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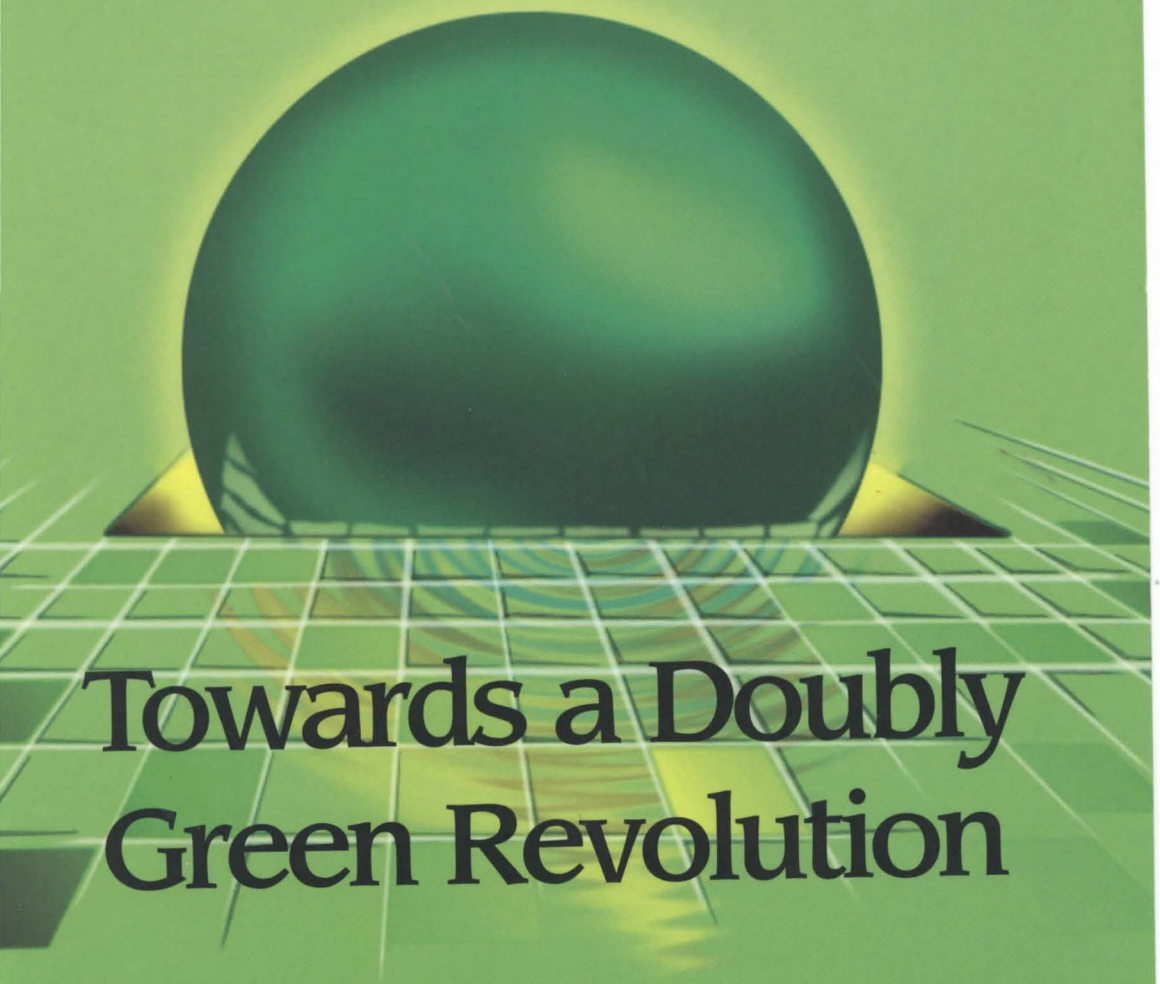

Towards a Doubly Green Revolution

CIRAD

... FONDATION PROSPECTIVE & INNOVATION

Papers from the Seminar of 8th and 9th November 1995

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Towards a Doubly Green Revolution

Organised by CIRAD and the Prospects and Innovation Foundation

Michel Griffon, Editor

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Opening of the Seminar

Speech by René Monory, President of the Senate, President of the Vienne General Council.

Ladies and Gentlemen,

I place a great deal of importance on your presence here at the Futuroscope, where you are participating in a conference organised jointly by CIRAD and the Prospects and Innovation Foundation. I sincerely hope that your work here will enable you to gain a better understanding of what will take place in forthcoming decades in terms of agriculture and food. May I congratulate you on participating in this innovative work. This will be, I believe, one of the very first times, in our country, that a debate will be undertaken concerning the new green revolution, a fact which is a great honour to us.

For some time I chaired the Interim Committee of the International Monetary Fund. I was already deeply concerned, at that time, about the future of a great number of poor countries. I also asked myself questions regarding population increased. How can societies ensure their food security, and how will they be able to succeed in producing satisfactory living conditions? In what conditions will these new inhabitants of our planet be received if we do not concern ourselves, here and now, with the preparation of solutions?

In this regard, I am concerned to see today that certain industrialised countries place limitations on their development aid to countries in need. I am thinking, in particular, of the continent of Africa with which "Département de la Vienne" has established close ties. I strongly desire to see the generosity of wealthy countries remain intact. France has always maintained its aid. Through its obstinacy and pugnacity in this area, France has always sought to draw other donor partners into this same cause. There would be great danger in the future if we were to allow certain areas of the world to collapse, and did not provide them with the resources they need.

I wish you great success with your work. We consider your time here at Futuroscope as a great honour for the "Département de la Vienne".

Remarks by Louis Caudron, Deputy Managing Director of Vienne Services[1]

I would like to thank CIRAD and the Prospects and Innovation Foundation, chaired by Mr René Monory, President of the Senate, for organising this conference here at Futuroscope, a place, as you know, which is resolutely future-looking. I would like to tell you, in just a few words, about the similarities between the approach taken when Futuroscope was created, and to yours when you propose directing efforts towards a new, radically innovative green revolution.

Vienne is a "département" with a small population, with no major assets for its economic and social development. The President of the General Council, Mr René Monory and the General Members undertook a prospects exercise aimed at identifying means to enable this "département" to prepare for the 21st century. After consideration, two areas were seen as buoyant : future technologies for communications and for training.

These two areas could be the basis for investment which does not have to be located in a megapole. Investment could be made close to Poitiers which is both a university town and part of a rural area. It was believed that success would depend on the recreational quality of the activities to avoid confining knowledge of these new communication and teaching activities to a specialised austere environment. The challenge was to link a leisure park—but still a park where one learns a great deal—with a campus, bringing together teaching and service activities of the future. On the site, therefore are : a high-school/courses, a professional college, a university, the National Centre for Courses, CNRS Research Units, etc.

The Prospects and Innovation Foundation is located on this site. It includes a "Observatoire du Changement" of companies and European societies, and constantly questions what societies will be like in the future. It is directed by Olivier Cazenave.

1 Louis Caudron who is currently one of the Futuroscope managers, worked for many years in research and Development-oriented within the framework of international cooperation. He was, in particular, head of the "Development-oriented Research" Department at the Ministry of Research, and was Assistant Manager for Rural Development at the Ministry of Cooperation.

Apart from prospecting and the obsession with the future, our initiative is also characterised by the will to open up internationally. Futuroscope is a communication's link with the world. The communications port where we are today, the TELEPORT, illustrates this vocation.

I hope that our meeting will be facilitated by the state of mind which characterises Futuroscope : anticipating in order to assist the emergence of future societies, international communications to ensure that new ideas can be publicised more easily, and political will because it is only by political will that economic and social development policies capable of meeting the challenges of the future can take root.

Remarks by Guy Paillotin, President of CIRAD and INRA

I would like to greet all the highly skilled participants, managers in the world of research and development, who make up our assembly here today. Welcome to you all, on behalf of CIRAD. I am pleased to see this international seminar being held in France, particularly here in Poitiers. I am also very pleased to see the interest shown in our conference by the President of the Senate, Mr René Monory.

CIRAD is celebrating its tenth anniversary, but it is in fact the result of much older research bodies set up after the second world war. CIRAD therefore played a part, like many other research bodies, in the green revolution which we all know. However, whether in terms of this green revolution or of its "doubling", the questions raised with regard to eradicating hunger and poverty are by no means new ones. It has always been a question of knowing whether we can feed the world and whether, by producing food, we can reduce poverty.

In Asia, Latin America and industrialised countries, science and technology have enabled, albeit in highly auspicious or highly controlled conditions, a dramatic increase in yields from agriculture, livestock production and forestry. They are now ready to do more and better; look at the progress - which is sometimes put too forcefully to the fore - of advances made by biotechnologies. At the same time, such progress has modified comparative advantages, and one cannot avoid the fact that, at the international level, the major winners in the Green Revolution are in fact industrialised countries which have both larger land areas for cultivation and all the technologies. Many French and American farmers even claim that their agricultural output could be increased enough to compensate for food deficits the world over.

Today's innovation is that this expansion is encountering limitations due to environmental problems, both in northern and southern countries. Therefore, in order to preserve our environment and the sustainability of natural resources, particularly in zones subject to high demographical tensions, we must rethink our production methods, to make them "cleverer", and ensure that they "take care" of nature. In fact, they must be complementary to and, in harmony with nature itself. To do this, the "artificialisation" of environments must be reviewed. We must also find a balance between high productivity agricultural areas, which are already highly artificialised, and other areas which are less productive and more fragile. In this connection, we need to reflect on the preparation of research to be undertaken; such reflection will also help us to change the somewhat fixed ideas we still have and which can act as an obstacle to progress.

I would therefore like to offer my sincere thanks to the organisers from the Prospects and Innovation Foundation, those who have supported us in the organisation of this conference, the Secretariat of State for Research, the Ministry of Cooperation, and the Vienne General Council. I would also like to thank IFPRI for its essential conribution which will serve as an introduction to our discussions.

Finally, I would like to add a third touch of green -which in France is the colour of hope- because, over and above our scientific and technical work and our proposals in the field of economics, our common purpose is, indeed, the development of every man and of all men.

Problems of the future force us to drastically change our views

The 2020 Initiative

The 2020 Initiative was launched by the International Food Policy Research Institute (IFPRI) based in Washington D.C., with a view to defining a joint vision for the future and to reaching a consensus around the measures which should be taken in order to meet world food requirements in the next 25 years, while reducing poverty and protecting the environment.

This initiative was sponsored by an international advisory committee chaired by Yoweri K. Museveni, President of Republic of Uganda, and composed of top managers of research bodies and aid agencies, experts and political representatives from various countries.

Numerous actions have been undertaken: new work ordered by IFPRI from third parties, a forward-looking model (Global Food Model) and 18 seminars, some of which were thematic and others regional.

All this work resulted in the proposal of a vision of 2020 presented by P. Pinstrup-Andersen in June 1995, at a conference IFPRI held in Washington.

Thus for, the 2020 Vision initiative has:

- A series of 40 documents has been drawn up by researchers at IFPRI and numerous other bodies.
- A series of 50 "Discussion Papers"
- A series of 64 "2020 Briefs"
- A quarterly newsletter

LONG-TERM CHALLENGES FOR AGRICULTURE AND FOOD

Forward-looking work by IFPRI[1]

David Nygaard
Director of Country Programs, Coordinator of the 2020 Initiative

Perhaps the most interesting discovery of the "global 2020" analysis is the paradox posed by the emerging world food situation. Findings from the IFPRI Global Food Model Projections to the year 2020 show that the world will continue to have two distinct and very contrasting situations. On one hand, wealthy countries together with some rapidly growing developing countries will enjoy low food prices and food surpluses; they will be able to afford to import their food. On the other hand, poor slow-growing countries will, if present policies continue, make little progress in improving food security and reducing malnutrition. Fortunately, the projections also indicate the potential for significant improvement in food security in the lowest developing countries if national and international institutions increase their efforts to promote broad-based agricultural and economic growth.

Five main conclusions

I would like to summarize five conclusions that come from this analysis:

1. The aggregate global food supply and demand picture is relatively good. Food production in the world will grow fast enough. The world food prices will continue to be low and may even fall a bit, in spite of an increase in world population, and in spite of the rising incomes in several developing countries.

2. Despite this overall ability of the world's productive capacity to meet food effective demand for food, their will be trouble spots. We predict a worsening food scarcity security situation in Sub-Saharan Africa, and only a slow and small improvement in food security in much of the rest of the developing world, including most of South Asia.

1 International Food Policy Research Institute

3. Additional cuts in investments in agricultural research and rural development, which are now being contemplated by national governments and international development agencies would lead to a sharp reduction in food production and more dramatic malnutrition in the developing world.

4. However, if instead, national and international development institutions increase their investment in agriculture and economic development, big gains in caloric availability and, hence, large reductions in malnutrition can be achieved.

5. The debate on foreign aid continues. In much of the developed world, particularly in the United States, it is worth pointing out that the developed countries gain from public investments in developing countries'agriculture and economic development. That is because faster growth encourages greater use of agricultural inputs in the developing countries, and most of these inputs will come from the developed world.

IFPRI Food Model

IFPRI's food model projects productions and prices of crops and livestock at a country level, at the regional level and at the global level. It also projects food supply and demand balances. It projects imports and exports. It also projects per capita consumption of food in calories, and finally, it projects the number of malnourished children in the world. Models are simply tools that aid us in our understanding of particular problems. We believe the IFPRI model is a useful tool because it provides a consistent framework to test the effectiveness of different policies and different rates of crop productivity growth. It projects income, population growth, and long-term food balances, and allows us to look at issues regarding food security. The model covers 35 countries and regions which include virtually all of the world's food production and consumption conditions. It includes 17 commodities: all the cereals, roots and tubers, meats and dairy products.

I am going to present you first the baseline results. I want you to keep in mind that the objective is not just to come up with the baseline, but to allow us to make comparisons of scenarios with assumptions concerning changes that occur. We will look at some of those scenarios later.

The baseline scenario

The first set of results comes from the baseline scenario. This incorporates our best assessment of future growth in income, population, and the productivity of crops and livestock.

Supply and demand

The aggregate global food supply and demand picture is relatively good. Production growth will be sufficient to keep the world food prices on a downward trend. Cereals

prices are projected to drop by nearly 20% by the year 2020, and meat prices by about 10% (Table 1). These declines occur in spite of the significant growth in food demand in the developing world.

Table 1: Projected real world prices of major commodities, 1990 and 2020 (in 1990 US$ per metric ton)

Commodity	1990	2020	Change (%)
Wheat	156	132	- 15
Rice	231	181	- 22
Maize	109	84	- 23
Other coarse grains	89	67	- 25
Soybean	247	219	- 11
Roots and tubers	148	122	- 18
Beef	2,062	1,947	- 6
Pork	1,664	1,500	- 10
Mutton + lamb	1,907	1,825	- 4
Poultry	739	662	- 10
Eggs	897	668	- 26
Total: cereals	144	116	- 19
Total: meats	1,587	1,441	- 9

Source: IFPRI-IMPACT simulation results

The growth in demand is especially for meat (Table 2). Meat demand would increase by 80% in developing countries, and 60% in the world as a whole. This is somewhat different from information you can sometimes find in the press, which suggests food demand will double by the year 2020.

