1. Introduction

Oil palm growing began tentatively less than a century ago (circa 1910). Up to 1960 the palm oil consumed came from a few tens of thousands of hectares of estate plantations (Indonesia: 110 000 ha in 1940, Malaysia, Africa), but also a great deal from picking in the natural palm groves of Africa (Congo, Nigeria, Benin, Côte d'Ivoire, Ghana, Liberia, Cameroon, Guinea, etc.) or in semi-natural groves (Bahia/Brazil).

From the 1960s onwards, the commodity chain took off exponentially, firstly in Malaysia (1 million ha in 1980), then in Indonesia (0.5 million ha in 1985), and more moderately in numerous countries in Asia (Thailand, PNG, etc.), Africa (Côte d'Ivoire, Ghana, Cameroon, etc.) and Latin America (Colombia, Ecuador, Brazil, Costa Rica, etc.). That development was the result of efficient political determination; the best example is that of Malaysia with the structuring of industry and of smallholders around State-run organizations (FELDA); at the same time, to a lesser degree, Côte d'Ivoire, which was primarily dependent upon agricultural products such as cocoa and coffee, displayed a will to diversify through oil palm then natural rubber. To succeed in its achievements, that policy was able to incorporate the technical advances obtained by agricultural research (breeding, crop management sequences, etc.) into development operations.

Up to the 1990s, research continued to go hand in hand with development by helping to solve certain issues linked to the geographical and intensive development of the crop: progress in the planting material distributed, in crop management sequences, in productivity, and in disease and pest control, etc.

Since 1997-98 (El Niño climate event in SE Asia), the date of a major turning point, the large-scale clearance of forest zones, vast fires caused by burning operations to prepare for future plantations, have been rightly or wrongly blamed on oil palm development, which thus became a kind of scapegoat. We have thus arrived at a stage in development where the question of commodity chain sustainability arises. Can the current growth in areas planted be continued at the present rhythm? How can the commodity chain respond to attacks from environmentalists? What are the priority changes that need to be made to this development in order to allow rational development whilst safeguarding forests, biodiversity, the hydrological regime and associated social functions as much as possible, along with the environment inside and around plantations?

One response of the commodity chain has been to promote and organize a dialogue between all those concerned by such development and its environmental risks, by setting up RSPO® and jointly seeking for acceptable, practical responses: it is a way of getting to grips with real problems which we should be wary of minimizing.

What role could Research play in drawing up the awaited solutions? Does it already have any contributions to propose from a technical, economic, social and environmental point of view? How could it evolve and adapt to this new setting? This paper attempts to give some research tracks.

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1 CIRAD France
2 CIRAD Indonesia
3 CIRAD Nigeria
4 Roundtable for Sustainable Palm Oil, since 2003
2. The contribution of Research to oil palm commodity chain development

Prior to 1960, the public or private research organizations focusing on oil palm that left their stamp on that period were:
- AVROS (Indonesia)
- Several private companies (Malaysia) including SOCFIN, UNILEVER, H&C, UP, Guthrie, etc.
- INEAC (Congo)
- WAIFOR (Nigeria)
- IRHO

Up to the 1960s, the main purpose of all the advances brought about by Research was to increase production and productivity, in different forms: genetic potential, optimization of nutrition, disease and pest control, etc. As a fair share of that Research was directly in the hands of agroindustrial companies or was seeking to meet their requirements, it was perfectly natural for the major concern to be the maximization of productivity and a reduction in operating costs.

Worth mentioning is the revolutionary progress made in breeding as early as 1940, which gave rise to the yield improvements that can be seen today:
- discovery that the Tenera variety results from hybridization between the Dura and Pisifera varieties (Beinaert, Vanderweyen 1940, INEAC),
- the advantages offered by hybridization between origins Deli Dura x Africa Pisifera, Tenera: +25% production (International Experiment 1950-60).

During that period, the introduction of mineral fertilization in oil palm plantations led to spectacular increases in oil palm yields:
- potassium fertilizer for the Dabou savannah (Côte d'Ivoire) increased FFB production fivefold,
- phosphate fertilizer in Indonesia,
- development of the basics for using leaf analysis to manage nutrition in plantations (Prévot, 1954)
- etc.

