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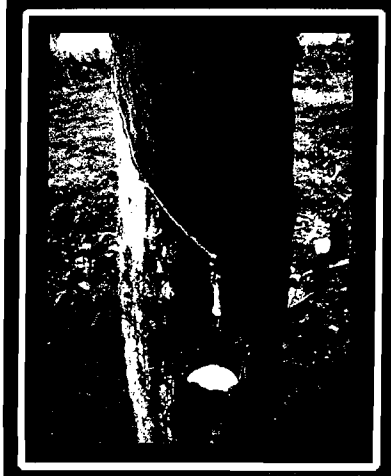

isionary Agriculture: Malaysian Commodity Crops In 100 Years"

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Poster Presentation

COMMODITIES IN A GLOBAL VISION FOR AGRICULTURE TOWARDS 2100

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Abstract - *It is impossible to see a hundred years into the future. So, how can we imagine what will become of commodity crops in Malaysia by 2100? Yet, worldwide, these commodity crops provide a living for hundreds of millions of people: how they evolve will have considerable economic, social and environmental consequences for many countries. It is therefore worth trying to steer that future rather than submitting to it. We adopted a three-stage approach to launch our deliberations on possible futures: an historical approach, an analysis of the current context, and hypotheses on possible developments. The historical approach draws lessons from a study of commodity crops up to the 20th century, taking the example of the cotton and palm oil sectors. The analysis of the current context brings out variables that are important for understanding the current situation and whose evolution could play a decisive role in future changes. Lastly, we propose imagining the future from three angles: the first, a trend hypothesis, prolongs the current major trends, with progressive and constructed changes; the second, a disaster hypothesis, describes certain key variables that are subject to sudden and imposed disruptions, and which could have serious repercussions for commodity crops; the third hypothesis is a positive fiction scenario applied to the palm oil sector, with severe but controlled and constructed breaks with trends. The conclusion draws lessons and identifies the limitations of the exercise, and proposes avenues for further deliberation. In order to construct the desired changes and keep abreast of foreseeable developments, it is essential beforehand to carry out a fine analysis of the variables of the context, their interrelations, and mechanisms for monitoring what becomes of them. Such an analysis requires the active participation of stakeholders in the sectors and players in the global context, some of whom have already undertaken foresight exercises: initially, it would be worth bringing together their results with a view to a true international foresight study.*

1- INTRODUCTION

Predicting the future of commodity crops in Malaysia by the end of the 21st century is an eminently difficult task, since it is impossible to see 100 years into the future. Forecasters rarely venture into such distant time scales and even specialists in foresight exercises - whereby possible futures are imagined, backed up by solid hypotheses on the evolution of numerous key variables - usually consider the exercise to be impossible beyond 20 to 25 years. Our approach is therefore risky, since it lies outside the strict framework of scientific rigour, but if we have the wherewithal to start constructing those deliberations, it is worth examining their limitations and weaknesses, and proposing ways of enhancing them.

Considering the prospects for commodity crops by 2100 first means asking whether there will still be any commodity crops by that date. If the answer is yes, let us try to imagine what they will be: what uses and externalities will they have to face? To answer those questions, we adopted a three-stage approach: an historical approach, an analysis of the current context, and hypotheses on possible developments.

We have chosen to begin in the past. What does the history of commodity crops in the 20th century tell us? Could the current status of commodity sciences and economics in 2007 be foreseen in 1907? A brief look at the history of cotton and oil palm is the first step in our study.

We then go on to analyse aspects of the current context because history shows that, whilst certain breaks with trends are totally unexpected, others are changes in

relation to a given context. To illustrate that, we have taken some variables that are felt to be important, bearing in mind that it is impossible to consider or study all the variables that might play a decisive role.

Lastly, based on prospective methods, though without claiming to be conducting a true foresight exercise, we propose to imagine the future from three different angles. The first is a trend hypothesis and consists in prolonging the current major trends, with gradual or constructed developments. Through it, we attempt to imagine the position of commodity crops. Then, in the second hypothesis, we examine strong, sudden and imposed disruptions that might have disastrous consequences on a world scale and serious repercussions for commodity crops. Lastly, in the third hypothesis, we describe a positive fiction scenario, with strong but controlled and constructed breaks with trends, which we have applied to the palm oil supply chain.

Our conclusion focuses on the lessons that can be drawn from this analysis as a whole. We also discuss its limitations and also consider the possibility of going further: how and in what form can we envisage a more ambitious, more rigorous exercise? The answer to that question is important, as the livelihoods of hundreds of millions of people depend directly on commodity crops, and it is our duty to work for their future.

2- HISTORICAL ANALYSIS OF THE COTTON AND PALM OIL SECTORS

George Orwell wrote *"He who controls the past controls the future"*. It is in that spirit that we have chosen to prepare for the future by analysing the past evolution of two major sectors, cotton and palm oil. We shall see that contrasts and similarities exist between the two. An historical analysis of those contrasts and similarities shows that forecasting 100 years ahead for a commodity crop is *apparently* impossible, though it does make it possible to establish variables for a "foresight" type analysis.

2.1- Eight thousand years of history for the cotton sector

Eighty countries grow cotton on 36 million hectares and produce 26 million tonnes of fibres, for an estimated value of 30 billion dollars. Textile use of cotton goes back to the earliest civilizations: cotton fibres 7,200 years old have been found in Mexico, and 8,000 years old in the Indus valley. The expansion of cotton has been closely linked to technological progress over the centuries, and the current global cotton map has been drawn by geopolitical circumstances.

First, fibre processing

18th and 19th centuries, major technological events

Since ancient times, India has had the world monopoly on cotton production and processing: Greeks, Romans, Arabs, then Europeans imported its luxurious cotton goods. However, in the 18th century, English industrialists succeeded in mechanizing Indian processing technologies: it brought an end to Indian supremacy and Europe started importing raw fibre.

Nevertheless, post-harvest processing continued to hold back an expansion in production: ginning, i.e. separation of fibres from the seed, was manual. One person ginned fewer than 3 kilos of fibre per day. But, in 1793, the American Eli Whitney invented the saw gin, a machine which then ginned 12 kilos of fibre per hour! That technical revolution contributed to the boom in modern cotton growing in the USA. In 1861, the USA produced 973,000 tonnes of fibre, i.e. 82% of world production at the time. England, the main purchaser of American cotton, then monopolized the textile industry.