The decline in prices is accompanied by an increase in world trade in food, with the developing world, as a group, increasing the food imports from the developed world. We bet cereal imports by developing countries will double by 2020. (Table 3)

This increasing trade flow simply means rapidly growing economies that are producing food when it is economically viable and importing food when it is cheaper to do so. This is the situation that characterizes much of East and South-East Asia. However, increased imports bring trouble elsewhere. For example in Sub-Saharan Africa. In this region cereal imports are projected to triple from 9 Mt in 1990 to 27 Mt in 2020. And, what is worse, Sub-Saharan Africa will not be able to pay for these growing imports. Therefore, the international community will need to find appropriate solutions for financing and providing food aid to bridge this food gap in Sub-Saharan Africa.

Table 2: Projected average annual growth rates (%) in total demand for major commodities, 1990-1992—baseline scenario

Commodity	Developed Countries	Developing Countries	Latin America	Sub-Saharan Africa	West Asia and North Africa	Asia
Beef	0.37	2.81	1.86	3.29	2.83	4.11
Pork	0.44	3.40	2.36	3.42	2.74	3.51
Mutton + lamb	0.63	3.10	1.94	3.12	2.63	3.62
Poultry	0.93	3.28	2.42	3.41	3.03	3.90
Total: meat	0.55	3.20	2.12	3.29	2.85	3.65
Eggs	0.77	3.27	2.58	3.57	3.04	3.48
Wheat	0.58	2.19	1.73	3.07	2.30	2.16
Rice	0.51	1.67	1.97	3.22	2.31	1.60
Maize	0.80	2.18	1.79	3.02	1.86	2.23
Other coarse grains	0.87	2.03	1.24	3.08	1.98	1.58
Total: cereals	0.75	2.00	1.71	3.07	2.18	1.88
Roots and tubers	0.64	1.77	1.52	2.96	1.91	1.02
Soybean	1.10	2.76	2.28	3.19	2.65	3.32

Source: IFPRI-IMPACT simulation results

Table 3: Production of, demand for, and net trade of crops by region, 1990 and 2020 (thousands of metric tons)—Trade liberalization

Commodity/ Region	1990			2020		
	Production	Demand	Net trade	Production	Demand	Net trade
Total cereals						
World	1,714,780	1,714,492	0	2,682,555	2,682,559	0
Developed countries	847,875	756,658	91,219	1,116,355	955,297	161,059
Developing countries	866,905	957,834	-91,219	1,566,200	1,727,262	-161,059
Asia	636,443	662,974	-26,531	1,103,557	1,164,264	-60,707
Latin America	99,407	112,715	-13,308	161,770	186,510	-24,740
Sub-Saharan Africa	54,580	63,862	-9,282	138,962	154,824	-15,862
West Asia and North Africa	76,473	118,214	-41,741	161,912	221,520	-59,608

Source: IFPRI-IMPACT simulation results

Food Security in the baseline scenario

Despite the overall ability of the world's productive capacity to meet effective demand for food, there will be little improvement in food security for the poor in many regions, particularly in South Asia and Sub-Saharan Africa. When we look at the average per capita calorie availability in this region, it shows that there is virtually no improvement (Table 4) More progress can be seen in South Asia where income growth is slightly graded on population growth. But even here there is no real difference between South Asia and the rest of the developing world. These trends in calorie availability imply a bleak projected future for food security and malnutrition.

We find an equivalent situation when we look at the number of children under 5 who have been alnourished since the recent past and will still be in the future. South Asia is the home of more than one half of rural malnourished children. As you can, see there has been little improvement overtime in South Asia, mainly in the last decade, due to the gradual decline in the growth of population of children age 0 to 5 years. In Sub-Saharan Africa, the picture is worse. There is an increase

Table 4: Per capita food availability (cal./day) 1990 and 2020—various scenarios

Region/Country	1990	2020		
		Baseline	Low Investment/ Slow Growth	High Investment/ Rapid Growth
World	2,773	2,895	2,758	3,032
Developed countries	3,353	3,532	3,492	3,599
Developing countries	2,500	2,821	2,662	2,978
Asia	2,500	3,034	2,851	3,225
China	2,667	3,408	3,271	3,616
South Asia	2,297	2,640	2,425	2,831
Bangladesh	1,978	2,170	1,881	2,350
India	2,332	2,692	2,490	2,886
Pakistan	2,370	2,584	2,382	2,753
Other South Asian countries	2,239	2,565	2,328	2,787
Southeast Asia	2,555	2,840	2,712	2,953
Latin America and the Caribbean	2,722	3,026	2,878	3,185
Sub-Saharan Africa	2,053	2,135	2,021	2,227
West Asia and North Africa	2,988	3,114	2,943	3,234

Source: IFPRI-IMPACT simulation results

of 14 million of malnourished children.The baseline results illustrate the paradox that I have been talking about. Declining food prices coexisting with sustained or increasing malnutrition in much of the world. Even with a relative abundance of food in the world, there is not enough production growth in Sub-Saharan Africa to improve the food security situation.

There are two fundamental global trends in demand and supply that I would like to mention before going further.

The demand side

On the demand side, 93% of the population growth will take place in the developing world thereby adding some 2 billion people. Note the growth in actual numbers mainly in Asia and in Africa. In addition, rapidly increasing urbanization, means that by the year 2020 or slightly before, half of the population of the developing world will live in urban areas. This rapid urbanization plus changing rates of preferences and rising incomes, are causing a shift to more diversified diets with higher per capita consumption of meat, milk, dairy products, vegetables, and a low per capita consumption of cereals. In China and in much of South-East Asia, per capita consumption of rice is already falling. And per capita cereal consumption is declining even in South Asia. This dietary transition which is going on in much of the developing world, reduces demand pressure on basic food staples.

The supply side

On the supply side we project the reduced crop productivity growth rates of the last decade to decline even more, but not faster than in the past. Additional yield increases in farmers' fields will be produced by conventional plant breeding for perhaps the next decade or so. And then the gains will increasingly come from wide crossing, transgenic crosses, and other tools resulting from advances in biotechnological research methods.

Now however, there are areas of concern on the supply side. Over 60% of the world fisheries are either fully exploited or over exploited. The harvest from the seas has stagnated at about 100 Mt over the past five years. However, the world catch per capita is about at the same level as in the 1970s. Indeed, the per capita catch is projected to decline over the next 25 years. While freshwater fish farming provides some hope for the future, the state of the world fisheries, given the recent news about over competition for these resources, is quite alarming.

Let me also highlight two regional trends; both are influencing our analysis.

Some regional aspects

The first is that the two giants of the developing world, China and India, will not put severe pressure on world cereal markets. China's net cereal imports are pro-

jected to increase from 13 Mt to 27 Mt, almost all of it will be wheat. We emphasize this point because it is in contrast with some other projections you can see in the international press. India is projected to remain essentially self-sufficient in cereals in effective market demand.

These results, however, depend on maintaining research investment levels. In-depth studies for China and India under the 2020 initiative shows that declines in research investment would lead China and India to increase their cereal imports. That would put significantly more pressure on world food markets.

Finally, the model projects dramatic shifts in Eastern Europe and the former Soviet Union countries from big cereal importers to substantial cereal exporters. Removal of food subsidies and other prices distortions combined with sharp income decline have already resulted in falling real consumption in these regions. The impact of these changes will be intensified over time. Improved feeding efficiency in the livestock industry, and a projected gradual recovery will cause both production and demand to grow. These developments will enable Eastern Europe and the former Soviet Union countries to shift from being net importers (1990) to becoming net exporters by the year 2020.

So far so good I hope. If, however, the baseline projections are wrong, we at least have a best-guess starting point which allows us to envisage change if the baseline assumptions change.

Two contrasted scenarios

The first scenario is called "low investment, low growth scenario"

Low investment and low growth scenario

This scenario includes a 25% reduction in agriculture income by the year 2020, compared to the baseline. It also includes a reduction in crop productivity growth. It will be due to a reduction of investment in research for the developing countries, both in the national and international systems'research budgets. It is based on a reduction in investment in health, education and sanitation, leading to a worsening of projected indicators of female education, indicators of access to clean water, and indicators of social expenditures. This reduction would be about 20%. So, if you combine those three changes, you will get a set of projections which we call the low investment scenario.

It includes the highly negative effects of reduced public investment in developing country food production, with production in cereals dropping by 10% or 150 Mt. The harder step is the major staples-wheat-rice which suffer the biggest decline in productivity from the reduction in public research investments.

High investment scenario

The high investment scenario, in contrast, shows that an annual cereal production in the developing world would be about 100 Mt higher by 2020 as a result of increased spending in agricultural research. This scenario assumes that we would have a 25% increase in non-agricultural income growth in developing countries. It assumes an increase in public investment in agricultural research of about 750 M dollars annually. It also assumes an increase in the indicators for female education, access to clean water, and social expenditures of about 20%. So it is the opposite of the low investment scenario.

Malnutrition under the different scenarios

How do these changes in population, production, income and prices affect malnutrition? If we compare the low investment scenario with the baseline: low investment and slower growth add 47 million children to the ranges of malnourished. The increase is concentrated in South Asia and Sub-Saharan Africa where malnutrition is already high. On a more encouraging note, there would be a sharp reduction in the number of malnourished observed in the developing world. The high investment scenario reduces the number of malnourished children from a 184 million in 1990 to an 117 million in 2020. This is an improvement since there are 67 million fewer malnourished children. A substantial gain. This progress however requires three forces to be at work; increased income growth generates demand for food, expanded investment in agricultural research, and higher expenditure on health, education and nutrition.

International efforts and benefits

Such efforts would require increased national and international commitment to agricultural development. These increased commitments from the international community may not be as painful as some or many seem to think. The point that I would like to make here is that developed countries also gain from increased investment in research and faster growth in the developing world.

If we compare the growth value of food exports from developed countries under the baseline and alternative scenarios, we see that the alternative investment scenarios tell an interesting story. If we first compare the value of exports from developed countries under the baseline and low investment scenarios it can be seen that the value of exports from the developed countries' crops vary little under the low investment case. That is because with reduced domestic production, developing countries rely a bit more on food imports. However, the high investment scenario results in an increase in the value of exports from the developed countries by 6 billion dollars relative to the baseline, or by 11 billion relative to the low investment case. Clearly increased international investment in agriculture, and improved growth in developing countries would be beneficial for agricultural exports from the developed world.

What I would like to do now is very briefly touch on four other pieces of work, give you a taste of what they are like, and then go to my conclusions. The first one is land degradation.

Land degradation

An expert consultancy in spring 1995 in Washington allowed us to draw a map of the soil degradation situation. A group of some 45 physical and social scientists tried to identify the magnitude of land degradation issues and identify critical issues that need urgent attention. I would like to emphasize that one of their findings was how poor the data on land degradation are internationally, and how important it is that these data be improved. And finally, I would also be willing to admit that our ability to capture land degradation in the global food model was somewhat less rigorous that we had hoped. Both improved data and better ways of modelling the impact of land degradation are high on our agenda for the future.

The second point I would like to make refers to the world's water situation.

The world's water situation

There is an alarming theory saying that water is or may become of short supply. South Asia and the Middle East are obviously good examples. Research indicates that there are some countries that are short of water even today, and this number could grow to at least 30 by the year 2020. In most of these areas, in most of these countries, it is worth pointing out that water is considered as a free good. It is distributed and used in agriculture by farmers who very seldom pay anything.

Biotechnology

We brought a group of private sector representatives together with a group of environmental experts and academics to look at the issue of pesticides and biotechnologies. A lot could be said about that workshop. The point I want to make is that there was a consensus that the private sector was not going to be spending much money trying to improve yields in the developing world. There are efforts being devoted but mainly to non-yield increasing factors in agriculture in developed countries, for example on the flavor and storage of vegetable and fruit. So there is very little that will come from the private sector that will be useful to the developing world. And coming to our 2020 recommendations, it is important to give the developing world the capacity to use the gains of biotechnological methodology for their own crops and their own uses.

The population issue

I must admit that we have glazed over the population issue. We have done that in part because that topic has been adequately covered in a number of international forums

over the past two years; the UN Conferences in Cairo and Beijing in particular. But it has also been glazed over in the 2020 vision, because the process of demographic change is slow enough that it is not going to have very much impact on our scenarios. However, what we do today in the area of population control will have enormous impact on what happens beyond the year 2020. We want to emphasize that in the 2020 Vision Conference in June 1995, it was reported that perhaps the most important thing we can do to reduce population growth in developing countries over the next few years is to educate young girls. And this has an added benefit since, in the long run, it also increases agricultural production, because these young women will eventually become producers and distributors of food in many of their countries. Details on this and other issues are available in 2020 publications.

Conclusion

Let me conclude. What I hope I have been able to show you today is that although world food prices are likely to decline in the future, national governments and international donors face a huge challenge in improving food security in the developing world. There is likely to be very little improvement in food security in much of the developing world. But increases in the number of malnourished children in Sub-Saharan Africa will probably not happen. However, if instead, public investment in agricultural research continues to decline, relatively favorable food situations will significantly worsen. A drop in investment in agricultural research and development by national governments and international development agencies would lead to reduced food production in the developing world, to a reversal of price decline, and a sharp worsening of malnutrition everywhere. But the results shown here also indicate that progress can be made in increasing food availability, reducing malnutrition around the globe, if faster economic growth is coupled with increases in economic investments, in agricultural research and in the areas of health, nutrition and education.

LONG-TERM CHALLENGES FOR AGRICULTURE AND FOOD

Comments and debates

Chairman: Christopher Nkwanyana (SADCC)

Investment efficiency

U. LELE: One of the many reasons why investment in agriculture has declined is because of the view that it was not efficient to begin with. So there has

been a shift from an investment focus strategy to a policy focus strategy in order to get even greater efficiency in resources. Do you take into account these considerations in your projections?

D. NYGAARD: The model considers increased expenditure (not only investment). It does not indicate whether expenditure money is going to be invested in physical capital or policy or research.

The relation between research efforts and yield

B. CHEVASSUS: How have you defined the relation between research development spending and increases in agricultural yields?

D. NYGAARD: Concerning the relationship between investment in research and the influence on yields, we do have return to investment data that we measure now in a number of parts of the world. We use these data in the model.

Assumptions on caloric level incidence on malnourishment

U. LELE: There is a permanent debate and controversy on the number of calories defining malnourishment levels. In India for example, some indicate that 2200 cal/day/capita is a sufficient level while others pretend that it is 3000. What assumptions are you using as the desirable level? What difference would that make to your estimate of malnourishment?

D. NYGAARD: I cannot tell you now what would happen to the number of malnourished with a variable standard. We feel that these indications are valid globally. I know that there is a debate on this issue. We have it in IFPRI as well. We feel reasonably comfortable in using the measure that we have used, but can change the assumptions and see what could change by region.

The meat consumption—income relation

B.CHEVASSUS: What relation have you established between meat consumption and income? In France, over the past ten years, meat consumption has no longer evolved in the classic econometric relationship which had prevailed for many years therefore.

D. NYGAARD: There is certainly a relationship between increasing incomes in South and South-East Asia and meat consumption, or changes in dietary transition. One of the discussion papers goes into some detail looking at the dietary transition in China, Taïwan and South Korea. At least, in the developing economies we feel that there is a strong relationship.