Other advances have left their mark on the history of oil palm research:
- determination of the vector responsible for Blast disease in Africa in the 1970s, after 25 years of studies on the wrong track
- discovery of the causal agent and vectors of Marchitez sorpresiva in Latin America in the 1970s, after taking the wrong track for ten years or more,
- successful marketing of high-yielding planting material with high resistance to vascular wilt disease, an endemic disease in Africa, at the beginning of the 1980s,
- a study on the predominant role of pollinating insects (and to a lesser extent the wind) in oil palm pollination, and the introduction of Elaeidobius kamerunicus in Malaysia then Indonesia (Syed,1981),
- the isolation of entomoviruses specific to leaf-eating caterpillars in the 1970s in Latin America,
- work on the pheromones of pests such as Oryctes rhinoceros in the 1990s and their olfactory trapping,
- use of owls for the biological regulation of rodent populations in plantations in the 1990s.
These are just a few examples of what Research has contributed in recent decades. A certain number of lessons can be learnt, bearing in mind that the achievements of Research can be appraised in various ways:

- either there are radical events (the origin of Tenera, inter-origin hybrids, pollinating insects, etc.), with farmers benefiting from progress in successive steps,

- or progress is ongoing, but not very visible immediately, like all research associated with genetic improvements from year to year, nutrition and mineral fertilization; moreover, in view of the large numbers of compartmentalized results provided by Research, it is difficult for industry to know which are truly worthy of interest,

- or progress declared to be a major event is questioned a few years later: such as the semi-commercial distribution of the *Elaeis guineensis* × *Elaeis oleifera* interspecific hybrid in the 1970s (an open pollination problem and low yields) or the commercial distribution of clonal materials at the beginning of the 1980s (victims of the mantled abnormality). In both cases, these failed attempts did not block all research in those sectors, which are strongly returning to the forefront 20-25 years later,

- or Research has not been able to answer the questions raised. Such is the case with the bud rot syndrome in Latin America, for which after 30 years it has still to be proved who is right between those researchers who claim a biotic origin and those claiming an abiotic origin! Likewise, harvest mechanization, which has also been on the agenda for more than 30 years, has yet to give any convincing results.

However, it should not be suggested that Research can answer all the questions raised or implied. Much progress has been achieved without the intervention of Research, at least at the outset. Highly dynamic plantation management is the source of numerous innovations of benefit to the entire commodity chain; through good plantation management it is possible to synthesize all the possible types of progress, determine priority innovations, and test them with a good probability of a return on investment. Also, for example, it was simple harvesters who launched the use of mules in Colombian plantations in the 1960s; or the advent of the Malayan knife fixed to a bamboo pole, replacing heavy ladders for harvesting tall palms in Malaysia in the 1970s, with research subsequently adapting that system to aluminium and duralumin rods.

3. **New development challenges and questions asked of Research**

In order to ensure the sustainability of the commodity chain in general, and of production units, be they estates or smallholdings, in particular, in addition to questions raised in the past that are still on the agenda in most cases or need to be stepped up (intensification, productivity gains, cost reduction), new issues are emerging for which Research can be called upon to find solutions.

   *a) Why intensify?*

Given the inexorable downward trend in vegetable oil, and palm oil (palm kernel) prices, in real terms, averaging 3% per year since 1950 (James Fry), there is fierce competition between these oils which are highly substitutable in their uses. Within that competition, there are fundamental differences between annual crops and tree crops: progress in genetic selection, which is much more rapid for annual crops, is directly transferable within a very short time span over considerable areas, whereas it can structurally only reach a very small proportion of the areas planted to oil palm (new extensions and replantings) with an added
delay of several years to measure its effects (palm starts bearing 5 years after the pollination required for seed production, and maximum yields another 3 to 5 years after).

Beyond any shadow of a doubt, the oil palm beats all its oilcrop rivals for annual oil yields: nonetheless, that difference is decreasing, to the detriment of oil palm competitiveness. For example, it is striking to see the stagnation of average yields obtained in Malaysia, even though that country has been the powerhouse of oil palm development since the 1960s (Fig.1), whilst over the same period yields recorded for soybean in Brazil doubled.