At the end of the 19th century, in Europe, the invention of ring spinning and the automatic loom led to a large gain in productivity. Consequently, the British textile industry lost its supremacy and shared cotton

processing with the other European countries and the USA.

20th century, rivalry then complementarity of artificial fibres

In the 1950s -1960s, cellulose and synthetic fibres flooded onto the market, and the share of cotton fibre fell substantially, arriving today at 48% of textile fibres consumed worldwide. That share is stabilizing: artificial fibres are now combined with cotton to create new textiles.

Then, agronomy

20th century, agronomic progress makes its mark

In 1912, the world area planted to cotton was 24.1 million hectares with a fibre yield of 242 kg/ha. It took until the 1970s to reach 400 kg/ha. Between 1996 and 2006, yield rose from 575 to 742 kg/ha and, by 2006, the world cotton area amounted to 36 million hectares. Initially, irrigation was a major factor - today, more than 47% of cotton areas are irrigated. Then, pesticides enabled a leap forward, along with fertilization. Lastly, the rise over the last decade was partly due to the boom in genetically modified cotton plants, which now occupy 45% of the areas.

Harvesting machines have also provided considerable progress, making it possible to maintain or develop production in some countries, such as the USA, Brazil, Australia and Uzbekistan.

End of the 20th century, varietal selection takes up the challenge of fibre quality

In recent years, varietal selection has helped to improve the technological characteristics of fibre, which are expressed all the better when production factors are effectively mastered, and has also helped to adapt those characteristics to processors' requirements. For instance, the development of open end cotton mills since 1990, which spin twice as fast as ring spinning, has led to a search for stronger fibres. Quality aspects are taking on increasing importance and generalization of the automatic classification of fibre batches in the USA as early as 1991 is the most tangible illustration of that. The other countries are following suit, with Australia and Brazil taking the lead, and the measures achieved in that way are increasingly becoming a reference.

Oil and by-products: other added-values

Much use is made of the oil obtained from cottonseed crushing. With 5 million tonnes produced per year, it ranks fifth in the world oils league. There is little cottonseed oil on the international market because there is strong local demand. Although used as an edible oil in the USA and the other producing countries, it also has multiple applications in the agrifood, soap making and, more recently, biofuel sectors. The by-products of cottonseed crushing are also used: presscakes for livestock feed, linter for papermaking and chemistry, and the husk for energy production.

A geographically mobile sector

Wars, factors of geographical distribution

From 1861 to 1865, the War of Secession temporarily paralysed American production and the European industrialized nations took advantage of that to start growing cotton in their colonial empires. However, that did not prevent the revival of American cotton and the world fibre price then depended on the quantities of cotton harvested in the USA. Then, World War I led to a break between suppliers and buyers of raw fibre, thread and fabric. Some countries then equipped themselves with a textile industry, others embarked upon cotton growing. World War II, then the independence of many producing countries further accelerated that expansion.

Over 80 producing countries, but an Asian textile industry

Despite the vast distribution of cotton growing in more than 80 countries, 90% of production is now concentrated in ten

countries. The leading four produce 68% of world fibre: China, USA, India, and Pakistan. Brazil comes in fifth position, followed by Uzbekistan, then French-speaking Africa, and lastly Turkey, Australia and Greece. China, the leading producer for more than 20 years, is also the leading importer and the leading processor, using up 40% of world cotton. The USA, the second leading producer, but main exporter, retains its dominant position. Although French-speaking Africa is the world's sixth leading producer, it is nevertheless the world's second exporter, with small family farms producing good quality cotton. Among the big four, China, India and Pakistan are importers and are also the three leading textile countries. Thus, after two centuries of Western supremacy, the beginning of the 21st century is characterized by the relocation of the textile industry to Asia, the birthplace of cotton processing a thousand years ago.

2.2- Palm oil, world leader in half a century

Throughout the 20th century, the oil palm conquered new territories and markets and the oil palm industry became a major player in Southeast Asia. A truly explosive expansion took place in the last quarter of the 20th century. In 2006, palm oil headed the oils and fats league, with 38 million tonnes, amounting to 30% of world vegetable oil production.

Up to the turn of the 20th century, an African gathering sector

The oil palm originates from the Gulf of Guinea in intertropical Africa. Wild oil palm groves were exploited there as part of the gathering economy for local food purposes. In Brazil and the West Indies, the oil palm followed the slave trade routes in the 16th century. In Southeast Asia, it was reported in the 19th century as an ornamental.

It was in the mid-19th century that Europe, notably England, started showing an interest in the oil palm in its colonial empires. It began to import palm kernels (oil palm seeds), along with some palm oil derived from the mesocarp of the fruit. Extraction was still of too poor a quality for agrifood use, but it suited industrial uses, such as candle, soap, margarine, glycerine and lubricant making. As the wild oil palm groves were near the coast, they benefited from the newly created African railway lines. Up to the first quarter of the 20th century, oil palm picking and trade in palm kernels and palm oil virtually only concerned Africa on the Gulf of Guinea and colonizing Europe, with England at the helm.

Mid-20th century, industrialization and a shift to Asia

At the same time, right at the beginning of the 20th century, some Europeans launched the first agroindustrial plantations in Sumatra, then in Malaysia. By 1938, 120,000 hectares had already been planted in Indonesia and Malaysia, which was already exporting more than the whole of Africa. It has to be said that the climate in Southeast Asia is ideal! Rainfall, sunlight and temperature conditions there are much more suitable than in the Gulf of Guinea. The soils too: the volcanic soils of Sumatra are incomparably more fertile than most African soils. Exploitation of cultivated oil palm plantations led to a radical change in world production, and there was a gradual shift from Africa to Asia.