LONG-TERM CHALLENGES FOR AGRICULTURE AND FOOD

Conclusions of 2020 Vision study[1]

Food security and nutrition

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Food security	Number of food-insecure people declining, but 800 million still lack access to sufficient food for healthy, productive lives	Enhance	Alleviate poverty, generate employment and incomes, and improve food distribution systems
Malnutrition	Bleak prospects for reducing malnutrition among children in Sub-Saharan Africa; reductions expected in other regions	Reverse in Sub-Saharan Africa; enhance elsewhere	Increase incomes, especially of women; enhance access to education health care, clean water, and sanitation
Obesity	Emerging in some areas, notably cities; likely to increase in coming years	Reverse	Change underlying behavioral trends; improve eating habits

Poverty and economic growth

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Poverty	Likely to persist in South Asia and Latin America and increase considerably in Sub-Saharan Africa	Reverse	Accelarate broad-based economic growth, with agriculture as the engine of growth in low-income countries
Economic growth	Growth rates expected to remain high in Asia and improve in Africa and Latin America, but disparities likely to continue as Sub-Saharan African lags behind	Enhance	Accelerate income growth in slow-growing countries through macroeconomic stabilization, market reforms, and improved human resources
Income disparities	Income gap widening between the rich and poor within and across countries	Reverse	Narrow gap by removing disparities inaccess to markets, assets, and human development ressources

1 IFPRI, 1996. A 2020 Vision for food, agriculture and the environment: the vision, challenge, and recommended action. Washington, IFPRI.

Human resource development

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Education	Enrollment rates increasing but dropout rates remain high; girls complete fewer years of schooling than boys	Reverse	Assure access to and support for completing primary education for all children, especially female and rural children
Health care	Improving, but 1 billion still lack health care	Enhance	Assure access to primary health care for all, especially women and children
Clean water	Improving; 70 percent have access to safe water now compared with 36 percent in late 1970s	Enhance	Improve access to clean water
Sanitation	Improving, but almost 2 billion people do not have access to sanitation services	Enhance	Improve access to sanitation and sewage services

Food demand and diet changes

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Food demand	Global per capita demand for foodgrains forecast to grow 4 percent and demand for livestock products 18 percent between 1990 and 2020; demand growing faster in developing than developed countries; not expected to increase in Sub-Saharan Africa	Enhance	Generate employment and incomes, especially in Sub-Saharan Africa; lower unit cost of food production and marketing
Diet changes	Diets becoming more diverse: demand for livestock products growing faster than for foodgrains; demand for wheat and maize growing faster than for rice	Subdue feedgrain demand	Improve feed conversion rates (feed needed for each unit of animal product produced) to reduce pressure on grain production

Demographic variables

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Population growth	World population likely to increase by about 2.2 billion between now and 2020, 94 percent of it in the developing world	Subdue	Reduce population growth rates, particulary in Africa; alleviate poverty; increase education, especially for women; and strengthen reproductive health services
Urbanization	Urban population of developing countries expected to more than double to3.6 billion by 2020	Subdue	Alleviate conditions in rural areas causing excessive migration; invest in both urban and rural areas to respond to migration
Age composition	Shifting toward older people in middle-income countries, while remaining very broad at young ages in low-income countries		Invest in education, employment creation, and income generation
Displacement of people	50 million people displaces inside or outside their countries; rapidly growing trend during past 10-20 years likely to continue	Reverse	Adress sources of displacement: breakdown of civil society poverty, and environmental degradation; enforce mechanisms for conflict resolution and laws protecting civilians conflicts

Food supply

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Food production	Growth rate of food production lagging, but foodgrain production likely to grow by 1.5 percent per year and livestock by 1.9 percent; relatively good global food situation masks serious food problems in Sub-Saharan Africa and South Asia	Enhance	Invest in agricultural research; encourage efficient, low-cost, and effective agricultural systems
Food price	Likely to remain stable or decline for most foods	Enhance	Increase food production; reduce marketing, distribution, storage, and processing cost
Yields	Stagnation or slowdown in rate of growth of major cereals	Reverse	Invest in yield-enhancing research and technology; reduce pre- and postharvest losses

Natural resources and agricultural inputs

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Soils	2 billion hectares degraded in past 50 years, much of which can be restored; 5-10 million hectares lost annually to severe degradation	Reverse	Prevent soils from becoming degrated by alleviation poverty, removing distorted resource policies, and securing property rights. Restore degraded soils through land husbandry measures and on-farm investments
Forests	15.4 million hectares of forests annually converted to other uses, two-thirds by small-scale, poor farmers seeking food security; such forest conversion likely to continue	Reverse	Help small-scale farmers obtain alternative ways of meeting food security; reforestation
Marine fisheries	World's fisheries are overxploited; production is at upper limits and is not likely to be higher in 2020	Reverse	Develop mechanisms to prevent exploitation beyond sustainable limits; intensify aquaculture production; improve resource management of natural fisheries
Water	Growing shortages of water across seasons, regions, and countries; competition for water becoming more acute between sectors and countries	Reverse	Reform water rights and water laws; improve incentives for appropriate water use; improve technology for efficient water supply and delivery; improve international cooperation in sharing water
	Deteriorating quality and increasing pollution of water	Reverse	Adopt regulatory and market mechanisms to discourage pollution; invest in provision of clean water and sanitation services
Fertilizers	Global fertilizer use projected to grow annually by 1.2 percent between 1990 and 2020 compared with 2.8 percent in the 1980s	Enhance	Promote balanced and efficient use of plant nutrients from both organic and inorganic sources

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Pesticides	Increased recognition of need to reduce chemical pesticides to protect human and environmental health	Reverse	Adopt environmentally sound alternatives as integrated pest management
Energy	Increasing agricultural production likely to call for increased energy use	Subdue	Develop additional sources of energy, especially renewable sources, and improve efficiency of energy use
Research and technology	Low-income countries underinvesting in agricultural research and cutting back on it; declining support to international agricultural research	Reverse	Expand support to national and international agricultural research systems
	Fragile areas, where a large shareof poor reside, neglected in past research priorities	Reverse	Direct more research to fragile areas
	Public-sector extension services not effective in communicating between farmers and research	Reverse	Develop innovative strategies and techniques to reach farmers; use mass media
Climate change	Global warming unlikely to change global food production in next 25 years, but could have varying regional effects	Subdue	As investment in longer-term future, change human behavior that is contributing to global warming

Markets, infrastructure, and international trade

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Market reforms	Growing trend in developing countries, but often there is insufficient competition in private sector; considerable confusion over role of governments	Enhance	Improve sequencing of market reforms; strengthen capacity of government to perform needed functions
Distribution costs	High in developing countries, especially Africa	Subdue	Invest in improved transportation infrastructure, and marketing facilities
Infrastructure	Infrastructure conditions and coverage poor; past investments have favored urban areas	Reverse	Invest in infrastructure construction and maintenance, especially in rural areas
International trade	Increased integration of developing countries into regional trading arrangements and world markets likely to continue	Enhance	Encourage increased regional integration and further global liberazation

Domestic resource mobilization and international assistance

Challenge	Current Status/ Future Trend	Change in Status/ Trend Required	Highlights of Actions
Domestic savings	Falling in low-income developing countries; too low to support investments needed to achieve the 2020 Vision	Reverse	Improve savings and credit markets
International assistance	Official development assistance to developing countries is slowing; assistance to agriculture declined in 1980s	Reverse	Increase assitance, especially to agricultural research; improve targeting and effectiveness of aid

A 2020 Vision for Food, Agriculture and the Environment

RECOMMENDED ACTION

Per Pinstrup Andersen
Director General IFPRI

Today 800 million people are food insecure. One out of every six persons in the developing world does not have access to enough food for a healthy and productive life. Today 185 million pre-school children are malnourished, not malnourished using some arbitrary calorie standard, but malnourished simply because their weight for age is below the standard; 40,000 pre-school children die every day from nutrition related to illness. But those who survive grow up to be poorly educated. We don't have to wait until 2020 to decide whether we have a food and nutrition problem. We have it right now.

We don't have to accept this. We have shown some scenarios from which in the best case we can bring down the number of malnourished children from 185 million to about 100 million. We have seen that in other scenarios, the number of malnourished children could exceed 200 million by 2020. The point that we are trying to make in these scenarios is that what we do matters. We don't have to accept that Africa is going to have more malnourished children tomorrow than it did yesterday. It all depends of what we do, we and the broader context of the international community including, obviously, first of all, the national governments, non-governmentale organizations, and individual households.

We, at IFPRI, think that it is reasonable to dream about a world that is free of food insecurity and malnutrition, a world where we have an efficient, effective and low cost agriculture that is compatible with sustainable use of natural resources. We call it a vision. You can call it a dream. Let us suppose that we can achieve it by 2020. But we don't have a recipe for you today on how we can achieve it. Primarily because those recipes have to be developed locally and nationally and not at this place or in Washington. But even if we can achieve it by 2020, if we can all agree that that is a reasonable goal to pursue, then maybe we will get half way to the year 2020. Maybe then instead of having 185 million pre-school children that are

malnourished, we will have 50 million. That is quite an improvement, particularly if the children are among those that no longer suffer from it.

So the point that we are making is that we have committed ourselves to this vision not really because it is anything new, but because we see the international community is floundering, and lacks a clear vision as to where we want to go and how we get there. And if you can subscribe to the 2020 Vision, and all the underlying goals, you don't have to quote IFPRI for any of this. Make it yours and claim ownership to it, and we will get somewhere.

I should also remind you that this vision is based on freedom from hunger being a basic human right. Our Governments have signed declaration after declaration on freedom from hunger and freedom from malnutrition—whatever the words that happen to be in these many declarations—and I think we have to stand by them not only in our own countries, but also in the countries that we are trying to assist.

We must change our behavior. We must act now. If we continue the "business as usual," as we have done over the last ten years, we know what the results are likely to be: a slight decrease in the number of malnourished children, a slight decrease in the number of food insecure people, but an increase in malnutrition in parts of the world, such as sub-Saharan Africa and possibly South Asia.

So what is it that we need to do?

Let me first repeat the point already made that IFPRI has no intention of claiming to have an action program that is going to work in each and every country. In fact, the plan I am going to show may not work in any country. It is a starting point from where each country and each international development agency can develop its own plan. So it is the best starting point, and therefore it has been coopted at somewhat of a general level.

Let me also mention that the vision document (a 2020 Vision for Food, Agriculture and the Environment) outlines a great many specific measures as part of the Action Plan. And obviously I can only give you some selective pieces of this Action Plan .

Some selective pieces of the Action Plan

We started with a broad look at the direction that the world must take to achieve the 2020 Vision. It will only be achieved if broad based economic growth is accelerated, particularly in the poorest developing countries. Such growth must not only involve agriculture, but agriculture must be the lead sector. I am talking about low income developing countries, not the middle income ones. In the poorest developing countries agriculture employs 75% of the labor force. It generates nearly half the national income. It produces more than half the export earnings. It is true that the world food supplies are sufficient to feed everybody an adequate

diet. But that does not mean we should stop investing in agriculture, because agriculture is the lead sector for economic growth. Agriculture is where we have to start if we want to alleviate poverty and assure sustainable use of natural resources. Even if we have enough food, we would use agriculture as the lead sector. I am stressing this because there is a great deal of misinformation about why we should, or shouldn't, invest in agriculture. If we have a pile of food in the EU and in the USA - the piles are much less than they were a couple of months ago - it does not mean we should not invest in developing countries'agriculture, for the reasons that I just mentioned.

The 2020 Vision requires that research, technology, infrastructure, and competitive markets be put to work, to reduce the cost of producing and marketing each unit of food.

Some practices for managing natural resources must be adopted to assure that more intensive farming methods are sustainable and to prevent or minimize environmental degradation while maintaining biodiversity.

Poor people, especially poor women, must gain greater access to productive resources, to markets, to employment, to education, to clean water and sanitation, and to primary healthcare. Women must be given a louder voice in decision-making at all levels. I am not saying this because it happens to be politically correct. I am saying this because we now have massive evidence to show that power and income in the hands of women in low income household is often likely to have a much greater effect on child malnutrition and food security than power in the hands of men.

The condition that led to involuntary migration and displacement of people such as civil strives and conflicts, poverty and environmental degradation must be addressed. We have just finished a study as part of the 2020 Vision initiative on the links between armed conflict and food security. There is a great deal to be done in this area. In fact food security may well be the security issue in the future, as the cold war was.

Six areas of action

From the basis of this general assessment we have identified six areas of action required to achieve the 2020 Vision.

First, developing country governments must be strengthened to undertake activities best done by Governments. The international development community as well as national governments the world over must depart from the popular view that weak government is good government.

Strengthening the Governments

Non-governmental organizations and the private sector are of extreme importance but they cannot achieve the 2020 Vision alone. Common efforts to reform the public sector threaten to weaken the ability of governments to do what they must do. For example, governments must maintain law and order. We from Western Europe take this for granted. In Colombia, Zaire, Rwanda and many other countries, it is not taken for granted. Governments must establish and enforce property rights jointly with local communities, again something we take for granted. It is extremely important if we want to assure sustainable use of natural resources. Government must establish and enforce regulations, standards and measures and promote competition in private sector markets. This is something that much of the international community is over-looking. The argument that if you can just remove the inefficient parastatal agencies in agricultural markets, then small traders will come in to play immediately and compete among themselves, is not good.

Agricultural research

We estimated in our work that all developing countries spend at least 1% of the value of their agricultural output on agricultural research. This figure should move towards 2% over the next 5 to 10 years.

Let us take another look at how things are going in one of the most critical areas as far as food security is concerned. During the 1960s Sub-Saharan Africa increased its agricultural research by close to 7% a year. During the 1970s there was an increase of about 2.4%. Then during the 1980s, there were no increase. Past investments in training researchers of Sub-Saharan Africa continued to pay off during the 1980s, so Sub-Saharan Africa got more and more researchers, but no more money. So each researcher has much less money now than he had 15 years ago. In fact, if you travel around visiting national research institutions in Africa, you will know that there is little money available for doing research; that is pathetic. So we are not helping to support what we helped to build in the 1960s and 1970s.

The national agricultural research systems must be supported by a vibrant international agricultural research system that undertakes research with large international benefits, because such an international system can make the national programs much more efficient and much more effective by disseminating results that have wide applicability across countries. Such research is frequently not undertaken by national institutions because an individual national institution cannot reap enough benefit. But when it is applied in a large number of countries, it becomes very profitable. And, of course, the investment in international agricultural research is grossly insufficient as is investment in national agricultural research particularly, but not exclusively, in Sub-Saharan Africa.

Although more research is needed for eco-regions, research needs to be particularly increased in the less-favored areas. What we are referring to are areas

with agricultural potential, fragile soils, limited or irregular rainfall, and many poor people.

Another point is that in the industrialized countries, molecular biology and biotechnological research are producing exciting break-throughs and significant gains for agriculture. There is a lot in the pipeline. We have the opportunity to tap into the pipeline, but almost everything in it is aimed at temperate zone agriculture. And while some of the methods, of course, are applicable to tropical agriculture, the empirical content frequently is not, because it is not focused on solving problems of agriculture and poor farmers in tropical regions. It is of critical importance that the use of molecular biology be expanded to help solve agricultural problems in developing countries. There is, I think, a misconception that molecular biology methods and other "high sciences" is inappropriate for solving small farmers' problems. We disagree with that perception. It may well be that what the small farmer in semi-dry areas or in the less-favored areas needs most is a drought tolerant cereal variety. And it may well be that we need "high science" to develop that. Maybe there is a need to push one more time for nitrogen fixing grasses. Maybe there is a need to look for pest resistance in various crops that are grown by the poor farmers in the less favored areas. So why not use the best science available to deal with the poor farmers'problems?

