparas de ramos fragmentados (**ARF**) a partir de plantações em vez de reservar os ramos para queimar ou deixá-los ao abandono. Os argumentos que iremos apresentar são importantes e merecem ser encarados sob o ponto de vista social e económico, por razões biológicas, científicas e históricas.

ZUSAMMENFASSUNG

DIE ÖKONOMISCHEN UND WISSENSCHAFTLISCHEN KEIME DER GRÜNEN REVOLUTION IM SAHEL.

Die schnelle Entwicklung der Kenntnisse in den letzen 25 Jahren hat zu Feststellungen geführt, die so mancher in Angst versetzen, die aber zugleich große Hoffnungen erwecken. Die Landwirtschaft, die ursprunglich nur Ernte war, ist später eine Productionsaktivität geworden und geht jetzt den von der Chemie, Physik und Physikochemie im letzten Jahrhundert vorgezeichneten Weg. Die erreichten Ergebnisse können als das Wichtigste betrachtet werden, was unsere Zivilization je erreicht hat. In den letzten Jahrzehnten, zeigten uns die Tatsachen, daß wir eine Schwelle erreicht haben, wo die Rentabilität der Techniken in Frage gestellt werden kann, was natürlich Auswirkungen auf die Industrie, den Wert des Geldes und auf die tatsächliche Produktivität hat. Die ökonomischen und sozialen Schwierigkeiten, die wir durchmachen, sind ein Beweis dafür. Wir haben uns für eine dauerhafte Entwicklung enschieden, was die ersetzbaren Reichtümer betrifft, aber wir verlieren uns in Vermutungen, weil wir die jetzigen Tendenzen als Modell annehmen für das, was auf lange Frist geschehen wird.

Anfänglich dachten alle, daß dieser Zusammenbruch das Los der südlichen Länder war und daß unsere Kenntnisse den Norden vor den angekündigten Katastrophen schützen würden, obwohl sie in den verschiedensten Formen auf uns zukommen. So haben wir nicht schon seit Ende der 70=er Jahre Bereiche untersucht, wo Armut anscheinend blüht und gedeiht und dies wo allerlei Reichtümer vorhanden waren? So mancher versteht unter Reichtum nur edle Metalle oder das Vorhandensein von Metallen in großen, industriellen Mengen, was auch für Holz und landwirtschaftliche Produktionen gilt. Die Bewirtschaffung dieser Reichtümer hat uns dazu gebracht den wichtigsten Reichtum zu vergessen nämlich das Leben und all seine Bestandteile. Während wir dachten, daß die Wissenschaftler sich für die Erhaltung der Fruchtbarkeit und der Produktivität des Meeres einsetzten, haben wir uns für das interessiert, was man für das bescheidenste und best gekannte Element hielten: den Boden. Unsere Überraschung war desto größer, als wir zu der Einsicht kommen mußten, daß alle biologischen Aspekte, d.h. das Leben selbst, in all ihrer Komplexität und in ihrer Bedeutung, nur sehr schüchtern in Betracht gezogen worden war abgesehen von was die Mineralisierung und die Nährstoffe betrifft. Dies hat uns dazu gebracht den Befeuchtungsprozeß, wobei der des Waldes als allgemeines Modell gelten kann, näher zu untersuchen.

Es hat im Laufe der Jahre zu der Einsicht geführt, daß es eine Beziehung gibt zwischen den Wipfeln der Bäume und dem darunterliegenden Boden. Die Entdeckungen der letzten 10 Jahre haben die Wichtigkeit des Holzstoffes gezeigt und besonders die des wenig polymerisierten Holzstoffes bei der Entstehung von Waldboden unf für seine Fruchtbarkeit. Die Zweige enthalten nicht nur eine große Menge an Nährstoffen, sie sind auch eine wichtige Energiequelle in Form von Zuckerarten, Zellulosen, Hemizellulosen und Ligninen, zu denen noch die Gesamtheit der Aminosäure, eine große Anzahl an Proteinen, Vitaminen, Hormonen und Enzymen hinzukommen. Wir sind also auf die Idee gekommen, diese Zweige, die überall und zu jeder Zeit als Symbol für Armut und Verfall angesehen worden sind, zu zersplittern und sie der Erde oder dem Streu, je nachdem, ob es sich um Landwirtschaft oder Forstwirtschaft handelt, beizumengen. Es kam sehr schnell zu Ergebnissen: eine große Steigerung des Ertrags der Landwirtschafts- und Gemüse-produkte und eine bemerkenswerte Auswirkung auf die Keimfähigkeit und auf die Regeneration des Waldes.

Von der Hypothese ausgehend, daß der festgestellte Prozeß universell sein mußte, hat man landwirtschatfliche Untersuchungen in Afrika und den Antillen unternommen. Es kam noch zu besseren Ergebnissen als in der gemäßigten Zone, was den Weg für eine echte grüne Revolution bahnte, die wir anfänglich gar nicht erhofft hatten. Durch Beimengen der Gesamtheit der Nährstoffe an den Boden und Einführung von aktiven Mechanismen die sorgen für die Entstehung und Erhaltung der trofischen Kette wird der Agrarboden von einer"Waldnahrung" profitieren. Dies alles führt zur Wiederbelebung der biologischen Produktionsmaschine und sorgt für die Erhaltung der Böden, des Wassers und das Vorhandensein der Nährstoffe wenn diese benötigt werden und verhütet eine Verschwendung und Verschmutzung, die sonst durch diese Nährstoffe verursacht würden.