From the 1960s onwards, estates were planted in several Latin American countries. Nigeria, the world's leading producer and exporter, along with Zaire, virtually no longer exported anything. Ivory Coast became a small exporter. Following its independence in 1957, Malaysia started out on its course to become the world's leading producer and exporter through its rubber tree diversification policy. At the same time, socio-political circumstances handicapped Indonesia, but it started catching up in the 1980s and that country is now hard on the heels of Malaysia. Also from the 1980s onwards, other Southeast Asian countries embarked upon industrial production. Today, 40 countries, all in the intertropical zone, grow oil palm, but only two countries,

Indonesia and Malaysia, account for 86% of world palm oil production.

From 1940 onwards, agronomy and technology advance together

Up to the turn of the 20th century, industrialists were more interested in palm kernel oil, because the nut from which it was extracted was easier to transport and store than palm oil. The palm oil trade then really took off between the two World Wars, with the development of agroindustrial oil palm estates and considerable improvement in oil extraction technology.

Between 1940 and 1960, breeding of the *dura* oil palm, then crosses between *tenera* and *dura* palms, then *dura* and *pisifera*, resulted in a spectacular increase in the proportion of mesocarp and oil in the fruit. Agronomic progress, notably mineral fertilization with leaf analysis, also greatly improved yields. For instance, whilst only 300 kg of oil/ha was achieved at the beginning of the 20th century in wild groves, which corresponded to the productivity of annual oil crops, productivity reached 3 tonnes of CPO (Crude Palm Oil) per hectare in cultivated oil palm plantations in 1945 and 4 t/ha in the 1980s.

At the same time, extraction technologies were adapted with the invention of the screw press. The capacity of oil mills rose from a few hundred kilos of fruits processed per day in 1911 to more than 60 tonnes of FFB per hour today.

Since 1980, palm and palm kernel oils have dominated the market

In the 1970s, Malaysia and Indonesia established refineries, to use palm oil for human consumption, in addition to traditional coconut oil whose production was stagnating. Coconut oil was gradually reserved for export to industrialized countries. On the world market, palm kernel oil also compensated for the chronic lack of coconut oil, as the composition of those two oils is very similar.

In 1981, introduction of the pollinating insect *Elaeidobius kamerunicus* revolutionized production in Southeast Asia: natural pollination by those insects, which greatly increased fruit-set, replaced laborious hand pollination, which was very labour-intensive and not very efficient.

The oil palm, which is incredibly productive, has robbed the American and European continents of their supremacy in oils and fats production based on annual oil crops, which are ten times less productive. In the 1980s, the USA attempted to destabilize palm oil, a major rival of soybean oil, by comparing it to some animal fats. Those arguments were scientifically disparaged by nutritional studies, which showed the great versatility of palm oil use, its high technological stability, and the pointlessness of hydrogenization when used as an ingredient in margarines. Today, palm oil is thus ubiquitous in agrifoods: 80% used for human consumption and 20% for industrial uses.

In the 21st century, a stand-off between oils and the environment?

But the oil war is not yet over. It is shifting to the ecological field: indeed, the expansion of oil palm growing tends to increase the destruction of forests and their biodiversity. But, on the other hand, the limitless development of soybean cultivation appears to be the major culprit in the degradation of natural environments in South America over much wider areas than those newly planted to oil palm.

With the rise in petroleum oil prices, it is technically easy to replace it partially with vegetable oils as biofuels, especially with palm oil, which is the cheapest. Several questions then arise: how can palm oil production be stepped up to meet increasing agrifood, lipid chemistry and now biofuel requirements, whilst sparing biodiversity? How can rivalry be avoided between food and energy demands, which are both strategic?

2.3- To conclude, the historical vision brings out "foresight" variables

This brief historical analysis shows that no futurologist, as visionary as he might be, could imagine in the 1900s what the future of these commodities would be in 2007! It reveals strong contrasts in the evolutions observed:

- a history going back several thousand years for cotton, only two centuries for palm oil,
- a large international market for cotton, whereas trade was very limited for palm oil at the beginning of the 20th century,
- phases of fierce competition with other products of the same type (oil) or a different type (synthetic fibres).

But it also shows us that these two sectors have experienced very similar strong events over the centuries:

- a boom in the areas planted, yields and agricultural performance,
- decisive technological events, notably with improved varieties, agricultural practices, post-harvest processes,
- a major planetary shift in production, processing and markets, associated with social or economic upheavals,
- the importance of quality (fibre technology for cotton, chemical composition for palm oil).

These aspects of the sectors' evolution need to be taken as variables in a "foresight' type analysis. The same analysis in other sectors brings out other variables, and makes it possible to appreciate their incidence on the scale of a decade or a century. This brief historical vision shows us, however, that one should not limit oneself to a sectorial vision by supply chain, but that studies should be opened up to experts from outside the agricultural sector, such as demographers, doctors, or legal experts.

3- CURRENT CONTEXT: KEY VARIABLES FOR THE FUTURE

The historical analysis of the cotton and palm oil sectors brought out breaks in trends, some of which were totally unexpected, whilst others fitted in with changes in context. For the exercise in which we are involved, by the end of the 21st century, unpredictable breaks in trends can only be dealt with from a fictional angle. However, it is necessary to study the variables of the current context: what becomes of them is, of course, decisive for the future of agriculture in human activities. An analysis of those evolutions will enable us to identify variables whose role might be decisive in major agricultural changes, be they on a national, regional or global scale.

In theory, those variables are many. They concern the global and demographic context, the strategies of the major stakeholders, international regulations, the dynamics of production and consumption, the betterment of knowledge and technical progress, and the availability of planetary resources.

We have chosen to outline a brief analysis of variables in the current context, by illustrating some of those which we feel to be important in terms of externalities and uses linked to commodity crops: competition between natural and synthetic production, food supplies, land management, landscape, forest environments, energy needs, climate change, and the globalization of trade.

3.1- Natural-synthetic competition: the example of wood and rubber

Wood was long the main raw material for energy and the archetype construction material: its great physical resistance compared to its density, its easy manual working, and its abundant natural production left no place for any rival. Then, access to cheap fossil fuels (coal, oil) led to a boom in an energy-intensive industry for the large-scale production and processing of materials rivalling wood, such as metal alloys, concrete and plastics, whose technological characteristics and the ease with which they adapted to the production of complex shapes, pushed wood towards more specific uses.