Focusing on less-favored areas

About 80% of the world's poor people are in rural areas, and 50% live in less-favored areas. Of course we cannot guarantee that the numbers are exact, but they are orders of magnitude and are probably good enough for the particular purpose to which they are being put to use.

If we are really serious about focusing on alleviating poverty and protecting natural resources, we have to go to those areas, because that is where most of the poor people live, and they are depleting natural resources to survive. They randomly farm the hill sides, they cut down the forests, they do whatever they have to do to survive probably because they don't have the appropriate technology, infrastructure, or education. We need to emphasize those areas, not at the expense of the high potential areas or the more-favored areas, but in addition to them. Much of the increase in support that I am hoping for would have to go in those less-favored areas.

Working with communities and NGOs

We need to work there with communities because many of the problems in those areas are best solved by communities. We have to give them incentives to deal with the natural resource issues while expanding agricultural production. There are many natural resource management problems that requires the attention of governments and non-governmental organizations. Let me mention three:

First, declining soil fertility in Sub-Saharan Africa and a number of other low income developing countries. This is becoming an extremely serious matter. African farmers are simply removing more nutrients than they put back, and clearly creating an agricultural situation that is not sustainable. One of the problems, of course, is that fertilizers are extremely expensive in Sub-Saharan Africa. And another problem is the organic matter available to the farmers in their production systems may not be as appropriate as they could be. So it seems that we have to work with farmers in those areas to replenish the soil. One idea is to look upon nutrient replenishment, for example phosphorus, as an infrastructure investment. The African soils are in many cases low in phosphorus. One could look upon that as an infrastructure investment like roads and education. The problem, of course, is that the farmers are reaping the benefits. So why should society pay for it in the first place? But it is a problem that cannot be ignored much longer if we want to assist Sub-Saharan Africa in expanding food production and agricultural productivity. In certain circumstances price subsidies for fertilizers might be appropriate as a temporary measure. There is no question in my mind that where infrastructure is extremely weak and soil fertility is being reduced every year, and where there is a need to increase productivity and governments must deal with temporary high prices for plants nutrients, investments should made in infrastructure that will bring down the cost of plants nutrients, and fertilizer subsidies might be justified. But there is a trade off the governments have to deal with: subsidizing-fertilizers or spending money for research, education or infrastructure.

The issue is much clearer as far pesticides are concerned, because developing countries obviously are using too much chemical pesticides. So we must, as a matter of urgency, move towards integrated pest management. We must strengthen research and applications of integrated pest management with, of course, the use of chemical pesticides where they are the only solution.

The last natural resource management issue I want to discuss here has to do with water scarcity. It is not so much water scarcity as such, but inappropriate use of existing water. Water use efficiency is low both in agriculture and elsewhere. That is not a surprise, of course, because water is, for all practical purposes, like air, free of charge for most users around the world. Being a scarce resource, however, should be priced according to its scarcity, just like other goods and services. There are all kinds of cultural and relative reasons why it is very difficult to price water. But it is necessary to work with governments in order to set appropriate market prices for water, so that it can be allocated accordingly. It is also necessary to work with local communities, and user associations so that they too allocate water in a more effective manner.

Improving marketing systems

The fifth area of action has to do with marketing systems. They must be improved in low income countries. It is too expensive to move food from the producer to the

consumer in a lot of countries. And it is not because the consumer wants it processed and packaged. It has to do with poor infrastructure, lack of competition, and many other things. There are a lot of opportunities that are embodied in getting the marketing system right. The marketing costs for African countries are much higher than in Asia.

Assisting countries committed to hunger, poverty, and malnutrition alleviation

The last area for action has to do with foreign assistance. We suggest that foreign assistance has to be made available to countries that have demonstrated a commitment to reducing hunger, poverty and malnutrition and to protecting the environment. Those are the goals underlying 2020 Vision. We are not so presumptuous as to say that only countries that subscribe to 2020 Vision should have foreign assistance, but it should be limited to countries that subscribe to the goals underlying this vision.

We are also suggesting that, in view of the large amount of international capital now available, foreign assistance be targeted more specifically on the low income developing countries. We don't see much of a reason to continue providing foreign assistance to middle income developing countries who can get access to capital in the international market.

I want to share with you another concern related to foreign assistance. Some years ago, OECD countries agreed among themselves that they would allocate 0.7% of GNP to foreign assistance. Not many countries remember that. We ought to move more in this direction instead of moving the opposite way. But the other frightening trend I want to point out concerns assistance to agricultural development. It has been suggested that we should not give so much support to agricultural projects, and FAO statistics prove that there has been a tremendous drop. If we consider that providing aid to agriculture is generally an investment, the situation is not so good. We have completed a study at IFPRI that shows that for each dollar you invest in developing countries'agriculture, these countries increase their imports by more than 4 dollars. Aid is not bad business.

Conclusion

Let me summarize the six recommended action as follows: Government and civil societies should invest in agricultural productivity, sustainable use of water and other natural resources, and improvements in agricultural markets.

Let me now try to put all this together with respect to the implications for agricultural research, because this conference is about agricultural research and the Doubly Green Revolution.

We have to focus on the triple goal of poverty alleviation, sustainable use of natural resources, and improved food security. If we are to achieve the 2020 Vision, we have to expand investment in agricultural research, nationally and internationally. We have to redress the balance between investments (not just research but all investments) in less-favored versus more-favored areas.

We need to emphasize Sub-Saharan Africa and South Asia, because that is where we are going to have the biggest food security problems and potentially very important environmental problems.

But it is not enough to put more money into agricultural research. We also have to make research more effective in solving small farmers'problems. For this, we need more effective farmer level participation. We must learn to start our research at the farm level by understanding the problems, opportunities, and challenges, and then set our priorities on the basis of that. This is difficult to do for an agricultural researcher who has been told during all his training that he alone sees what the research priorities should be.

We think it is of paramount importance that agricultural research focus on reducing production costs. I want to remind you, before you tell me that it is impossible, that the Green Revolution has reduced the unit cost of wheat and rice by 30%. And that matters to low income households who spend 50 to 70% of their income on food. We must focus on increasing plant nutrient response, and focus on cases where the micro-nutrient content in crops can be increased. We must emphasize integrated pest management and try to reduce the chemical component.

Because of the tremendous increase in livestock demand, we must look for increased feed efficiency and for new sources.

We must improve the incentives for sustainable use of natural resources, including at the community level.

And we must, of course, improve information and consultation about food policy. Our work is to show very clearly, the importance of having the right food policy, and the interaction between food policy and technology.

Let me finish by saying that the earth can feed 8 billion people today and also by the year 2020. The problem is not the carrying capacity as some would argue. However, if we keep degrading the natural resources we will get to a stage where we will be constrained by it. Action is very urgent, because the carrying capacity depends on what we do between now and the year 2020.

Thank you very much.

Agriculture, food and the environment in 2020

COMMENTS AND DEBATES

Chaired by Christopher Nkwanyana and Gunther Dresrusse

The growing scarcity of water

P. DUBREUIL: It is said that the growing scarcity of water is partly due to inefficiency of use in irrigated systems. In the model, do you take account of an improvement in water usage efficiency towards 2020? What percentage of food supplies do you assign to production from irrigated crops? Do you consider that extra efforts should be made for irrigated rather than rainfed crops, or not?

D. NYGAARD: The model does not assume a growth in irrigated areas. The area is not expected to grow greatly during the next 25 years. It assumes improved efficiency in managing irrigated agriculture. The assumptions were made by region based on regional seminars.

P. PINSTRUP ANDERSEN: Should we devote major efforts to irrigate agriculture? I think we need much more work to deal with the waterlogging and salinisation that is occurring in irrigated areas in many developing countries. There is also a need for research to get the policies right so that the water is allocated such that we don't continue to couch waterlogging and salinisation in irrigated systems. But the problem is that we desperately need research in less favoured areas. And I want to make it clear again that I am not arguing about taking money away from irrigated areas and putting in into the hillside. I am arguing about expanding the total support, and using a large share of that expansion for the hillside areas and the less favoured areas. It is of course a matter of balance.

D. NYGAARD: A comment in addition. Water shortage is becoming an important problem. In Egypt for example, more than 90% of the waters go to agriculture primarily. The projection is that may drop to 70 to 80% by 2020. And the country has to feed another 25 million people. The competition is more from industry and domestic use. But Egypt would be able to make important strides in its ability to increase agriculture production over the next 25 years by conserving or more efficiently using the water that is allocated to agriculture.

The role of biotechnologies

F. HEIDHUES: Biotechnologies are focused for crops in countries where agriculture is industrialised. If biotechnology has a great potential, how can we make it better serve the needs of the poor? Do you have a vision of which role the CGIAR could play in this domain?

P. PINSTRUP ANDERSEN: I think we need to strengthen partnerships between research institutions in the industrialised world and in developing countries, of the kind that have been so effectively implemented by French institutions over many years. The work being done by the research institutions and universities in the industrialised world could be much better used in the developing countries. We also have to strengthen the capacities of those countries in biotechnology.

The CGIAR centres can strengthen the partnership between industrialised countries research and that of the developing countries.

D. NYGAARD: The best example is the Rockefeller Foundation support for rice programmes. Researchers from Asia have been trained and then participated in the creation of biotech- research programmes in collaboration with international centres in their own countries.

J. PEACOCK: Can the model give indications on populations concerned with micro-nutrient deficiencies? Iron deficiencies and other deficiencies can be reduced by genetic engineering.

D. NYGAARD: No, the model is not robust enough to give ideas of a targeted program to reduce deficiencies.

P. PINSTRUP ANDERSEN: Three centres, CIAT, IRRI and CIMMYT, are widespread attempting to breed additional iron and zinc content into crops. Iron deficiency is widespread around the world, particularly in low income countries, and particularly in women. A lot of work has been done in Australia and at Cornell University.

N. MBAYE: Biotechnologies are not yet readily available in our countries. Access costs remain very high. No doubt regional groupings and support, within the framework of international cooperation, should be considered, in a similar manner to what is being done in other fields of interest.

Food crop

ML. MOYNET: In your view of 2020, will there be more crop species cultivated ? Or will current species be adapted to other environments. Maize, for example, has been adapted to drought by means of biotechnology.

P. PINSTRUP ANDERSEN: Drought resistant maize is available to southern Africa and has a major impact. But we have to do much more not only, for other regions, but also for other crops, even new crops if their development is needed by the local populations.

M. JACQUOT: It is true that we are still wondering a great deal about the possibility of improving a large number of plants which are currently "orphans", in that research has shown very little interest in them. These are plants which could become of greater importance in the future, particularly in regions with low production potentials.

The role of industrial crop

D. PICARD: Results from the 2020 model mainly cover food crop production. Production systems generally combine food crops with other productions. The income they generate, and regional economic development, both depend on all the crops. Does the model take this aspect into account?

D. NYGAARD: Other crops like cotton, coffee, cocoa are not modelled explicitly. All the non food activities are aggregated. But they do affect the model by generating more income. As we extend the model, our first priority would be to get more details by region and by country. Africa is nighly aggregated too.

E. HANAK-FREUD: Speaking now of the vision, how do the export crops—or cash crops or industrial crops—fit into the 2020 vision? Agricultural growth and diminution of poverty can also include the role of these crops. For CIRAD, not only food crops can contribute to these goals. So what priority should be put on research on the industrial crops?

P. PINSTRUP ANDERSEN: Cash crops and industrial crops are obviously an important source of income and have to be taken into account in achieving the goals of reducing poverty and food insecurity. It is correct that CGIAR is mainly focused on food.

Priority for high potential zones or for others

M. SEBILLOTTE: There is a major difference between the first presentation relating to the model and the recommendations made during the second presentation which does not appear to me, in view of the information we have, to have needed the work of the model in order to be recognised. You have produced a global model, but in the conclusions one arrives at the idea that highly geographically localised efforts are to be made. How does the global scale of the analysis work alongside the more locally targeted

scale of the recommendations? How can one justify giving priority to the poorest zones in one country compared with other zones?

P. PINSTRUP ANDERSEN: The model that we keep talking about is a very small part of the 2020 Vision initiative. It is a tool to help us understand global and regional issues, as they relate to food demand, food supply and nutrition. But we really have made no attempt to incorporate many of the things that we are talking about into the model. We do not model what would happen if we increased water use efficiency either. We want to keep the model in its place. It is only a tool for providing indicators.We try to use a lot of common sense, a lot of qualitative information. I want to make it very clear. IFPRI is not a modelling institution. We use models for very specific purposes.

Less-favoured areas and agriculture cannot imitate the Green Revolution agriculture

M. VERBLOW: In some cases, for example in East Africa, smallholders are imitating the commercial farmers by using hybrid maize, a lot of inputs, ect. But they are living in marginal conditions. This is the result of the evolution of consumption patterns. But it would probably be better for the smallholders to grow drought-resistant root crops. What can be done?

D. NYGAARD: It might have to do with relative prices, and also with the fact that we are "imposing" the same production systems in a lot of places. It is not only a matter of imitating, it is also a matter of time preferences. Poor people also try to set aside time for non agricultural activities. This could push in the direction of grain replacing root crops.

Investments in agriculture are decreasing

M. PETIT: One may also achieve consensus within the international community on the necessity to increase public aid to agriculture. However, I would warn the authors against the limitations of the data which have been borrowed by the FAO to illustrate the decrease in aid to agriculture. A major share of the credits included come from the World Bank. I have worked on these data and I can tell you that they are not very significant. A major share of the aid to agriculture granted by the IBRD in the 80s - agriculture represented 30% of commitments - dealt with integrated rural development projects and agricultural credit projects. A great deal of spending by these projects was not used to finance investments. The largest share of investments in agriculture were in fact made by the farmers themselves. This investment indicator is therefore a poor one.

P. PINSTRUP ANDERSEN: We have also collected our own data directly from the institutions, and have compared them closely with the FAO data. We have used different definitions of investment in agriculture. But for agricultural research, the data are quite reliable. They have been collected from the countries by ISNAR and more recently by IFPRI, and come from a number of institutions. Signifiant cuts have been made in agricultural research.

Is agriculture a driving sector for development?

M. VERBLOW: To some extent CIRAD has demonstrated the position and importance of agronomic research in production growth. For thirty years, agronomic research has been considered as part of a chain. I would like to quote the highly French term of "filière" commodity, thanks to which one can almost directly monitor the effect of research in the growth of production and productivity. By changing methods of public intervention, this form of organisation disappears. The link between research and production is no longer so direct. It is true that one has too great a tendency to continually change the method of public intervention, and as P. Pinstrup Andersen said, to rapidly change band wagons maybe only to go back to the same ones again after a certain amount of time. For example, by returning to the question of priority sector choices and their efficiency in development.

P. PINSTRUP ANDERSEN: I agree, that we must not develop another "band wagon" along sectoral lines, for example. I don't think that agriculture is going to solve all our problems. But the reason that I stressed agriculture is that it fell off the band wagon. We have a lot of experience with having farmers lead broad-based economic growth. We seem to somehow use that experience less and less as we proceed to assist low income developing countries. That is why I am emphasizing agriculture, not that we should get back on sectorial line. I am in complete agreement that we should not. That is why I also stress investment in poor people: health care, education, access to productive assets (in some cases it means land reform, in other cases credit), infrastructures. But, in low income developing countries, we cannot achieve the environnent and poverty goal unless we make agriculture "vibrant"

Investing more in research, or making better investments?