![FFB and CPO yield in Malaysia](image)

**Fig. 1. source : MPOB**
For ten years or so, scientists and officials in Malaysia have been trying to explain the stagnating performance achieved whilst yields announced by Research often speak of double for FFB/ha and + 50% for the extraction rate. The national political objective, which approaches that Research optimum, is "Vision 35:25", i.e. 35 t FFB/ha and 25% extraction rate (OER) rather than 19:19 today. With the areas in production in 2004 (3.9 million ha), that would amount to 34 million t CPO rather than the 14 actually extracted. Over and above this somewhat Utopian wager, the true questions we are interested in at the moment are: Does that potential exist today, even partially, in existing plantings and, if so, why is it not possible to realize it in practice? Or is further substantial progress needed (new events?) on a Research level for that potential to be truly passed on to development, probably meaning another 25 years or so?

Another factor unfavourable to oil palm competitiveness is the current impossibility of mechanizing its harvest under practical and economical conditions. This arises from several major constraints: i) a harvest spread throughout the year requiring machines to come to the foot of each palm three times a month to collect a small proportion of the annual harvest (harvesting once per cycle for annual oilcrops), ii) variable height of ripe bunches in palms (between 0 and 12-15 m during the cycle), iii) random arrangement of the bunches to be harvested around the crown, iv) the topography is often not flat, making access difficult for any machine, v) fallen fruits scattered in the weeding circle which it is essential to gather. This means that the harvesting machines imagined to date are too heavy, difficult to handle, lack flexibility, and require more labour for detecting ripe fruits and the harvest itself than in the case of completely manual conventional harvesting, hence high investment and operating costs for mediocre productivity.

b) How can environment and sustainability issues be taken into account?

Alongside so-called conventional research, should environmental issues also be grasped by Research?

Contrary to what one might imagine, a great deal of work has been undertaken in the past on farm sustainability (fertility maintenance, profitability maintenance) especially when oil price fluctuations place them temporarily in danger. The way planting sites are selected has long been one of the concerns (Olivin, 1968) of agronomists responsible for advising development companies, particularly in Africa and Latin America: soil surveys, taking into consideration climate data, the topography the existing vegetation, social data, then feasibility studies with an evaluation of production potential, profitability, etc., in order to concentrate plantations in places where foreseeable yields would be best, enabling maximum production on a limited area.

The aims were both to seek higher potential (possibility of subsequent intensification), and to be able to produce a maximum of oil on a limited area, thereby avoiding pointless expansion to the detriment of forests, for example.

That methodology was also used to redefine zones for replanting or reconversion (other crops, reforestation, etc.) for CDC in Cameroon, in order to intensify the best land areas as much as possible (Nguyen Hugo Van, 1974). That relatively expensive and slow way of proceeding appears to have fallen out of use, and numerous development projects in SE Asia, on a much larger scale, have been implemented without such detailed prior studies, even though modern methods (remote sensing, GIS, GPS) greatly facilitate them.

However, it seems that such studies prior to planting need to incorporate environmental and social aspects more closely, notably with regard to the considerable challenge raised today by forest and biodiversity conservation. Hence the challenge of identifying high conservation value areas, be it with regard to exceptional or critical ecological attributes, services provided
by the ecosystem, or social functions, on a national or regional scale when choosing concessions, or within the same concession, in order to guide political decision-makers and plantation managers in land development and sustainable practices.

The HCVF concept (High Conservation Value Forest) developed under the FSC (Forest Stewardship Council), and which could be extended to the HCFA concept (High Conservation Value Area) so as not to limit ourselves to forest areas, is thus a worthwhile tool that can be applied to the issues involved in oil palm development/extension projects.

However, many questions still remain if this tool is to be usable in the field: Depending on the scale considered, are the criteria to be taken into account appropriate and what are the thresholds? What can be mapped? How can dynamic evolution be integrated? How should social aspects be taken into account? Is the time required for adequate field studies (biodiversity inventory, sociological surveys, etc.) acceptable? Are we really in a position to determine adequate and necessary areas to be placed out of bounds (area, "shape" and interconnection of reserves and corridors) with a view to conservation? etc. The same questions arise in the more general framework of Environmental Impact Assessments (EIA).