For its part, natural rubber experienced the disorganization of its supply

circuits by the two World Wars. In the first half of the 20th century, synthetic products, primarily derived from petroleum oils, appeared on the market. However, those products did not destabilize the sector, as they were expensive and technologically not very reliable. In the second half of the 20th century, progress in chemistry led to the elaboration of synthetic products with stable and uniform characteristics, available in a wide range of articles effectively meeting the requirements of industry. They then seriously rivalled natural rubber, a much more heterogeneous biological product, though without replacing it completely: indeed, the industry has never succeeded in identically reproducing some of its specific characteristics at reasonable cost.

For wood, as for natural rubber, competition was fierce, but a balance was finally established. Today, those two products owe their place on the markets to their inherent qualities - which, for example, made natural rubber an essential constituent of truck tyres - and especially to numerous innovations - wood is converted into plywoods, reconstituted panels, glue-laminated beams, etc.

In addition, as fossil energy is inevitably rising in price, strong renewed interest is currently being shown in wood and natural rubber, due to their production conditions. The rubber tree is the only biological factory functioning on carbon from the atmosphere, capable of producing a polymer with a highly favourable energy balance, since it takes 0.4 tonnes equivalent of petroleum oil to produce one tonne of natural rubber, whereas it takes ten times more to produce one tonne of synthetic rubber. As regards wood, supply and demand are roughly stabilized; the sector has derived fresh vigour from the strongly growing Asian markets and, in other respects, the more environmentalist vision of forest potential and its use for the carbon market.

3.2- Quality food, a challenge for industrialized and developing nations

Whilst calorie intake was the strong argument for food security until now, food quality aspects are now being taken into account, particularly the balance in macronutrients and the role of micronutrients in human health.

Emergency plans are being implemented on an international scale to try and alleviate the main deficiencies (iron, zinc, provitamin A) through dietary supplements. But their efficiency seems to be in doubt. Indeed, at the same time, chronic non-transmissible diseases, which are widespread in industrialized countries, are exploding in developing countries: obesity, type B diabetes, cardiovascular diseases, cancers, etc. It also happens frequently that the same people - notably at-risk people such as pregnant women - display both iron and vitamin A deficiencies and obesity symptoms. The reasons given would seem to be more the nutritional imbalance than excess food, but the reality is complex. Mention is also made of a deficiency in antioxidant molecules, which are insufficient to counterbalance the excess in so-called free radical molecules, whose metabolic synthesis is linked to numerous factors, such as modern living - a sedentary life style, stress, type of diet, exposure to pollution - but the proof is still lacking. The only known way of limiting these veritable epidemics is the combination of a healthy life, with a physical activity and a balanced, diversified diet rich in micronutrients. No food supplement can replace a healthy diet. It is now acknowledged that fruits and vegetables are foods that contribute most in supplying some essential micronutrients. Below an average consumption of 400 g of fruits and vegetables per day per adult, the risks of non-transmissible chronic diseases could greatly increase. In terms of the availability of agricultural produce, in Africa that quantity may be reached in a few countries of the rainforest zone, but that is no longer the case at all in the Sahel region, where the consumption level is from 50 to 100 g/day and the situation can be considered highly critical. In Asia, there are many reasons for a lack of fruit and vegetable consumption: production deficit, dietary habits, accessibility,

distribution circuits for highly perishable goods, weak agroindustry.

A joint initiative by FAO and WHO to promote fruits and vegetables was launched in 2004 in order to make countries, politicians and donors aware of the measures needed to overcome the serious public health problems facing them. This is one of the great challenges of the 21st century.

3.3- *Land management, a vital aspect for rural development*

Today, three major types of land tenure situations are usually found in the world:

- a land tenure situation with severe inequalities, where family agriculture is marginalized (e.g. Latin America). Landless farmers have become labourers on large estates managed with a view to making maximum profits,
- a land tenure situation regulated by the land market (sale, rent), where agriculture is mostly family-based (e.g. France). One of the aims of the farmer is to maintain or improve the land assets of his farm,
- a land tenure situation where land is a resource managed by the community (e.g. Africa). When population pressure is moderate, such collective management makes it possible to distribute the land to everybody (young people, migrants, etc.).

But these collective rules are currently evolving towards much more individualistic management. Land inequalities are appearing between families who founded the village and other less well endowed families. In addition, in those countries, even though the State still claims the right of ownership as set down in the laws, an unofficial agricultural land market is appearing in a very active way.

Depopulation of the countryside, the underrating of agriculture, and rural exodus are often considered to be strong trends on a world scale. Whilst effectively characterizing industrialized countries, that observation cannot be generalized to tropical countries, where rural populations are continuing to grow. That creates strong tensions for agricultural land, which are partly to blame for recent socio-political disputes, though the control of mining resources also remains a major source of conflict. Such land tenure tensions are amplified, as in certain African and Latin American countries, when land extensions by the richest and State requisition are permitted by the unregulated land market. On the other hand, they are calmed when the industrial sector develops and provides work for rural people who have migrated to towns, as in some Asian countries.

The strategy of access to new, hence theoretically fertile, lands, which takes the form of migratory flows and the establishment of forest-agriculture frontiers (cotton and cocoa in Africa, livestock rearing in Latin America), has always sidelined the strategy of restoring degraded soils, which is more labour-intensive. It is only when rural populations have not been able to migrate and the population density has exceeded a certain threshold, that land restoration techniques have been applied on a significant scale. In Africa, that initiative has largely been due to the efforts of farmers, whereas in Asia (mainly India), it has been accompanied by proactive agricultural policies.

However today, notably in Africa, family farms are faced with a scarcity of quality land, and it is becoming increasingly difficult to clear fertile forest lands (e.g. for cocoa) or former cleared land (e.g. for yam or cotton). These sectors, and family farms that depend on that, need to find technical solutions and no longer count on the natural stock of fertility in certain areas yet to be cultivated. The need to innovate to intensify farming systems is therefore a strong priority, especially for producing more per unit area.