V. DOLLÉ: The scenario highlighted by the 2020 Vision highlights growth in investments in agriculture and agronomic research. However, one may also consider a scenario in which one would invest differently. One must

therefore be better capable of analysing the effects of previous investments, asking questions regarding our capacity for working on new subjects, and implementing other research methods. Since these are new subjects, more work needs to be done on the transformation of food products, small food companies, the quality of products and in putting them on the market. One should also look at organisational methods for agriculture in the future. The limitations of the green revolution have been observed; we know the limitations of collectivist agricultural system. What can one say regarding the future of family-based agriculture which, in many countries, represents the vast majority of producers?

Will researchers be able to base their work on the demonstrated requirements?

M. SEBILLOTTE: How can one prevent western experts (who make up the vast majority) from continuing to think in terms of western models? In this respect, we have already been trying for a long time to train researchers to define their orders of priority on the basis of analyses made in the field and by farmers themselves. Change is slow, however.

P. PINSTRUP ANDERSEN: When you have a PhD, you think that you know better than a poor farmer. The problem is that you don't know the same things. You may know how to do research but the farmer probably knows better what can be done or not. It is a mentality we have to change. I am aware of a lot of the work that has been done in French universities and research centres, also in some international centres like CIAT. We have to keep pushing for this view: try first to understand what farmers need, what they could do, and then bring that back to the agriculture researchers. Farmers can participate much more effectively in knowledge generation and in agricultural research.

How does one decide what to do today, whilst aiming at 2020?

S. SNRECH: Are there any strategies that can be implemented in order to resolve problems which will arise in 25 years time? I have the feeling that we are looking at a long term view or at responses which are a juxtaposition of short-term programmes and not—even supposing that it were possible—at a 25-year strategy.

P. PINSTRUP ANDERSEN: We have been looking for ways to guide actions that have a long term perspective. Some of the décisions we make now are responsable for the future. For example, as long as international food prices

are low, we won't have investments in agriculture in developing countries. It is an obvious position even today, but certainly if you take a 25 year time horizon not investing enough in agriculture is a terrible decision that we have made implicitly.

D. NYGAARD: It is urgent to think about 25-year strategies. A lot of what we are going to do during the next five years will be important for the next 25 years. The more obvious and perhaps even more important is population; what we do in the next five years is critical to what happens to next 30, and if we don't do something, we will miss an opportunity. So there is some urgency in the process.

S. SNRECH: One should rather show more pragmatism in recommendations, weighing the urgency of problems against our capacity for acting on them. There are some serious problems to which we do not have any solutions we need to find compromises between what aid can do and what it cannot do.

Poverty and malnutrition. How can they be measured?

L. TUBIANA: Is what you term under-nourished in the model merely a question of a number of calories or of balance in diet? Moreover, is there a relation between the decrease in mulnutrition and economic growth? It is said that growth reduces under-nutrition, however even in high growth economies one can observe a resurgence or extension of malnutrition. This is of course a problem of income distribution but may also be due to dietary transitions.

P. PINSTRUP ANDERSEN: There is a frightening statistic. In 1960, the 20% poorest of the world population captured 2,5% of the world's income. Today, the 20% of the world poorest captures 1,2%, the half. If that tendency continues, we are going to see a lot of malnutrition.

D. NYGAARD: We have the same problem in measuring malnutrition and poverty itself.

What is poverty?

S. SNRECH: Should one not have a better understanding of why people are poor and what the processes are which have caused people to become poor, including social and regional processes? Otherwise, do we not risk offering only partial solutions? If, for example, one neglects strong power bases within societies, do solutions offered not risk being "taken" from the poor and "recovered" by others?

D. NYGAARD: It does seem to me that we have learned a lot about the development experience in the past years, and we are not showing that enough or effectively. We know a lot about why people are poor. We know a lot more about targeting food systems so that they are efficient and, so that the food gets to the right people, etc. We try to put it in the briefs from which we have a lot of feedback and comment. There is a need for this kind of synthesis. It helps starting the dialogue with policy-makers on some of these issues we have never been talking to before.

M. PETIT: I would also like to underline the following limitation: we have difficulty in taking account of the reality of social relations which is, nonetheless, of capital importance.

N. MBAYE: In this approach to poverty, one should analyse the origins of both rural and urban poverty. Urban poverty is growing in West Africa, although it is still lower than rural poverty.

P. PINSTRUP ANDERSEN: On the rural urban poverty aspect, I completely agree. There is a high risk that policy—makers are going to increase the urban poverty that already exists in so many low income developing countries. The urban poor few but very visible and very local will draw the attention of policy makers, while the rural poor will not. Rural poverty is causing too rapid migration from rural to urban areas. It is important that we keep telling the policy-makers that most of the poor people are still in the rural areas, and that it is not to late to deal with the poverty problem in those areas.

If they don't, they will have to deal with an urban problem, and it could well be considerably more expensive both economically and politically. If we switch over now and, focus even more on the urban areas, we will make the problem more severe. But we should also help the urban poor.

Reducing poverty. Has sufficient research been done with a view to this objective?

H. ROUILLÉ D'ORFEUIL: The question of the poor is central to the work undertaken by IFPRI. However, like Mr Snrech, I consider it necessary to go further towards understanding how poverty occurs and, where it comes from? Who are the poor? Where are they? Would investment in research be sufficient to create development conditions or should one first ensure that structural obstacles to the elimination of poverty are removed? Is this not first and foremost an economic policy problem since societies create wealth and poverty at the same time? We cannot consider these 800 million poor as being a new problem which we must deal with today, without reference to everything which has been done by societies throughout their history. It is true that reducing poverty implies a strong will to

deal with political and social problems which can no longer be allowed to continue.

P. PINSTRUP ANDERSEN: Regarding, for example aspects of poverty in the less favoured areas. We have a lot more information now about how natural resource degradation occurs, how much, where, and by whom and for what reasons. But we need much more information about land degradation and its effects on productivity. It is not generally too much, but rather too little technology that causes degradation. It is farmers who have to climb the hillsides to survive because they don't have access to land in other areas or appropriate technology including in many cases better varieties and, better integration between livestock and crop production. A very large part of the natural resource degradation in low income developing countries is brought out by poverty, not because some commercial interest is exploiting nature.

About 20% of the deforestation, for example, is caused by commercial logging, the other 80% is caused by people who trie to survive using the forest. Let's not blame the victims! Let's just recognise what happens. Now, you add to that the fact that there is very little new technology that is appropriate for the less favoured areas, and that agricultural research in the past has tended to focus on areas where the biggest production increases could be obtained, etc.

Is there in practice a unanimous approach to the combat against food insecurity?

M. PETIT: Much has been said about the necessity for sharing the 2020 Vision, particularly in northern countries, and about the importance of the combat against poverty and food insecurity. I consider that the problem is perhaps even more difficult in countries in the south. Maybe in the north a coalition could be re-forged, rather as the President of the Senate suggested at the beginning of our meeting, both in terms of generosity and well-understood interests for the future. However, there is an area where contradiction is particularly evident and affects us directly. SNRAs often target objectives other than the combat against poverty and food insecurity. Agricultural competitiveness objectives are of course also legitimate but do not necessarily tally with the objective of food security. How can partnerships be forged with countries and their governments who share only part of the 2020 Vision?

The food question and the prevention of social conflicts

P. STRASTEVEGEM: Financial resources available for development and research have been decreasing, partly because of emergency actions. How does the

model cover conflict prevention and thus, causally, reduce the need for emergency relief operations?

D. NYGAARD: We are aware that we have not treated the problems of conflicts, We have commissions of research on this issue. The number of refugees has grown well enough tenfold in the past 10 years. It is an enormous number of people, and the speed with which these numbers are growing is frightening. It is difficult to put this in a prédictive model. But the point is correct: it could very much affect the amount of money that is safe for long term development.

Complementarity of interests between donors and recipients

A. DE LATTRE: When one has a vision the important thing is to share it, which is never easy. How do you intend to share this vision, particularly amongst donor countries? You have argued the complementarity of interests between donors and recipients, particularly in terms of research. The "High Growth Scenario" would lead to agricultural exports on the part of donor countries. Could you develop a detailed argument on this question?

D. NYGAARD: Donors' self interest is probably the most powerful motivation. Altruism can be a motivation especially in emergency situations. So we have to avoid spending mostly on emergencies in order to keep a lot for development assistance. And development assistance is not easy to move on the bases of altruism.That is why we try to understand the relationship between investment in developing countries and export market creation as the primary goal of foreign assistance. But it can also be an important secondary goal which may drive the system so that we can achieve the primary goal. We are also looking at technology flyback to donor countries. Much of the research of the CGIAR is also relevant for some donor countries. In the US, a large majority of the rice areas grows varieties developed by IRRI and other CGIAR Centres. Similar situations exist for maize and potatoes. But this is a secondary effect, not a motivating fact.

Is investment in agricultural research really so worthwhile?

S. TOURÉ: You have said that investments by industrialised countries in research for developing countries can considerably increase exports from the former to the latter. If this "yield" is of such interest, why is finance lacking?

P. PINSTRUP ANDERSEN: The export market for industrialised countries is certainly the best self interest indicator of the benefits for these countries themselves. For many years we have known that the economic returns from agricultural research and primary education are very high. My guess is that the industrialised country governments do not invest as much as they should in agricultural research because the implications of doing or not doing so are long term. We also have to ask this question to the developing countries. If you are faced with the choice between fertiliser subsidies - which, if taken away, will hinder the farmers tomorrow -, and agricultural research, which will affect society ten years from now, you probably choose fertiliser subsidies, particularly if you are not quite sure you are going to stay in power if you don't! There is a political economy question that is important. Another reason is that many decision makers don't really believe that the rates of return are so high, because it is difficult to understand and handle. It is society that benefits globally.

Making public action legitimate again

M. PETIT: Laurence Tubiana noted the courage shown by Per Pinstrup Andersen when he said that it is necessary to restore the legitimacy of public action. There is agreement on this point. Very often, the World Bank acts as a scapegoat which is only too easy to caricature. However, on this question, we are all convinced that governments should govern less, in order to govern better. It is true that every idea put forward by the World Bank goes in the direction of a reduction in the State role. However, there is increasing agreement as to what should be done.

How can progress be achieved in institutional change?

A. DE LATTRE: You have pleaded for measures of an institutional nature. Aid and cooperation have invested very little in this area because structural adjustment is easier to propose than institutional change. IFPRI could work on the following theme: how can progress be achieved in institutional change, and particularly in the field of agricultural development?

P. PINSTRUP ANDERSEN: Privatisation does not work in all cases, and perhaps not even in the majority of cases. So, if we send messages calling for privatisation and for strongly reducing the role of the State, it should not be a surprise to us if the results are not good. I think we ought to develop professional relations with developing country governments, and try to strengthen the institutions.

The success of ideas within the 2020 vision depends on societies' capability to change institutions

L. TUBIANA: You place a great deal of hope in aid and agricultural research policies. However, the "2020 Vision" presupposes a different concept for aid and research policies. You lay down a challenge to be met, but you must give directions for the institutional reforms to be undertaken in order to ensure that this vision is shared.

P. PINSTRUP ANDERSEN: I completely agree that it doesn't really make any difference if IFPRI has a 2020 Vision or not. What matters is that the people who take decisions can see the difference. Are they committed to the goals underlying the 2020 Vision? We hope that people will catch the vision, and run with it.

M. PETIT: We have learned over these years of financing projects and adjustment policies that institutional development is essential. This means that aid for development is becoming increasing difficult since institutional development conditions are not very well known, and when they are known, they are difficult to achieve. This is, therefore, a challenge for researchers. Decision-makers must be informed about institutional development. How can a project be constructed in such a way as to ensure that it strengthens institutions.

P. PINSTRUP ANDERSEN: How do we build institutions? Some years ago, powerful decisions were made to train African agricultural researchers. The problem is that "we" do not automatically choose to continue to invest in institution-building where these agriculture researchers are employed. And that is one of the reasons why these institutions now function very poorly. And that is why PhD are driving taxicabs in Washington DC. They cannot find employment in their home countries. But in fact, we have a lot of experience in both how to build institutions and certainly how not to.

Defining procedures for scientific cooperation

A. DE LATTRE: It is true that agricultural research in Africa is a disaster area. This is not only because insufficient "capacity building" has been done. France, for example, has contributed heavily to African budgets, amongst other things for the support of research bodies. Many jobs were created, but operational means did not follow, with the result that research efficiency was considerably limited. What can be done now? Procedures for scientific cooperation must be re-defined for countries with budgetary difficulties when we know that governments cannot correctly finance their research

institutions. If this indeed happens during the next 20 years, what can be done next? We have already tried budgetary subsidies and technical assistance. IFPRI should make a contribution to this debate.

P. PINSTRUP ANDERSEN: It is very clear that sub-Saharan Africa has been successful in training agricultural researchers, but unsuccessful in ensuring support for them. So it seems to me that the best we can do from outside of Africa is to provide financial support, rather than send researchers. Of course, the argument is a bit risky. But the point is that the researchers that have been trained and available are in fact qualified, but some of them are still young and need experience. So sending our more experienced researchers in order to guide the younger ones would be a good thing.

But I have a problem with the point that the countries are too poor to invest in agricultural research. It is, I think, in the final analysis, a matter of priorities. Do you want to invest in agricultural research, or do you want to invest in other things?

Donor coordination: a condition for success

M. VERBLOW: One of the problems for having efficient aid is the coordination problem. Each donor proposes its own aid package. The only way to do something about this is to have donors be quite a bit more objective and less selfish. Donor-Donor Coordination is becoming absolutely necessary.

P. PINSTRUP ANDERSEN: I think the best thing we can do is help develop national capacities for setting priorities. The worst thing we could do is having donors get together in a darkroom and deciding what is good for a particular country. We must work with recipient countries so that they can set priorities, and then donors should coordinate to achieve those priorities. But we are not doing really very much to strengthen these national capacities because conditionality tends to do the opposite.

The way to success

P. PINSTRUP ANDERSEN: The 2020 Vision action programme is not all new. We too quickly gave up a lot of what we tried in the past, including integrated rural development. We gave it up because we did not quite know how to do it, so we jumped on another band wagon. Distribution with growth was tried in the 1960s. It was quite a success. I think there is a lot to be done in strengthening the effort that we tried in the past but did not quite get right the first time.s I think the Doubly Green Revolution we are going to talk about is essentiel to achieving the 2020 Vision. The link between the 2020

Vision and the Doubly Green Revolution is that the vision provides an overall goal towards which we shall all strive in our development work. And the Doubly Green Revolution is one of the critical and essentiel activities that will have to be pursued.

Introduction to a Doubly Green Revolution

Doubly Green Revolution, a new outlook for the agricultural research

Video-conference by Ismail Serageldin
Chairman, Consultative Group on International Agricultural Research CGIAR
Vice-President, Environmentally Sustainable Development, World Bank

I would have preferred to be with you in person, not only because I know and respect the major role of Futuroscope in promoting science but, equally, because I have close working relationships and friendships with many of you.

I regret my inability to make the journey to Poitiers all the more because I see this seminar as a key event in the articulation of a new vision of agricultural research. Poitiers is part of a process which must review and transform both the policies that govern and the tools that are used for agricultural research. This new vision and these new policies must be based on a clear understanding of the ecological, economic and social challenges that confront us.