Moreover, in addition to whether existing tools or those to be adapted are appropriate there arises the question of control and checking: Do these tools provide all the necessary guarantees? Are official controls possible and efficient? etc.

\[ c) \text{What are the main risks of environmental pollution from oil palm plantations?} \]

The environmental impact of management practices in existing plantations also needs to be measured. Out of fertilizers, pesticides and oil mill effluents, which are likely to pollute? How can the impact of soil management practices on the atmosphere, water tables, rivers, and biodiversity be assessed? What indicators exist? Are they reliable, robust and consensual?

\[ d) \text{Are smallholdings sustainable?} \]

The inadequate production levels achieved by a fair number of smallholdings (notably in Africa) is worrying, since the economic survival of that type of farm comes under threat when it is managed over long periods without fertilization and without pest control. The absence of agricultural credit for investment, campaign credit, and the lack of supervision and training prevent satisfactory rational management: in order to live off the income earned from oil palm, they need large areas (extensive cultivation), which is bound to exacerbate the risks of deforestation.

4. How can Research convert these issues into research projects?

The results obtained by some companies (United Plantations, SOCFINDO) happily show that significant progress in sustainability can be made (Fig. 2), one decade to the next, from one generation to another (the 4th is underway on some plantations), resulting from a combination of different advances as and when they occur: improved potential of replanted planting material, progress in fertilizer management and crop protection, more efficient oil mills, estate management, etc.
In order to maintain the competitiveness of the commodity chain, any research leading on to a gain in productivity (increase in palm yields and labour output, reduction of production costs) needs to be continued, if not stepped up, with modern tools that exist today: biotechnologies, in vitro culture, precision agriculture, soil resources, fertilizer efficiency and reduction of losses through leaching, IPM, utilization of oil mill waste and by-products.

The search for planting material resistant to Ganoderma, by screening after inoculating the fungus in the nursery, appears to be very promising (Breton, PIPOC 2005), which would allow replanting in endemic zones, in SE Asia, despite rising fungal pressure.

Likewise, improvement of the *guineensis x oleifera* hybrid in Latin America and backcross programmes combined with in vitro culture, suggest a practical solution for numerous plantations affected by Bud Rot.

In Malaysia, the causes of stagnating average oil palm yields has given rise to numerous hypotheses which may have additive effects, though each of them needs to be quantified beforehand. For example, there is the drop in the quality of the most recent extensions (soil, topography), hence in the potential of new plantings compared to old plantings, with labour shortages preventing optimum harvesting (not fully ripe, fallen fruits not gathered), the delay in replanting (loss of yields from palms too tall to harvest), etc. Research needs to be able to assess the functioning of an agroindustrial complex on a true scale, both overall and in detail: what quantity of FFB, what extraction rate exists potentially in the field on the day of harvest, what losses occur throughout the production chain, how efficient is the oil mill? What fertilization is given? What are the operating costs? How does management function? etc.
Such appraisals carried out on a representative sample of estates and smallholdings, with an essential socio-economic dimension, would doubtless improve knowledge about the main constraints, with a view to overcoming them as effectively as possible. Integrated research, bringing into play multidisciplinary teams working together, is an avenue worth exploring for solving this type of problems with multiple causes.

If harvest mechanization has yet to come about today, the problem no doubt needs to be approached from a different angle, by seeking to adapt the palm and its production to the machine, rather than the other way round. By conventional genetic improvement or genetic engineering a palm could be produced that does not lose fruits from its ripe bunches (non-shedding palms), which would make it possible to reduce harvesting frequency (once/month?), which would improve machine profitability, since more bunches would be harvested on each round. There would no longer be the constraint of fallen fruits with, no doubt, ultimately an oil of better quality because it would be less acid, as the FFA rate is mostly linked to fallen fruits whose lipase activity is triggered when wounding occurs. This research can perfectly well be considered right away, by teams with access to large genetic variability.