Lastly, especially in the humid Tropics, it is impossible to gloss over the land status of forest zones, which still remain land reserves suitable for logging initially, then agricultural development. The increase in petroleum oil prices might channel those biomass resources towards the biofuel sector. That tendency should speed up the

exploitation of forest areas. Yet their land status is complex: it is usually a formal status of State ownership, to which are added local legal practices whose scope is sometimes blurred. Two hypotheses are on the agenda. In the first, States attribute large concessions for logging which would then be returned to smallholders. In the second, States could encourage the redistribution of those vast areas already exploited for timber to agroindustrial groups committed to biofuel production. Today, there is no proven fact that suggests a move to one or other of these two hypotheses. Developments will depend both on technical data and on social pressures, such as the rising cost of hired labour and the ability of local rural populations to have a say in the choice of land allocations made by States.

3.4- The landscape, a way of diagnosing agricultural development

The landscape reflects the functioning of a society, and it is claimed either individually or collectively by those who inherit it. The first indications on the perception of the environment come from China in the 2nd century, then from Europe in the 16th century. Today, even though each society develops its own sensitivity, the way in which the landscape is perceived amounts to the visual side of our relationship with the environment.

New observation tools, such as aerial photographs and satellite images, or computerized geographic systems, have widely contributed to a generalized perception of landscapes as "mosaics" derived from land-use methods. Today, those tools are used by numerous players to considerably broaden their point of view, which used to be limited to what our eyes alone could see. Landscape analysis has become a tool for understanding and intervening in the environment.

Large-scale farming has a considerable impact on landscapes, particularly in the humid Tropics. Vast areas of natural forests have been converted to planted areas, often into monotonous monocultures, in managed systems leaving little room for variation and heterogeneity. By rationalizing production processes, agricultural intensification increases their productivity, but it amplifies negative ecological impacts, such as a reduction in biodiversity, soil and water pollution, a reduction in the variety of crops. It homogenizes human skills and erases multiple perception capacities. Lastly, it reduces the possibilities of complementarity and consensus between different agricultural options.

In that agricultural development context, landscape analysis is the basis for all environmental, economic or social diagnosis, whatever the scale. It is the main tool in landscape ecology. That disciplinary field, which has emerged in the last 25 years, makes it possible to understand how the positioning of elements in a landscape interacts with ecological processes, in both time and space. The joint involvement of ecologists, agronomists and geographers then becomes necessary to foresee the most suitable land-use modes for future requirements and constraints. For their part, historians, sociologists and economists are involved in the way society will perceive and appreciate those layouts, in order to integrate them within an environment that best corresponds to their aspirations. It is therefore a highly integrative approach that landscape ecology proposes for making the artificialization of territories viable and sustainable.

During the 21st century, the landscape is thus set to take front stage. The technological tools needed to visualize, describe and analyse it, along with the accompanying concepts, are booming. They will help to greatly improve the perception of our environment and more widely share the sustainable development approach.

3.5- Tropical forest environments: essential for ecological and economic balance

Forests and natural environments currently account for almost half of the land areas in the tropical regions. Those environments

contain the major share of terrestrial diversity and greatly contribute to biological carbon flows, whilst also playing a major social and economic role for numerous human societies.

Some tropical countries have a high rate of forest cover, such as Brazil, Gabon, Congo, Malaysia and Indonesia. However, deforestation of the tropical regions amounts globally to 10 million hectares per year (1% of their forest area), again with great variability between countries. The main causes are clearance for agricultural purposes, for small-scale slash and burn agriculture or estates, overlogging in countries that do not have a strategy for sustainable forest management, and the construction of infrastructures as part of national development.

The evolution of tropical forests is determined by numerous factors, the most important of which are as follows:

- the economic and ecological consequences of climate change, notably in terms of biodiversity and productivity, but also in terms of new "carbon" markets,
- the priorities given to natural ecosystem protection, on national and international scales, by politicians and civil society, associated with changes in the stakeholders and governance of those areas and their resources,
- the need to increase agricultural food production in developing countries, which will lead to further deforestation, despite the expected increases in productivity,
- the search for high added-value molecules for medicine and green chemistry,
- increasing demand for lignocellulosic biomass, composite timber for construction and furniture, paper pulp production, and charcoal in the steel industry to replace coal, notably in the major emerging countries of the South,
- petroleum oil replacement by producing lignocellulosic biomass converted into biofuels,
- the development of carbon markets, in terms of "avoided deforestation" and stored carbon.

In this context, forest environments need to evolve towards an organization in four major sectors:

- large plantations of short rotation crops (eucalyptus, acacias, etc.) for industrial biomass production,
- rural agroforestry plantations to supply timber (teak, mahogany, rubber wood, etc.),
- the establishment of protected areas, exceeding 20% of the natural environments involved, intended to conserve and manage biodiversity with the help of novel reward mechanisms,
- sustainable management of semi-natural forests for the production of high added-value wood and non-wood resources.

Such modifications result in substantial changes in landscapes and players. Landscapes evolve towards very pronounced forest-agriculture mosaics. Companies, farmers and non-governmental organizations play a greater role, and States and international organizations focus on their legislative and regulatory functions.

3.6- Energy needs: the contribution of agriculture

World consumption of primary energy (oil, natural gas, coal, nuclear, renewable energies) has increased by 25% since the 1970s virtually linearly. In the global energy balance, the share of each of them has varied little over recent years: the share of oil has risen from 35 to 40%, gas from 15 to 20 %, whilst the share of coal and biomass have remained stable, at 25% for coal and a little over 10% for biomass, whilst nuclear approaches 10%. On a global scale, the share of biomass is slightly higher than nuclear because it is virtually the sole source of energy accessible to populations in developing countries.

In terms of renewable energies, cultivated and natural biomass holds an important position. The production of heat and motive force from wood matter covers 95% of the 10% of biomass-based energy currently consumed and it offers considerable potential. In other respects, hydrocarbons dedicated to transport only amount to 15% of total fossil fuel consumption: that is why the entire bioenergy approach should not be geared towards the production of fuels intended to replace petroleum products. Using biomass to produce heat then motive force converted into mechanical work or electrical energy offers a much better energy balance than most of the biofuel production pathways. However, this type of sector can be penalized by the distance between the resource harvesting site and the energy consumption site. The location of the processing and production site then becomes strategic and that spatial factor becomes a principal feasibility factor.