Die billigste Lösung für den Sahel bietet uns wahrscheinlich die Produktion von zerstücktem Fragmentiertes Zweigholz **(FZH)** aus der Plantage, dies anstatt diese Zweige als Brennholz zu verwenden oder ungebraucht zu lassen. Die Argumente, die wir hervorbringen werden, sind wichtig und verdienen, daß man sie aus biologischen, wissenschaftlichen und historischen Gründen aus sozialen und ökonomischen Standpunkt näher betrachtet.

SAMENVATTING

DE ECONOMISCHE EN WETENSCHAPPELIJKE KIEMEN VAN DE ECOLOGISCHE OMWENTELING IN SAHEL.

De snelle ontwikkeling van de kennissen in de loop van de laatste 25 jaar heeft tot vaststellingen geleid die meer dan één schrik aanjagen, maar die tevens ongelooflijke hoop gewekt hebben. De landbouw, die zich oorspronkelijk tot het oogsten beperkte en pas later een produktieaktiviteit geworden is, is in de laatste eeuw de kant opgegaan van de chemie, de fysica en van de fysische chemie. Het bereikte resultaat kan beschouwd worden als het belangrijkste wat onze beschaving ooit opgebracht heeft. In de loop van de laatste decennia, laten de feiten ons zien dat we een punt bereikt hebben waar de rentabiliteit van de technieken in twijfel getrokken wordt, wat gevolgen heeft op de industrie, de waarde van het geld en op de feitelijke produktiviteit. De economische en sociale moeilijkheden die we ondergaan zijn een bewijs daarvan. Wat de hernieuwbare rijkdommen betreft, hebben we partij gekozen voor een duurzame ontwikkeling maar daarvoor nemen we de huidige tendenzen als werkhypothesen op lange termijn en raken wij in gissingen verloren.

Allen dachten eerst dat deze ondergang het lot was van het zuiden en dat onze kennissen ons voor de aangekondigde rampen - hoewel ze de meest gevarieërde vormen aanenmen - zouden beschermen. Zo, hebben we niet reeds sinds het einde van de jaren 70 gebieden bestudeerd waar armoede schijnbaar bloeit en gedijt en dat in aanwezigheid van allerlei rijkdommen? Sommigen verstaan onder het woord rijkdommen alleen maar edele metalen of metalen die in grote hoeveelheden voorkomen en bruikbaar in de industrie; hetzelfde geldt voor het hout of de agrarische produktie. De exploitatie van deze rijkdommmen heeft ons allen de grootste rijkdom laten vergeten, namelijk het leven en zijn bestanddelen. Terwijl we dachten dat de wetenschappers zorgden voor de instandhouding van de vruchtbaarheid en de produktiviteit van de zee, hebben we ons geïnteresseerd voor wat ons het meest gekende en het meest bescheidene element scheen te zijn: de bodem. Onze verrassing was des te groter toen we moesten vaststellen dat alle biologische aspekten, d.w.z. het leven, ook in zijn ingewikkeldheid en in zijn betekenis, bijna buiten beschouwing was gebleven, behalve wat de mineralisatie en de nutriënten betreft. Die heeft ons daartoe gebracht het bevochtigingsproces, waarvan het woud voor universeel model staat, nader te bekijken.

Dit heeft ons tot het inzicht gebracht dat er een verband bestaat tussen de kruin van de bomen en de onderliggende bodem. De ontdekkingen van de laatste 10 jaar hebben het belang laten zien van de lignine en meer bepaald van de weinig gepolymeriseerde lignine, bij het ontstaan van bosgrond en voor zijn vruchtbaarheid. Niet alleen bevatten de takken een grote concentratie aan nutriënten, ze zijn ook een ongeloofelijke energiebron in vorm van suikers, cellulozen, hemicellulozen en ligninen . Daarbij, moet nog de aanwezigheid van al de aminozuren, een groot aantal proteïnen, vitaminen, en enzymen vermeld worden. We zijn dus op het idee gekomen deze takken die steeds en overal als het symbool van armoed en verval worden beschouwd - tot snippers te verkleinen en ze met de aarde of het stro bij te mengen naargelang het de landbouw of de bosbouw betreft. De resultaten lieten niet op zich wachten: het kwam tot een belangrijke toename van het rendement voor wat de agrarische produkten en de groenteteelt aangaat, evenals tot opvallende resultaten voor wat het kiemen en de regeneratie van bossen betreft.

Uitgaande van de hypothese dat het waargenomem proces universeel moet zijn, zijn wij met agarische experimenten in Afrika en in de Antillen begonnen. De resultaten waren nog beter dan onder gematigde klimaat, zodat ze als baanbrekend beschouwd konden worden voor een echte "groene revolutie", die alle verwachtingen overtrof. De invoering in de bodem van alle nutriënten en ook van de processen die zorgen voor het scheppen en het instandhouden van de trofische verbindingen leidt tot de overgang voor de landbouwgronden tot een voedingspatroon kenmerkend voor de bosbouw. Dit wakkert de "biologische produktiemachine" weer aan en zorgt voor het beheer van de gronden, van het water en tevens van de nutriënten, alleen wanneer ze nodig zijn, zodat verspilling en pollutie die daarmee anders gepaard gaan kunnen vermeden worden.

De goedkoopste oplossing voor Sahelafrika schijnt ons geboden door de economische productie van versnipperd kruinhout uit de beplantingen, in plaats van die takken ongebruikt te laten liggen of als vuurhout te gebruiken. De argumenten waarop we ons zullen beroepen zijn belangrijk en verdienen om biologische, wetenschappelijke en historische redenen vanuit een sociaal en economisch standpunt nader bekeken te worden.

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