The principles and criteria considered by RSPO are designed to make it easier to assess the sustainability of palm oil production. In order to avoid a subjective or vague interpretation, a certain number of indicators will have to be tested for their reliability and robustness, with the agreement of all those involved in the commodity chain. The example of the agri–environmental indicator "Indigo" for nitrogen (NH₃, NO₃, N₂O) presented by Caliman (PIPOC 2005), which he intends to extend to phosphates, potassium, and to pesticides, reveals the complexity of the phenomena that will have to be simplified in the form of degraded models to make them operational and usable routinely by each and everyone. Is this not a typical example of where multi-disciplinary Research must play its role fully?

Management of oil mill effluents and waste has made substantial progress in recent years, and some deduce that the problem has been solved. However, it is highly likely that such is not the general case. The matter of methane emissions (very powerful greenhouse gas) from effluent purification ponds is still on the agenda. EFB transportation and rationalized utilization of effluents still requires further research to optimize agricultural use (organic matter, mineral nutrients), develop environmental impact indicators, and reduce manufacturing (e.g. compost) and transportation costs.

In environmental terms, a clearer picture of the environmental impact of plantations on the ecosystem, both the biophysical and human environment, is needed, on scales other than the plot or farm, and notably on a catchment area scale (particularly for hydrological aspects), on a landscape scale and on a regional scale. Research can shed light on and provide a clearer understanding of ecological and social dynamics, and for measuring the impact of plantations on the biophysical and human environment. Although the intrinsic timescales for this type of research seem long and not particularly adapted to the urgency of the issue, it appears necessary to have information that is as precise as possible, in order to define consensual criteria and thresholds that are based on reliable and robust data.

In addition, in terms of delimiting concessions that are potentially plantable with oil palm, along with land development inside those concessions, as previously noted, agricultural research already has long-standing experience on the subject, and it is therefore important to make use of that basis, whilst continuing to incorporate into it the contributions made by agroecology, landscape ecology, socio-economics, ethnoecology, etc. in order to have an integrative vision that takes into account the contributions and viewpoints of all stakeholders.

Environmental and social challenges can also be tackled by incorporating participatory approaches (of the Multidisciplinary Landscape Assessment type developed by CIFOR) and
calling upon simulation tools and multi-agent systems, such as those developed in negotiation and conflict resolution (example of the CORMAS initiative).

By their very nature, small family farms are very different depending on the country, the development systems of smallholding programmes, the degree of supervision at the outset and persisting today, their structuring (cooperative, etc.), the proximity and role played by agroindustry, and any support provided in terms of inputs. They come up against the problem of their intensification, though it is as crucial for them as it is for agroindustry. Research, with all its technical, economic, social and cultural dimensions has the duty to especially study this human diversity, understand its decision-making rules, and perceive training needs, so that each farmer can act as a veritable company manager.

5. Conclusion

Since the dawn of oil palm growing, research has gone hand in hand with its development, with a certain number of successes to show for it. Research should continue to be called upon, to work in interaction with development workers, and provide its contribution with respect to ongoing or new questions raised by the expansion of the commodity chain today.

We feel that four major issues are priorities at this stage:

- Further rational intensification in order to produce more from the areas already planted (or to be replanted), from shortening the gap between potential production and actual production, to longer-term research to improve that potential,
- Maximum safeguarding of recognized biodiversity, by strictly planning the attribution of concessions in accordance with robust and shared criteria, followed by a development plan within the concession making it possible to maintain a maximum of the ecological attributes, ecosystem services and social functions,
- Rationalization and utilization of oil mill waste, with minimum negative effects on the environment,
- Taking into account multiple known or little-known difficulties encountered by farmers, so that they can fully participate in the competitiveness of the commodity chain, bearing all their responsibilities.

The complexity of the issues raised requires an increasingly integrated multi-disciplinary approach in order to take into account these economic, social, environmental and cultural aspects in their entirety.

Thus, in order to respond to all these questions, in addition to bringing into play all the stakeholders in the oil palm commodity chain, and involving NGO members which has already begun, it is necessary to call upon scientists at universities and research centres, in disciplines other than those specialized in oil palm. Pilot projects bringing together all these players, along with on-site hosting of researchers for more precise scientific projects, must therefore be promoted.

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