In analysing these challenges and their consequences for agricultural research, the Conway Report, produced for the CGIAR by a panel of eminent persons under the chairmanship of Gordon Conway of Sussex University, was the first to speak about the need for a "doubly green revolution"—green for productivity and green for environmental harmony. The CGIAR Ministerial Meeting held in Lucerne in February 1995 endorsed this approach to agricultural research and urged the CGIAR to make it the centerpiece of its research policy and agenda. These analyses, deliberations and recommendations were all part of an 18-month program of renewal that the CGIAR launched in May 1994 in New Delhi and brought to a successful conclusion in Washington DC last week (October 1995). But our tasks are by no means completed.

We have clarified the vision of the CGIAR, refocussed its research agenda, broadened its partnerships, tightened its governance, secured commitments from the international community to stabilize its finances, and significantly increased the role of Southern countries within the Group. We must now move ahead, participating in and contributing to the evolution of the international research agenda with colleagues such as yourselves. Poitiers therefore occurs at exactly the right time: to concretize

the debate and assist in preparing the global research system to equip itself for meeting future challenges effectively. We need to be ready for two kinds of challenges: the workaday challenges that are part and parcel of the life of research institutions, and those more complicated ones which punctuate international life.

The development of agricultural research, to which we aspire, is not for Southern countries alone, still less is it sometimes conceived of and promoted by the North for the South. It affects both North and South as it requires transformation of the basic concepts of agricultural research. In this process, it is absolutely essential to increase cooperation among all those involved: Northern countries, Southern countries, international organizations, the public and private sectors and organizations within civil society. Meetings such as this one are important, to convince decision-makers that the time has come to change direction, to convey the message of change from laboratories and research stations to the farthest flung research workers ... and, indeed, to the whole of the agricultural community, farmers, particularly farmers, included.

We are all familiar—perhaps, too familiar—with the impact on the lives of the world's poor of increasing ecological, economic and social imbalances. We all know that every ten years in the foreseeale future the World's population will increase by an extra billion human beings. IFPRI has provided us with statistics alerting us to food needs and the possibility of food shortages by the year 2020. Other groups, often with differing approaches and time scales, confirm these trends. I am not going to bore you with statistics or attempt to pick one set of projections against another. Life is not a numbers game. My major concern, therefore, is not quantitative but qualitative. Even though the scale of projected shortages is worrying, what concerns me most is the pressing need to carry out our programs in such a way that they deal simultaneously with ecological, economic and social imbalances.

The agricultural production models which we know today do not take account of or, at least, do not give the same level of concern to all three of these dimensions which must be considered indivisible. Our approach, then, must be one of dealing in a holistic way with the following nexus of problems: stagnating production, deterioration of natural resources, which are also production factors, and social polarization. In following this approach, we need to be clear about the levels at which research is organized, and of the repositioning of research in terms of producers. To my mind this calls for a Copernican revolution.

First, the question of levels. Today research is subjected to dual pressure. On the one hand, it must take account of the diversity of natural and human environments and therefore come to terms with location-specific realities. On the other hand, it is influenced by globalization factors: the awakening of a planetary conscience against common challenges, the revolution of basic sciences, particularly in biology; the interconnection of communications networks, economic liberalization, and so on. The emergence of a "global system" is manifest. However, in this area, as in others, we must ensure that this "globalization" of research does not provide an opportunity

for a few powers to dominate the world. In short, this system must be participatory, open and inclusive and, built from the base up. This is the only way in which diversity can be taken into account, particularly bio- and ethno-diversity which gives the world its beauty, and offers the world opportunities for multi-faceted development. It is because we are aware of the emergence of this global system for agricultural research and we are committed to opening it to all that the World Bank created a special unit within my Vice Presidency for supporting the work of national agricultural research systems in developing countries and invited our partners to hook into it.

Turning to the issue of repositioning research within the technical innovation process, this is based on a profound change of our vision and concepts. In the field of research, as in others, we must leave behind our standardized state vision. Technical innovation is an eminently complex process in which the farmers - men and women - play a central role. The farmer manages a system which must both produce an income and reproduce a capital, particularly a biological capital: local varieties and soil fertility for example. He is the trustee of a heritage and is limited by factors involving economics, politics, legislation and the environment, as well as by physical factors. In view of this context, he takes his decisions as a producer in his own best interest. The farmers' adoption of new technologies is intimately linked to these realities. Therefore agricultural research, if it is to be relevant and realistic, must be built in collaboration with farmers and farmers'organizations, and must be sensitive to the economic, social, and conceptual framework within which farming communities make decisions. The era of research which produces technological popularization, and of "passive" producers who simplistically follow instructions, is behind us.

At the same time, however, the effective use of advanced technologies requires that public research be in synergy with the private sector. "Public assets" and "private assets" each have their own logic. These must be clearly understood, and their differences as well as complementarities respected, if we are to ensure that all usable assets are deployed for the production of public goods. This principle applies to the protection of intellectual property as well as in the field of biological research. Results from the overall system depend on finding for each actor a position which corresponds to his comparative advantages. Once these positions have been adopted, the synergies between public and private actors in agricultural research will acquire their own momentum. So, while setting our sights on the "doubly green revolution", let us be conscious of the need to concentrate efforts at the level of the producer and his holding. It is in fact at this level that the forms of agricultural production and natural resource management will be defined.

The protection of natural resources will only be possible, moreover, if intensification of land already cultivated means that the opening up of new land can be avoided. It is also at this level of production units that wealth or poverty will be created, and poverty results in exclusion processes which deprive the poorest from all access to the world of production. Finally, it is at this level that food security will be established, both for rural and town dwellers.

In a normal context, the farmer has two objectives, the competitiveness of his production and the durability of his production tools. Research must have the same double objective: increasing production and increasing financial, physical and biological capital. Productivity and durability must no longer be separated, and it is at the level of agricultural systems that this linkage will either be achieved or not.

In numerous developing regions, as was the case in industrialized countries, the modernization of agriculture is accompanied by a concentration of wealth. If, however, agricultural growth takes place as part of a wider transformation of society's productive base, within a framework of good economic management, including an absence of price distortions, it is accompanied by the creation of jobs within the farming community and beyond, and by an improvement in the distribution of incomes. This ensures the well-being of populations, even that of the worst off in society. Unfortunately, this prospect is subverted by state policies which encourage urbanization and urban populations at the expense of poor farmers, who have very little political clout. This is also a situation that cries out for transformation. This is as important as such technical considerations as land planning, water management, protection of the hillsides, biological control techniques, crop protection and product conservation. The will to see progress in all three ecological, economical and social aspects, towards truly lasting development is for me at the heart of reflection on the "doubly green revolution". It is urgent that we go further into these considerations, experiment with new approaches and design economic policy measures which can motivate the various actors —first and foremost the farmers—to incorporate the attainment of these three objectives into their work. Indeed it would serve no purpose to develop new techniques if economic policy, for example pricing policy, were to send out contradictory messages.

I am aware that today I have opened up before you a whole series of windows. Some of these windows open out into the unknown. Earlier, I mentioned the necessity of opening a Copernican revolution in our vision of the world. All the actors in the global agricultural research system, namely the "National Agricultural Research Systems", the "Advanced Research Organizations", and the "International Agricultural Research Centres" are called on to transform themselves and, in so doing, to create a synergetic, balanced and efficient global system.

The future is ours. Can we watch the planet being pillaged without reacting? Or the impoverishment of an increasing part of humanity? Can we accept such violence? We must take the measure of the questions put to us today, consolidate the concrete responses which can be put forward immediately in our own work, and experiment with and put into practice the new methods of agricultural research which take seriously the risks which threaten the future of our planet.

Let us dare to be bold. There is no doubt that the world around us is changing, and we must change with it and set out today on the road to a sustainable future.

The Doubly Green Revolution

Gordon Conway
Vice Chancellor, The University of Sussex

"To die of hunger is the bitterest of fates"
Homer, the Odyssey, 12, 342
(Translated by Ash, 1941)

Odysseus and his companions have resisted the lure of the Sirens, sailed safely between Scylla and Charabdis and have come to the island of Thrinacie where the Sun-god's cattle and plump sheep graze. Odysseus has been warned they are not to be harmed, but his companions succumb to the temptation. "To die of hunger" declares Eurylochus "is the bitterest of fates." They kill the cattle and feast. Afterwards they set sail again. Zeus sends a hurricane to punish them and all perish except for Odysseus.

Today there are over 700 million who, like Odysseus's companions, live in a world where food is plentiful yet it is denied to them (Alexandratos, 1995). They either do not have enough land to produce the food they need, or sufficient income to buy the food on the market. Many of those most seriously deprived are women and children, often in female headed households. More than 180 million children are underweight. Vitamin A deficiencies are widespread and growing. Malnourishment is contributing to at least one third of child deaths.

Paradoxically, hunger is common despite a period of rapidly declining world food prices. In many countries there is enough food to meet the market demand, yet many go hungry. Although food prices are low, they are still high relative to the earning capacity of the poor. India, for example, is "self-sufficient", over 30 million tons of grain are surplus to the market and held as stocks. Yet more than 400 million Indians live below the poverty line, and over half of these are chronically undernourished.

If nothing is done, the numbers of poor and hungry could rise rapidly. Until well into the next century approximately 100 million people will be added to the world population each year. By the year 2025 the population of the globe will be about 8.5 billion, of whom 6.7 will be in the developing countries (United Nations, 1995). On present trends, the number deprived of an adequate diet could be greater than a billion.

The first question we ought to ask ourselves is: why should we be concerned? Part of the answer to this question is political. The end of the Cold War has not brought about an increase in global stability. While conflict between East and West has declined, there is a fast growing divide between the world of the peoples, countries and regions who "belong" in global power terms and those who are excluded. Confronting the increasing globalisation of government, capital, technology and trade are the surging expectations of the poor.

An increasingly polarised world will result in growing political unrest. Already the consequences of economic stagnation, population growth, environmental degradation and civil war are producing unprecedented movements of peoples. There are currently some 14 million refugees in need of assistance living in foreign countries and at least double that number who are refugees or displaced persons within their own countries. In today's world, poverty and hunger, however remote, affect us all.

Justice and equity also demand that poverty be eliminated. Moreover it is a goal within our capacity. Globalisation while threatening, on the one hand, to concentrate power and increase division, on the other contains the economic and technological potential to transform the lives of rich and poor alike. Much depends on where our priorities lie and, in particular, whether there is sufficient access by the poor to the economic opportunities created by the products of the new technologies.

Since the 1960s we have seen spectacular increases in global food production. In large measure these were the products of the Green Revolution. A concerted effort by the international donor community, mediated through the creation of a system of International Agricultural Research Centres (IARCs), brought the best of modern science and technology to bear on the problems of raising yields (Conway and Barbier, 1990). In essence, the success was a product of three interrelated actions:

1. Breeding programmes for staple cereals to produce early maturing, day-length insensitive and high-yielding varieties (HYVs).

2. The organisation and distribution of packages of high pay-off inputs, such as fertilisers, pesticides and water regulation.

3. Implementation of these technical innovations in the most favourable agroclimatic regions and for those classes of farmers with the best expectations of realising the potential yields.

As a result global cereal yields have more than doubled since the 1950s, from just over 1.1 tons per ha, to about 2.7 tons, and food production has risen from about 300 kg per capita to about 360 kg i.e. has more than kept pace with population growth (Dyson, 1996). The great famines of Asia are now history (although they continue in sub-Saharan Africa where per capita food production continues to

decline). Without the Green Revolution many more millions would be denied access to an adequate diet.

Today we face three challenges. Can we:

- Continue to increase food production at the same or a greater rate for the next 30 years?
- In a sustainable manner, without significantly damaging the environment?
- And ensure it is accessible to all, so that everyone receives at least an adequate diet?

In theory the increased production could be met by subsidised shipments from the industrialised countries (Islam, 1995), but this would place heavy burdens on the developing countries and would be likely to depress local prices, adding to existing disincentives for local food production. Moreover, the industrialised countries would have to at least double food production, inevitably incurring high economic and environmental costs.

A more fundamental objection to this scenario is that a significant portion of the population in the developing world would fail to participate in global economic growth. The alternative scenario is for the developing countries to undertake a rapid and broad-based growth, not only in food production, but in agricultural and natural resource development as part of a larger development process.

Agriculture, forestry and fisheries can be powerful engines for development, helping to create employment and incomes for the mass of the poor, reduce birth rates through increased food and income security, protect and conserve the environment and stimulate global trade and greater political stability.

Such a scenario explicitly recognises that food security is not solely a matter of producing enough food. It also depends on employment and incomes. The task is not simply to meet the market demand for food, but to increase the market demand for food.

The challenges posed by this scenario are formidable. Success will require a concerted effort on the part of the world community, in both the industrialised and developing countries, the application of new scientific and technological discoveries in a manner that is environmentally sensitive and, above all, the creation of new partnerships between scientists and farmers which will respond to the needs of the poor.

We need a second Green Revolution, but one that does not simply reflect the successes of the first. It must not only benefit the poor more directly, but must be applicable under highly diverse conditions and be environmentally sustainable. By implication, it must make greater use of indigenous resources, complemented by a far more judicious use of external inputs.

In effect, we require a Double-Green Revolution, a revolution that is even more productive than the first Green Revolution and even more 'Green' in terms of conserving natural resources and the environment (Conway et al., 1994).

Over the next three decades it must aim to repeat the successes of the Green Revolution, on a global scale, in many diverse localities and be equitable, sustainable, and environmentally friendly.

While the first Green Revolution took as its starting point the biological challenge inherent in producing new high yielding food crops and then looked to determine how the benefits could reach the poor, this new revolution has to reverse the chain of logic, starting with the socio-economic demands of poor households and then seeking to identify the appropriate research priorities. Its goal is the creation of food security and sustainable livelihoods for the poor.

There are, in theory, no major physiological, genetic or agronomic constraints to achieving the necessary yield gains. Conventional plant breeding techniques, increasingly augmented by genetic engineering, should be able to produce improved plant types capable of significantly higher yields in all parts of the world. And there is considerable potential for increased fertiliser use. Although application rates are relatively high in those regions where the Green Revolution has occurred, the average in South Asia is still only 64 kg of nitrogen per hectare, in Latin America it is 49 kg and in sub-Saharan Africa 13 kg This compares with an average of 182 kg for East Asia (Dyson, 1996). However, in the intensively farmed lands of both the industrialised and developing countries heavy fertiliser applications are producing nitrate levels in drinking water that approach or exceed permitted levels, increasing the likelihood of government restrictions on fertiliser use.

There is also a potential for improved supply of water through irrigation and various means of water conservation. One estimate is that the current 170 million hectares of irrigated land in the developing countries could be expanded by nearly 60%, most of the potential lying in India, China and other countries in Asia (Crosson and Anderson, 1992). But while such large scale expansion of irrigation is theoretically possible, it would require an investment of $500-1000 billion, and face formidable technological, environmental and social constraints. The most feasible approach, especially for sub-Saharan Africa, is through small scale harnessing of water, but this will require appropriate incentives and institutions together with new skills and technologies. An extra 34 m ha of irrigated land is a more realistic target.

At the root of our current crises is the manner in which technology is being used. We are depleting the natural resource base on which our food production depends at an alarming rate and causing damage of a kind unknown before (Alexandratos, 1995; Conway, 1995). The arithmetic of our loss is a familiar litany. We are running out of cultivable land. In Asia the amount of cropland per person will decline to a mere tenth of a hectare by the year 2020. Our primary forests are being destroyed

at a rate of about 16 million hectares each year and, in our oceans, most fish stocks are being rapidly depleted, largely through overfishing. The global fish harvest has declined from a peak of 90 million tonnes in 1989 to 84 tonnes in 1993.