The production of biofuels from dedicated crops has now been launched. This involves sugar or starch bearing plants that provide ethanol (petrol substitute) or oil bearing plants (diesel substitute). The fundamental question arises in terms of energy efficiency, i.e. the ratio between the energy produced and the energy consumed. Most energy crops envisaged in industrialized countries have low energy efficiency, sometimes even negative, whilst it is excellent for tropical crops such as sugarcane or oil palm. However, all these crops will not satisfy demand as it stands at the moment. If current palm oil production were to be totally used as fuel, it would only cover 1.6% of current petroleum oil consumption and that of sugarcane would approach 2%! Nevertheless, energy crops will play an essential role in rural economic development, particularly in emerging countries, and will be a tool for the perpetuation of agriculture in industrialized countries.

Lignocellulosic biomass offers much greater potential. This pathway calls for a further research effort to achieve industrial technological solutions. In the short term, it will be possible to find solutions for pyrolysis and gasification of the whole plant, the current obstacle being the production of a quality gas to achieve efficient fuels. In the medium term, cellulose extraction needs to be developed for its hydrolysis and conversion into fuel.

In the 21st century, under the dual threat of fossil fuel shortages and climatic upheaval, it is essential for human society to step up technological and social innovations towards new energy pathways and a less energy-consuming world.

3.7- Global warming: worrying prospects

The climate determines the functioning of natural and cultivated ecosystems, the growth of cultivated species and the potential productivity of those species. On a global scale, forecasting the net temperature increase is just one of the aspects of climate change. Rainfall intensity and distribution are also going to play a decisive role in tropical agricultures where it is often water that determines agricultural rhythms.

The increase in temperature has different consequences depending on whether a tropical or temperate region is considered. In a tropical region, the increase in temperature results in shorter development phases, which reduces the amount of energy intercepted by the plant cover and can therefore reduce productivity. Whereas temperate regions could benefit from a longer season propitious to plant development, as the temperature in those regions is a limiting factor today; tropical regions will have to cope with the negative effects of higher maximum temperatures.

If the biology of plant and animal species is disturbed, the dynamics of those species, their balances and, ultimately, their geographic distributions are likely to change. Such modifications will affect wild species, cultivated or domesticated species, but also their associated pests and diseases. Natural ecosystems, subjected to a change in balances between species, with increased competition

that cooperation will be established between previously rival countries in order to take up this formidable challenge. On the other hand, food products with a high cultural and ethnic content will be distributed on local markets, for which farming systems and marketing chains will have environmental impacts that are kept to a minimum. In that global context, the concept of competing agricultural exporting countries or blocks will disappear.

3.9- Conclusion: different viewpoints about the future

We have just briefly described aspects of the commodity crop development context: competition between natural and synthetic production, food, land management, the landscape, forest environments, energy requirements, climate change, and trade globalization. Of course, this brief analysis is not exhaustive and does not indicate orders of importance. It proposes food for thought based on key variables, notably for agriculture in the regions of the South, which could, depending on developments, lead to radically different futures. It is those variants that we go on to examine in the following section, organizing the evolution hypotheses according to three points of view: trend, disaster and optimistic fiction.

4- Evolution hypotheses: trend, disaster, optimistic fiction

What will be the role of agriculture in the planetary evolution scenarios towards the end of the 21st century? What major challenges will have to be faced, to ensure farmer prosperity, the sustainability of cultivated areas, and the satisfaction of food requirements, and also to contribute to the world's energy needs? These are the questions that guided our analysis of the evolution hypotheses for a few major determinants of the possible future of commodity crops.

4.1- Trend hypotheses

World context

The global population grows up to the middle of the 21st century, then peaks at 9 billion people. The major pandemics so feared at the beginning of the century have not had any notorious effect on global demography, even though they severely affected certain populations randomly. Despite the demographic transition, the demand for agricultural products continues to increase, particularly as a large share of the world population still lives below the threshold of basic needs.

Pressure on agricultural product prices keeps them low. Consequently, farmer incomes depend not only on production but also on the creation of added-value and making use of externalities. One of the consequences of these developments is a drop in the number of farmers. That drop, associated with agricultural intensification, helps to improve the living standards of the farmers in place. This scenario, experienced by Europe in the 20th century, nonetheless remains hypothetical for countries with a large population such as India and China.

The drop in the number of farmers increases migrant flows from countries with a large agricultural population. Those flows move from the countryside to the towns, but also go increasingly further, between South and North, and between regions of the South. Those migrants rarely find jobs in the agricultural sector: education plays a major role in their integration in other sectors of activity.

Fossil energy resources severely diminish. Other resources take over and, among them, those derived from forest and agricultural biomass. Competition between food and energy production becomes fiercer. Agriculture alone cannot cope with the energy demand, particularly as it consumes energy itself.

The disruption of natural phenomena linked to cycles of the major elements—carbon, nitrogen and water—has contrasting

effects depending on the regions. In the Tropics, the change in rainfall patterns has serious consequences for agricultural productivity since the crops grown there primarily depend on water availability—such is the case, for example, with oil palm and natural rubber, which are both highly dependent on sunlight and rainfall distribution.

International political relations are stepped up, but it is still too early to say whether they are being established in a context of globalization or regionalization. Everything depends on the nature and degree of the tensions experienced by the agricultural world. However, one certainty is the preponderant political clout of emerging countries with strong agricultural potential.

Strategy of the major stakeholders

In the 20th century, international negotiations were the preserve of States. New macro-players now enter the game. Multinational companies intervene without hesitation in areas other than the economy, and even as donors, via foundations. That trend increases but is counterbalanced by the growing influence of professional organizations and non-governmental organizations. The major global challenges are therefore debated in very diversified forums.

Political regionalization gradually limits the role of each nation on the international stage. In fact, block strategies take over from national strategies. On a world scale, Common Agricultural Policies, be they regional or continental, become negotiating instruments in the sector.

In terms of information exchanges, the information asymmetry known in the 20th century has been greatly reduced by the growing influence of non-governmental organizations and professional organizations, which rely on the development of new information technologies.

International regulations

New types of regulation emerge, be it for the organization of international trade or international agreements on the climate, biodiversity, marine resources, or governance and management of health risks. Those regulations extend to social aspects.