Of equal, if not greater, significance we are destroying the planet's biodiversity. An estimated 15 percent of the world's plant and animal species could become extinct by 2020. This represents not only a loss of useful organisms, for example the predators and parasites that provide natural control of our pests, but more fundamentally a destruction of the world's treasure trove of DNA. Genetic engineering holds out the promise of combining in new and exciting permutations the genetic stock contained in our plants and animals to provide novel sources of materials, energy, medicine and food. If we continue to deplete that stock, we will seriously deprive ourselves of solutions to our growing problems.

In addition to this quantitative loss we are gravely affecting the quality of our natural resource endowment (Scherr and Yadav, 1996). Globally, nearly 2 billion hectares of soils (17 percent of all vegetated areas) have become degraded through water and wind erosion, loss of soil nutrients, salinisation, acidification, pollution, compaction, water logging and subsidence. Most, but not all, results from inappropriate agricultural practices. Lack of terraces, failure to replace nutrients and organic matter, and excessive irrigation or drainage damage arable land. Rangeland is degraded by overgrazing, often as a result of the breakdown of indigenous institutions capable of managing common property resources.

And agriculture is both the culprit and victim of pollution (Conway and Pretty, 1991). In addition to the damage caused by fertiliser use, pesticides are producing resistance and resurgence in pest populations and high levels of human morbidity and mortality. Agriculture is also a growing contributor to global pollution, producing significant levels of methane, carbon dioxide, nitrous oxide and ammonia. Individually or in combination, these gases are contributing to global warming, the depletion of stratospheric ozone, acid deposition and the build up of ozone in the lower atmosphere. All these consequences have a potential effect on food production. For example, heat and water stress may result in yield reductions, especially in the low latitudes, where most of the developing countries are situated. By contrast, in the middle and high latitudes the combined effect of temperature increases and the direct physiological effect of increased CO2 are likely to result in higher yields. But there are many unknowns: one consequence of global warming may be a greater incidence of extreme weather conditions with unpredictable effects.

Just as the consequences of depletion and degradation are complex, so are the causes. Poverty and hunger often lead to desperate strategies for survival, and attempts to meet basic needs often take precedence in the short-term over longer-term sustainability. But the blame should not be placed on the poor and hungry. Considerable damage is caused by the irresponsible exploitation of resources by the rich.

In practice, destruction often results from conflicts over resource use. Small farmers and large landowners cut down forests to make way for crops and livestock. In our coastal zones, particularly in the wet tropics, conflicts arise between intensive fisheries, rice production and the natural productivity of mangrove and other swamp forests. And world wide there is growing competition between agriculture and natural resources, on the one hand, and expanding urbanisation and industrialisation, on the other.

More fundamentally, the causes lie in inappropriate systems for natural resource management, unresponsive institutions, short term national and regional policies and a lack of economic mechanisms which will adequately value natural resources in relation to all their potential uses, now and in the future.

The complexity of the challenge facing the Doubly Green Revolution is daunting. Abandoning technology is no answer. A case in point is the application of biotechnology. Through genetic engineering we have the potential to develop crops and livestock that are resistant to pests and diseases, that can compensate for mineral deficiencies and withstand salinity, toxins and drought, and can make more efficient use of sunlight, water and nutrients. By these means we can increase productivity in the face of dwindling natural resources, but only if we use the technology wisely, in the light of sophisticated ecological and physiological knowledge.

In recent years ecology, in tandem with economics, sociology and anthropology, has rapidly increased our capacity to design, in partnership with farmers, sustainable agroecosystems and livelihoods. Recent advances in population, community and ecosystem research are providing a better understanding of the complex dynamics that arise within crop populations, in multiple cropping and agroforestry systems and in range management. Ecological thinking has also begun to inform our understanding of the livelihoods of poor households, particularly their patterns of response to environmental stresses and shocks. Such knowledge can contribute to better practical appreciation of the ways small farmers and poor households can utilise specific agricultural technologies to enhance their livelihoods and render them more sustainable.

Many of the rural poor are landless or poor labourers who live in the well endowed, high agricultural production lands. They will benefit from agricultural technologies that not only increase production and are environmentally sustainable, but also generate greater employment and incomes. The majority of the rural poor, however, live in areas that are typically resource poor, highly heterogeneous and risk prone. Agriculture is usually limited by low rainfall and a relatively poor potential for irrigation, or steep slopes or poor soil structure, or lack of macro or micro nutrients, or presence of salts and other toxic compounds or some combination of these. Here the appropriate research will be aimed at improving farming systems rather than specific commodities, with less reliance on the exploitation of resources originating outside the farm - fertilisers and pesticides.

Such resources are often costly and sometimes unreliable, and frequently contribute to environmental degradation. They will continue to be essential if even higher productivity is to be attained. But more attention will need to be paid to better use of resources of agriculture - the parasites or predators of pest, algae or green manures that fix nitrogen, cropping systems that reduce erosion. Inherently these are inexpensive resources yet, with skill and ingenuit, can be used to generate higher productivity on a sustainable basis.

The way forward for the Doubly Green Revolution, in both well and poorly endowed regions, lies in the development of Integrated Natural Resource and Agricultural Management - INRAM. There is a model for this concept in Integrated Pest Management (IPM) - an approach that is nearly forty years old and is tested and tried. In essence it combines modern technology, the application of synthetic, yet selective, pesticides and the engineering of pest resistance, with natural methods of control, including agronomic practices and the use of natural predators and parasites. The outcome is sustainable, efficient pest control that is also often cheaper than the conventional use of pesticides. One outstanding example, among many, is IPM developed for rice pests in Indonesia. Research has shown, that the damaging outbreaks of the brown planthopper on rice often are due to the pesticides which kill off the spiders and other natural enemies of the planthoppers. Under IPM farmers are trained to recognise and regularly monitor the pests and their natural enemies. They then use simple yet effective rules to determine the minimum necessary use of pesticides, so reducing the average number of spraying to one per season, while simultaneously increasing yields by over a ton per hectare (Kenmore, 1991).

We now have to translate the success of IPM on to the larger scale of agricultural and natural resource management. One lesson from IPM is the importance of combining, in new and often subtle ways, "natural" and "artificial" technologies. For example, to achieve higher yields we cannot rely solely on organic nutrients. In Africa, in particular, we will have to greatly increase the use of synthetic fertilisers, but in combination with organic nutrients so ensuring the soils can sustain the high yields. Equally important, as IPM has shown, is the participation by farmers not only in implementation of development programmes, but in their analysis and design. Local knowledge, local culture and local ecology are crucial to success. There are now many examples of the power of such participation. I will briefly refer to three of these with which I have been involved.

The first is the ambitious programme of development facilitated by the Aga Khan Rural Support Programme (AKRSP) in several hundred villages lying in the Unza and neighbouring valleys of northern Pakistan. An arid mountain region: it is not naturally well endowed but the inhabitants are highly skilled in the use of the local natural resources. The development programme consists of a series of interactive dialogues through which the villagers, acting as a community, identify, plan and implement a key infrastructure project in each village. In many cases the projects

are impressive feats of engineering that bring irrigation water from the glaciers to open up new land for agriculture. Over 200 such projects have been completed, and the programme is now engaged in realising the potential of the new infrastructure through a variety of initiatives funded by the villagers' savings.

The second example concerns small scale irrigation. In the state of Tamil Nadu in Southern India are numerous tank systems. The tanks are small reservoirs which are filled by the monsoon rains and then used by the villagers to irrigate crop fields. In the past the maintenance of the tanks and the irrigation canals was the responsibility of government authorities but, since independence, the systems have progressively fallen into disrepair. A current aid project is attempting their rehabilitation by hiring contractors who work to a blueprint; not surprisingly this produces inappropriate and excessively costly solutions. As an experiment, funded by the Ford Foundation, villagers are being given a grant directly and encouraged to design, plan and manage the rehabilitation themselves. So far the results are very encouraging. The villagers are showing a high degree of competence and inventiveness, and the outcome is systems which the villagers feel they own and to which they are committed.

The third example is the process of Joint Forest Management in India. Much of the government forest land is highly degraded; the trees are cut down and the ensuing scrub and grassland is overgrazed. Government authorities are powerless to stop the degradation and local people feel no sense of responsibility. Joint Forest Management, pioneered by the State of West Bengal, involves a partnership between the Forest Department and local villages. Each village is given rights to both timber and non-timber products and the responsibility of management according to their own priorities. Again the experiment is working well. Forest cover in the affected regions of West Bengal is growing rapidly, the aims of the Forest Department are being achieved, and the income of the villagers is growing. Women, in particular, are benefiting from a steady flow of income from such products as firewood, oils and seeds, silk and leaves for plate making.

The process of participation, reflected in these three examples, has been transformed in recent years by the development of a series of techniques which fall under the heading of Participatory Rural Appraisal (PRA). Although the methods are apparently simple—involving semi-structured dialogues based on a variety of maps and diagrams generated by farmers and other rural people—they are extremely powerful, permitting farmers to analyse, design and manage agricultural systems in partnership with research scientists and extension specialists.

This approach may seem very distant in its emphasis and style from the molecular technology underlying genetic engineering, nevertheless they are both revolutionary in their potential impact. They are also both crucial to the Doubly Green Revolution. Success will only come when molecular biologists, ecologists and farmers begin to work as partners, not just in the conference room and laboratory, but in the farmers' fields.

The way forward lies in harnessing the power of modern technology, but harnessing it wisely in the interests of the poor and hungry and with respect for the environment in which we live. We need a shared vision, based on the potential of the new paradigms of molecular biology and ecology and on the creation of new working partnerships.

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The Doubly Green Revolution

COMMENTS AND DEBATES

Chaired by Anne de Lattre,
French Ministry for Research

S. SNRECH: What is our capacity for reproducing, on a large scale, a participatory approach to research at village level, when we are aware of the number and spread of villages which would be involved? For example, in the African Sahel there are 40,000 villages. We have extremely good examples of local successes with what we know as "territorial management". It is also true that participatory diagnosis, even if crowned with success, is only an initial step. In order to ensure that the desired changes come into being, villages have financial requirements which they cannot meet alone.

G. CONWAY: Of course, it is an enormous challenge. What has to be done is to involve not just simply government actors but also all range of NGOs in the extent to which NGOs can carry forward this Participatory Research message and the participation methods in a dramatic fashion. These kinds of techniques were not very well known some years ago, and are now being put into practice by thousands of NGOs throughout the world. In India for example, on a very large scale, NGOs are undertaking this kind of work with individual villages. It seems to me that it is the only way you can go forward. You have to have governments that will enable this to happen. My guess is that much of the work in the poorest areas will be done through NGO mediation.

L. TUBIANA: You have just put the question regarding the role of the various actors involved in the change. NGOs. which support research and development processes on the basis of participation by local populations are asking themselves what relays they will obtain from research institutions to allow them to go further than the results of local work.

Here we run into major institutional, legal and economic problems. I believe in fact that there is increasing agreement amongst decision-makers who consider that local participation by those involved is important and that one must start from such a basis in order to identify efficient solutions, partic-

ularly in areas where very little progress has been made. However, today there is silence as to the way in which NGOs, research and authorities in the countries and on an international level will work together. I believe, in particular, that property rights attached to research results may, in certain cases, be major obstacles to progress. Serious problems may arise regarding access to genetic resources. There are also difficulties in financing participatory research actions. Today, there is no satisfactory bridge between these research activities and the research carried out by scientific bodies. There is, therefore, a risk that the Doubly Green Revolution has two aspects which cannot be linked: new varieties produced by scientific research and local innovations resulting from participatory approaches. Institutional solutions must be found to the problem posed by the lack of a link between research and NGOs. Otherwise, the NGOs will remain in a position of dispute vis-à-vis research - including in the international system - because they have not succeeded in creating a dialogue with it.

G. CONWAY: It is a very important question for the future. We have to answer it and find solutions. The CGIAR system can play a role in developing more relations between NARS (National Agriculture Research Systems) and ARO (Agricultural Research Organisations from Developed Countries). That is one route on which you can go, but of course it is only one and it does not resolve the problem you are presenting.

F. HEIDHUES: I have tried to make the link between the "2020 Vision" and the "Doubly Green Revolution". Per Pinstrup Andersen emphasized the role of Government and agricultural services in achieving the development goals. The good results of a village participatory approach, can give the impression that we don't have to disturb village life; villagers know what they are doing. I think we need to clarify this institutional problem. Who are the actors who could drive the process of the Doubly Green Revolution?

G. CONWAY: I know that some get the impression that, using the participatory approach, we should not change anything, we should not interfere. Generally, participatory approaches are highly interventionist, but the villages increase their driving participation. In some cases, these programmes are driven both by Ministry departments and local communities. There are really good ways of involving Governments, NGOs and Researchers in partnership with villages to make changes.

U. LELE: The participatory approach that you emphasize so much is important. But we need to make a rigorous quantitative analysis of the real impact of this participatory approach; what is the real net contribution of this approach to development?

In the 70, it was very fashionable to talk about participatory approaches. Then disappeared. It is now coming back. If it has not been highly devel-

oped, it is probably because there are extremely complex socio-political dynamics at the village level. In some places the participatory approach is easy and supported by Government. In other places no. In India for example, participatory approaches fit in well in the states where, for a long period of time, the government has been very committed to getting rural people much better education. We have to be much more analytical about the socio-political dynamics which may be highly variable. Then the question is how important a role the governments will have to play in this process? How will they adjust to this process ? Will the revolution of the grass roots ascend up to the top? We have to answer this question with rigor.

G. CONWAY: I agree with your comments. I think what is most important however is to be quite clear how we measure success in all of this. If you are measuring return to economic investment, a lot of this may not stick very well. But if you measure the return to reduction of malnourishment among the rural poor, then it may well be more relevant. If you are simply looking for economic return, you are strictly in the Green Revolution that meets demand for food and forgets about environment and forgets about the poor. It is much more difficult to measure success of participatory measures of this "Doubly Green Revolution" than that of the previous Green Revolution. That is one of the problems we have to face.

The Doubly Green Revolution: elements for methods, models and theories

Ecoregionality in research for development: french research proposals

Hubert Manichon,
CIRAD

This document was prepared by a work group[1] comprised of French institutes of agricultural research (CIRAD, INRA and ORSTOM), created at the request of the Ministry of Higher Education and Research to generate joint proposals on Ecoregionality. This concept is currently being developed in the Consultative Group for International Agricultural Research (CGIAR) and forms a component in the progress in research on development. Its importance is growing within the CGIAR. French institutes, which already participate in several ecoregional programs, believe that these initiatives can make research on development more effective. The goal of the proposals in this paper is to go even further in this direction by defining the principles of a "second generation" of ecoregional projects that French research will propose to its partners for discussion and implementation.

Research for development and ecoregionality

From a logical standpoint, the efficiency of research for development, in particular in countries of the South, should be measured by its contributions to economic and social development in the countries where it is conducted. We are presently unable to quantify these measures, for the development process is highly complex, much like the functioning of human society. Depending upon the case, research is blamed or praised (and this can have consequences on the level of resources that the community accepts to allocate to it) without the objective proof of its role in successes or failures having really been established.