Product standardization and the procedures launched in the 20th century by States are subject to the growing influence of private macro-players, who impose their economic power on that level. However, the major areas yet to be tackled, such as social, environmental and ethical standards, are negotiated by States or groups of States. International companies closely monitor those negotiations as they are highly concerned by the economic fallout.

Capital transfers, mostly between the North and the South in the 20th century, become substantial between the regions of the South. New geopolitical rivalries are taking shape.

Production dynamics

Urbanization-agriculture rivalry increases, leading to higher land prices and speculation on agricultural land. Tensions over agricultural areas with high production potential also increase.

Two systems are possible: specialization and integration. Specialization responds to economic criteria and market forces: zones with high potential are earmarked for high added-value production, notably food products, zones with less potential are used for energy production and high ecology value zones become reserves. However, specialization gives rise to many negative externalities. As for integration, in addition to economic agricultural expectations, it also takes into account social and political expectations. It results in numerous types of enterprises with multiple functions, no longer just agricultural.

The recovery of abandoned land is a priority. Some soils reputed to be uncultivated land or even soils naturally without vegetation start to be used by a new agriculture, where the necessary water and nutrients are provided. The loss of agricultural land due to rising water (lagoons, estuaries, polders, etc.) is compensated for in some regions by the creation of farms for marine species or alga cultivation.

Animal production methods evolve, especially since fishing stocks are rapidly exhausted. Production with low energy efficiency (e.g. red meat) is replaced by less energy-consuming production (poultry, etc.).

Whilst, in the 20th century, the agricultural sector was balanced between smallholdings and large agroindustrial complexes, that balance changes in the 21st century. The increasing cost of hired labour steps up the rise in small-scale agriculture with more diversified activities. On the other hand, the processing of agricultural primary products into finished products remains highly dependent upon firms, which procure the added-value. Processing increasingly approaches production, leading to a scarcity of primary products on the markets, especially the international markets. In order to meet local and regional demand, or highly diversified world demand, processed products are numerous and specialized. However, international trade is reduced, due to the prohibitive costs of transport. Countries and regions increasingly consume what they produce.

Growth in the use of biotechnologies profoundly modifies the production sector. Conventional breeding of plant species and the creation of genetically modified varieties, combined with better knowledge of genome functioning, also lead to a greater specialization of cultivated plants. New species are also created, notably for producing high added-value molecules for green chemistry. Nonetheless, the culture of microorganisms derived from genetic modification compete with those cultivated plants, as was already the case in the 20th century for certain pharmaceutical molecules.

Consumption dynamics

The quantitative demand for agricultural food products increases steadily during the 21st century to meet calorie needs. In quality terms, the 21st century began with a very strong emergence of health problems linked to inadequate consumption of fruits and vegetables, whose prices were prohibitive, moreover. There is therefore a dual challenge: produce more and provide consumers with cheaper products. The specialized high added-value production of periurban crops is therefore re-thought, to the benefit of other, more distant supply circuits, which offer farmers a capacity for diversification that has a positive effect on their incomes.

Consumers are increasingly sensitive to food safety. States set in place highly elaborated standardization. In that context, organic agriculture plays an increasing role by improving its productivity to meet that growing demand.

Knowledge and technologies

Technological progress follows in the wake of major discoveries. Human societies consider that science and the resulting innovations can help to solve numerous problems. Yet, at the same time, they wish to include an ethical dimension, and checks by civil society on the use made of those innovations. The investment allocated to research is increasing steadily, given the new extent of problems affecting the agricultural sector. The key words "sustainable development" are more than a fad, as their relevance has been confirmed over the years. Research objectives are therefore staked out in the long term by this challenge of the utmost importance.

Conventional targeted research themes are maintained, even though new modes of social and economic coordination, linked to information technologies, are appearing, and even though new technological

breakthroughs are occurring in breeding, precision agriculture, IPM, product processing, etc. Increasing importance is being given to increasingly integrative complexity approaches, from the genome to economics, capable of taking into account problems related to changes of scale.

New research-development players are seeing the light of day, due to better training for farmers, and increasing access to information. Participatory research is becoming much more efficient.

Research funding is still ensured by public and private investments. The balance between the two increasingly depends on the strategic interest of the field of research considered. The concept of creating public or private goods through research is tending to fade, with both sectors setting up partnerships to apply the results of their work together.

4.2- Hypotheses of sudden breaks with trends, with disastrous consequences

Beyond the development of trends just described, some determinants, under certain conditions, might evolve disastrously, casting 21st century agriculture into a state of absolute crisis.

Uncontrolled population growth

The world population increases well beyond the forecast of a demographic transition in the mid-21st century, especially in some large regions. Tensions centring on food, land and energy, and on the use of resources, culminate in major conflicts. Social tensions further impoverish the rural world, causing a rural exodus and runaway urbanization in the megacities, which are incapable of ensuring their own supplies. Lastly, the failure of education prevents the rural populations of the poorest countries from climbing aboard the train of technological progress.

Economic and political globalization fails

Global dialogue is in deadlock, there is a return to protectionism, which is hardly likely to respond to global challenges. New tariff and non-tariff barriers are established, added-value remains in the hands of stakeholders in a dominant position, who hold back information, thereby preventing economic systems inherited from the past from evolving.

Education and research find nothing and no longer innovate

Human society no longer trusts innovation. Fundamentalism in all its forms is taking over. World evolution is blocked, institutions are inward-looking, exchanges become sterile and innovation, which depends on exchanges between people, is no longer a source of proposals.

Natural resources become scarce and the environment deteriorates

There is increasing pressure on the environment, few solutions are found. The degradation of essential resources (air, water, biodiversity, etc.) is often irreversible.

Natural risks affect all regions of the world

Global warming is out of control and accelerating. Droughts, floods, cyclones and typhoons become intense and frequent. There is considerable agricultural damage. Agricultural yields drop or become unpredictable.

Fossil fuels in short supply

No viable solution has been found to replace fossil fuels. The gap between energy requirements and availability widens, particularly because life styles have not changed since the 20th century. The rise in costs is disastrous for agriculture, product processing and availability for consumers. Water shortages and famine become chronic in some regions.

Tensions worsen in the agricultural world

Due to increased competition between different types of agriculture, the deterioration of the living standards of the poorest populations worsens. Some of the rural world lags behind in the world integration process. For those farmers, hunger and poverty have not been beaten and

worsen, increased by land speculation, which speeds up the rural exodus and transfers those tensions to the towns.

Political uncertainty and tensions increase

State structures prove incapable of adapting to a world in the throes of change. States act as a brake on change and their capacities for dialogue, regulation and standardization fall apart. Social cohesion, which alone is able to ensure the introduction of structures capable of taking up the challenges, collapses.

4.3- Optimistic fiction scenario: 2106, megaproduction of palm oil

In 2106, the doubly green revolution, precision agriculture, sustainable development and fair trade have become as familiar and essential to humans as the mobile phone in 2007! In this highly positive context, oil palm growing still holds a preponderant position in Southeast Asian agriculture. The oil palm has become a highly versatile and productive plant, which responds amazingly well to biotechnological and agronomic innovations. Some researchers are even working on creating an annual oil palm species, which could be machine-harvested!

A radically equitable world context

Around 40 years earlier, in the 2060s, family agriculture in tropical countries completed its transition from a subsistence system to a commercial agriculture. In its great majority, it has taken into account the requirements of the doubly green revolution, encouraged by the generalization of microcredit and mutual management of agricultural and industrial commodity prices by FAICP (Fund for the mutualized management of Agricultural and Industrial Commodity Prices, a UN organization created after the depletion of proven fossil energy stocks). Through such mutual management, FAICP has enabled a boom in fair trade and done away with commodity prices based on outdated factors such as short-term speculation of marginal surplus or deficit effects.

Whilst the forests of Malaysia and Indonesia seemed to be destined to disappear in the 2030s-2040s, the combination of all these technical and socio-economic factors has completely reversed the trend: the forest area in those two countries has increased by around 15 million hectares (500,000 ha/year) in the form of agroforests and managed forests, combining short- and long-cycle species. However, the reconstitution of forest areas needs to be continued for 30 to 40 years at a sustained rhythm (1 million hectares per year) to stabilize micro- and macro-climatic variations and slow down the water cycle on numerous islands of the archipelago. Given the rising waters, the former coastal mangroves have recovered their prime functions as biodiversity reserves and buffers between the marine environment and the coast, thereby forming effective barriers in regions affected by cyclones. The reforestation programme is backed by FAICP, following the virtual disappearance of noble hardwoods around the middle of the 21st century.

An infinite range of specialized palms

Breeders now have a catalogue of extremely specialized clonal or traditional varieties, which can also be prototyped on request for industrial requirements.

The oil palm has a production cycle of 10 years, starting to bear at 12 months, enabling continual adaptation to market needs. Genetic production potential reaches 12 to 14 tonnes of CPO (Crude Palm Oil) per hectare per year. In Malaysia and Indonesia, average yields are 9 tonnes, despite the impact of recurring climate problems linked to fluctuations in ocean currents and cyclones.

Molecular biology work has made it possible to master the "distributed programme" managing genome functioning on the level of the cell, plant and interactions with the environment. For almost 20 years, introgression of agronomic traits has been practised right from the embryonic stage in variety breeding schemes. Variety creation

takes place in a field-laboratory-nursery combination over 7 years per cycle rather than 30 years at the beginning of the 21st century!

Cloning by *in vitro* culture has become generalized and has enabled the propagation of high-yielding genotypes. As for potato in the 20th century, the technique has been simplified and most planting material producers have adopted it. Cloning has become a selection tool in its own right, enabling the rapid dissemination of varieties improved by genetic engineering. Under public pressure, governments and international agencies, and large seed producing groups, have also released their patents into the public domain.

A close understanding of the major metabolic regulation pathways has enabled oil palm growing to move into once marginal zones (degraded savannah, saline soils) with genetically modified varieties adapted to drought, salinity and cold. Polygenic resistant varieties have also made it possible to control major endemic diseases (vascular wilt, bud rot, *Ganoderma*). In addition, a combination of biological IPM and selection methods has done away with synthetic pesticide use throughout agroindustry. Only a few regions where family agriculture has yet to complete its transition to the doubly green revolution still use pesticides, but under very strict control.

In order to direct oil uses towards chemistry, the oil composition has been changed to take into account fatty acid profiles adapted to lipid chemistry: the chains are shorter, more unsaturated, with conjugated double bonds, and even hydroxyl groups that facilitate later grafting. Some varieties are dedicated to the manufacture of high-value nutritional elements: polyunsaturated fatty acids (Omega 6 and 3), fat-soluble vitamins (A, D, E, K), antioxidants (vitamin E, carotenoids, polyphenols, phytosterols).

Precision agronomy: microchips in stems and laser harvesting

As agricultural labour has become scarcer in line with the economic development of producing countries, estates and producer groups have invested in mechanization and precision agriculture. For harvesting, an optical ranging remote sensor is used to assess bunch ripeness and directly informs a highly specialized technician who uses a laser beam to cut the bunches and a robot to collect them. The harvesting equipment also records the weight and number of cut bunches. Bunches are collected by vehicles propelled on a cushion of air so as not to compact the soil, like all equipment entering the plantation plots.

Input consumption, particularly nitrogen, has been considerably reduced by the creation of palms with a high mineral assimilation capacity. Mechanized and robotized fertilization have virtually done away with mineral losses. The major application takes the form of composts recycling urban sludges, EFB and oil mill sludges. Those applications are carried out on request based on messages received from sensors managed by microchips inserted in the stems. Physiological data are transmitted to a drone-borne automatic central control unit. That unit evaluates physiological parameters (water, sugars and minerals) and determines daily energy needs.

In 2106, biotechnologies continue to follow avenues that are promising, but still far from applicable in the field: palms with triggered floral reversion, making it possible to envisage the mutation of the currently grown perennial species into an annual species capable of producing, along the lines of pineapple, 40 tonnes of fruits per hectare with a 35% extraction rate! This new palm would be machine-harvestable. However, some voices are raised drawing attention to the climatic impact of this innovation. Indeed, it would mean a switch from 7 million hectares of a perennial crop with high plant cover, concentrated in Indonesia and Malaysia, to an annual crop entailing