In spite of this difficulty, agricultural research institutes have a growing awareness of the necessity to meet social demands. More and more rare, however, are

1 The participants in this work group were: (i) for INRA: B. Vissac, C.) Albaladejo and A. Sontot; (ii) for ORSTOM: G. Hainnaux, A. Lericollais, and P. Gondard; (iii) for CIRAD: F. Forest, D. Sautier, P. Lhoste and H. Manichon.

researchers who consider that their individual contribution can be the sharing of personally chosen themes. The importance of collaborative organisation (thus less monodisciplinary research) and programming based on the analysis (highly research) has developed considerably over the past years.

The ecoregional approach takes advantage of these developments. It focussed current trends to make the objectives, the problematic and the organisation of research on development more understandable and convincing. This approach has drawn the attention of sponsors who would like to see greater effectiveness in studies of the economic, social and environmental problems of the countries of the South.

For the CGIAR governing bodies which has been developing this approach for the past few years, the "Green Revolution" is a way to face the difficulties encountered in zones with high constraints and now in zones with strong potential, and to focus more attention on environmental problems. To do this, will require extending the field of research beyond the biophysical production basis in order to, at the same time, deal with the technical and human dimensions of the problems (TAC, 1992, 1994).

The first step is to define the geographical zones in which this multi-disciplinary approach is to be conducted. In terms of organisation, the CGIAR has suggested that the continents be divided into "ecoregions" (based on the agro-ecological zones defined by the FAO) and has defined a list of priority actions among them. In some of these ecoregions, different research and development institutions, working together in consortia with CGIAR centres involved, have set up and are conducting joint programs. It is expected that this institutional approach, which is viewed as a renewal of collaborative efforts between North and South, will provide better coherence and greater effectiveness in research actions on development. However, it results in high "transaction costs" which, in a context of budget reductions, can only be acceptable if the hopes riding on this approach are not disappointed.

The importance of developing the ecoregional approach

The current ecoregional programs, some with French participation, are very diverse in nature (which is logical since there are great differences between regions) and in scientific approach. But there is no clear understanding of the reasons for these differences. Only in rare cases do these programs conform to the limits of an ecoregions within which, agricultural and environmental problems are not really similar.

Therefore, it is important to continue to develop this concept. And this has been recognised by the CGIAR governing body which recently set up a work group on

the subject [2]. With the same enthusiasm, in December 1994, the Dutch co-operation authorities organised a symposium on this issue for international centres.

An understanding of the scientific content of the ecoregional approach necessarily begins with its very finality—a contribution to the sustainable development of a geographic area. To do this, it is obviously not sufficient to simply set up research projects in an area. Nor is it sufficient that the questions studied be related to the major developmental issues. Lastly, it is not sufficient to perfect the methods of communicating the results of research.

In fact, experience shows that in order for knowledge which is generated to be adopted as an innovation, it must correspond to the needs and strategies of those to whom it is destined, and accommodate the constraints. Moreover, so that the solutions provided for a given problem do not result in the appearance of side effects when implemented, the consequences, both direct or indirect, must be analysed.

Yet, the diversity of the situations in a given geographic area is great, It may be between categories of actors (farmers, herders, etc.) are within a category. Consequently, the idea that it would be efficient to impose (assuming that it could be done) a single solution for a specific problem (for instance, increasing agricultural output, improving product transformation, or managing natural resources) is an illusion. While a single solution may be relevant for some of the actors, it certainly wouldn't be for them all. On the contrary, there is a need for diversified solutions, based on a diagnosis of the region, which highlights not only general problems but also the stakes of the various actors. These solutions must be made available into new practices.

Whether improving food security by increasing output, reducing poverty by raising income, ensuring the sustainable management of natural resources or preserving the environment, it is the role of actors in production and management which is at stake. The solutions provided will only be useful if they enable local actors to make positive changes in their activities: global development is necessarily a product of local actions.

It must therefore be acknowledged that contributions to the development of a geographic area must consider the area's residents and their activities as components of research.

Thus the ecoregional approach to research involves the comprehensive study of an area to determine, the degree of predictable progress and the means to attain it, starting with the current situation.

2 This group was presided over by Cyrus N'Diritu (Kenya) and included I. Abrol (India), H. Manichon (France), G. Norès (Argentina), and R. Van den Berg (Holland); the secretary was M. Collinson (of the CGIAR secretariat).

Clearly, these problems are not new. But it must be recognised that they are not often reflected in research programs, even when programs are concerted. In light of this, the following proposals could contribute to defining a "second generation" of ecoregional programs to complement and improve certain existing programs.

Proposals for a second generation of ecoregional programs

These proposals are based in particular on the French experience that is rooted in an understanding of the physical and human environments of the South which has been accumulated over time thanks to presence in the field and continued relations with partners from the South. In addition, this experience covers all types of production in this environment—animal and plant, subsistence and cash crops, food and non-food. Lastly, this experience is the result of the long-time application of the systems approach to the local environment, and its perception at different scales (production unit, village, local, agrarian system, region, etc.)[3].

The section that follows is a contribution to the role that research can play in identifying areas of sustainable development—social, economic and ecological—in a given region[4] and how this development can be put into practice. To this end, it suggests that the basis of the ecoregional approach and several principles on its implementation be spelt out. Obviously, this section can not cover the entire issue.

The contents of the ecoregional approach

A classical approach would be to successively tackle the following points: (i) the identification of the major development issues of the region and their order of importance; (ii) their translation into scientific questions and the search for answers that have already been given in the same region or elsewhere; (iii) the definition and the implementation of appropriate research methods and protocols to obtain answers if they do not already exist or are inapplicable to the region; (iv) the definition of ways to communicate the results to selected regional actors and have them implemented; and (v) the evaluation of the results obtained.

While this list contains numerous activities that must be dealt with, it cannot form the basis for the organisation and management of a research programme likely to reach the objectives identified above.

Clearly, the issue that must be dealt with first is the identification of regional issues and real research needs and it must be given close attention. Identifying these issues obviously requires gathering expert opinions and summarising avail-

3 There are several references on these subjects in the bibliography.
4 The meaning of this term will be specified later in the paper.

able information, which is often considerable because of the quantity of work done previously. But to engage a relevant research program in a region, an exploratory phase is insufficient such as this because researchers have a tendency to project their own perceptions on peasants, economic decision-makers and politicians.

To guarantee greater relevance and better effectiveness of these projects, a comprehensive diagnosis of the current functioning of the region must be carried out with the help of various actors in the region who will be directly involved in designing the research project and its institutional setting. This diagnosis, which is not conducted by researchers only, is the result of the comparison and the negotiation between social demand (which must be known) and the supply of research (which must be provided). This negotiation must be conducted from the very beginning of the process.

After having made this diagnosis of the region, it is easier to identify additional research needs and develop consistent protocols to conduct them by combining surveys, experiments and syntheses.

However, it is important to note that as the research progresses, the phase in which knowledge is being generated must not be disconnected from its practical use. That is to say that researchers should not simply content themselves with passing on their findings. On the contrary, several reasons make it clear that it is important that research be simultaneously linked to the implementation of these findings. In fact, the time required to obtain certain results can be quite long while for other subjects existing knowledge is immediately transferable. Research partners would not understand delaying implementation until all the results have been obtained. Moreover, by doing so, the opportunity to test the validity of the results under real conditions would be lost. Yet it is often by applying "solutions," which are thought to be well tested, that their deficiencies are discovered and new research needs are identified. The implementation of findings to generate innovations must therefore involve researchers interacting effectively with those targeted by the work. This implies a need to conduct initiatives which incorporate research and action.

Since it is not always possible to conduct experiments on how to put results into practice, other means must be made available. A necessary tool to progressively integrate findings and simulate the results of their implementation is naturally a model of how the region functions. This model is based on the prerequisite diagnosis.

Obtaining a comprehensive representation of the structure and the current functioning of the region is thus at the heart of the ecoregional approach. It constitutes the foundation of the diagnosis and the identification of needs and enables developments to be simulated.

Thus designed, the ecoregional approach can be seen as an iterative process which takes time to set up. Its implementation is the progressive building of a part-

nership project established between researchers on the one hand, and regional actors on the other. This obviously reshapes the generally accepted traditional way of dividing tasks between fundamental research, strategic research and adaptive research as well as between research and development. In short, this is an integrated approach to research on development.

Principles for implementing this approach

This section deals with several issues: the geographic area in which the approach described above can be applied, the components of the diagnosis, and the regional model and its use. Other important issues such as the characteristics of the thematic research programs, communicating results, and evaluation will not be presented here.

The nature of the regional area to be studied

In practice, it is not possible to directly study an "ecoregion" such as it is defined above, that is, a vast transnational area whose contours are fixed by climatic limits which can be somewhat arbitrary. Additionally, it should be noted that while climatic and ecological factors are essential to comprehend the potential performances of animal and plant production and to study certain reasons for which the area is currently being used, they are not sufficient. The diversity of existing situations in the same climatic zone shows that this is not the only factor to take into account and that the weight of cultural, social and political factors in the orientation of systems of production cannot be neglected.

It therefore seems more practical to define smaller areas within the ecoregions, making it possible to simultaneously study all the factors that influence their management. This results in dividing the study of ecoregions into "regions," each being defined as an area in which men and women live and carry out activities resulting from: (i) from their own objectives and needs, (ii) resources (in particular, natural resources) that can be made available for this purpose, (iii) relations (trade, competition, etc.) which are maintained, and (iv) rules which govern these relations.

Thus defined, a region includes rural areas (in which economic activity revolves mainly around agriculture, herding, and forestry) and urban aeras, and, to some degree, the two interact.

It is convenient, at least in an initial analysis, to use the administrative subdivision of the State. In fact, we generally have access to thematic maps (terrains, climates, transport links, types of transportation, energy, etc.) and many statistics on the economic activity of the population which, even though their exactness must be verified, are valuable. Moreover, economic and consumption poles, poles of political decision-making and research partners are clearly and readily identifiable in these areas.

Such a choice can result in regions which include several different climatic zones. This should not be considered as an obstacle but, on the contrary, an advantage especially when the region's activities are complementary and inter-linking.

The verification of existing data and their synthesis using a Geographic Information System (GIS) makes it possible to obtain a spatial view of the region, its diversity and the relationship between the subsets that have been defined. This document, which is progressively enriched, will serve in choosing the sites where some of the research will have to be conducted, and will provide a basis for extrapolating the results.

If one should wish to study the relations and interactions between neighbouring regions within the same ecoregion or between ecoregions, it is necessary to start the analysis process over by taking each region as a whole: the ecoregional system may be comprised of several entities. If these regions are in the same State, the existence of invariant data will allow a certain economy of means. However, it would be contrary to the objectives being pursued to spread these means over several regions such that understanding of how any one of them functions is made impossible and their comparison cannot be made under valid conditions.

The components of the regional diagnosis

An approach is often used which involves identifying the levels of hierarchical organisation (the plot of land, the farm, the village, etc.) and then characterising them. An analysis of the higher level of organisation first requires synthesizing the data of the previous level. Under these conditions, it is somewhat difficult to avoid oversimplifications. In fact, there is a risk of losing sight of the diversity of the rationalities of the actors that intervene at each of the levels of organisation, or ignoring the fact that some actors intervene at several levels simultaneously.

To avoid these pitfalls, it is perhaps best to deal with the regional reality by combining several complementary, partially overlapping "points of view" which show the rationality of the different actors without necessarily linking them to one sole level of organisation.

Thus, we suggest that three points of view be examined which, taken as a whole, will comprise the regional diagnosis.

The food chain forms the first view of the regional picture. By chain, we mean all the functions (production, transformation, marketing, consumption) and actors involved in the process which results in biological material being made into finished goods ready for human consumption. These chains meet (or may not meet) the qualitative and quantitative needs (food, energy, money, work, housing, etc.) of the rural and urban populations of the region being studied. The export sector as well as the local economy are involved since they play a role—which will have to be assessed—in the regional economy. Studying each stage of each major chain makes it possible to identify the critical phases, the strength, and the defi-

ciencies (analysis of the production factors which are implemented and their efficiency).

The area is the second point of view used to analyse the region. Zoning based on the variability of these physical, economic and human characteristics provides a good sample for researchers focused mainly on farms[5]. Studying farms in a selected sample of villages makes it possible to understand the diversity of the ways in which the natural resources are managed (by farmers, herders, forest managers, and communities) and the rationale that they use, whatever it may be (technical, economic, legal, cultural or social). The relationships (be it in competition or in co-operation) between the various actors at the local level (in their villages), their methods of organisation and the pressure that they create on the area must be closely examined to give a global comprehension of its use and the results obtained. On this basis, diagnosis are drawn up on: (i) the cropping and livestock systems farming and the reasons for the gaps observed between current performances and potential levels of performance; (ii) the short- or long-term consequences of human activities on the environment, in natural or cultivated areas; and (iii) the use of resources in the area.

In addition, policies must be analysed as such. This includes policies on prices, credit, trade, land use, physical planning as well as demography and immigration. All this, like the functioning of markets and the organisation of extension, plays a part in determining the behaviour of the actors and their reactions when faced with uncertainties, and creates (or does not create) the conditions to develop activity.

In each of these points of view, the present situation in the region is analysed. But it is also necessary to utilise background data for a better understanding. For instance, this is the case for the pattern of land-use, for demography, crop yields and prices as well as subsidies.

The regional model and how it is used

The partial diagnosis drawn up for each of these components of the analysis of the region provides an initial list of questions about the region's development and thus can be used to determine research programs and appropriate ways of communicating results. This is what is called a thematic approach.

Combining the three approaches guarantees that the main actors involved in the region's functioning and development and their interactions are taken into account in preparing the regional diagnosis. This is achieved by identifying the region's subsets and by analysing their functioning, by developing the typology of the actors, and by portraying the spatial representation of global data using GIS. This

5 The term "farm" is taken here in the broad sense of a center where decisions are made about the use of natural (and other) resources to obtain an output and to meet the needs of a family. It also encompasses entities with some land as well as those without land. In both cases, the diversity of activities of each of the actors is taken into account.

combination of approaches must be carried out at the levels where production choices and decisions concerning the management of natural resources are made.

A complementary list of questions can thus be identified regarding the relations between the actors and the systems they manage.

This global diagnosis is then used to build a model of the current functioning of the region. This model is used to simulate the development of its functioning when major factors vary such as demography, prices of products and inputs, land use and credit policies, or when technological innovations are introduced.

To conduct these simulations, this model must explain the relations between the actors, the activities that they conduct and their determinants. In particular, it must show the connections between the use of factors and resources and the output obtained, the ways that the area is used and the economic and environmental repercussions, and the behaviour of the actors and their economic, cultural and social environment. To do this, it is necessary to collect data which, even if they cannot be quantified, are nonetheless essential in understanding the regional reality: the regional model must not be reduced to what is quantifiable, otherwise there is a risk of masking the complexity and the diversity of reality.

This tool is progressively enriched as the research progresses. Simulations show that the variability of economic and environmental results correspond to different development schemes. Thus they make it possible to identify new needs, for the future, in knowledge or in modes of social organisation, for example.

Conclusion

The organisation of research in the context of a specific geographic area is not the only approach to finalised research. Using thematic approaches on general topics is also a legitimate method, and their results make solid contributions to regional research.

The value of this research, however, resides in its capacity to integrate all the actors in the analysis (individuals, groups, companies, and institutions) of the area and combine their rationales to contribute to its development. This development can only be real and sustainable if there is a certain measure of consistency between these activities, notably regarding the use of resources available in the area. Research alone cannot provide all the answers for development. However, it is expected that the ecoregional approach will be able to contribute to the definition of what makes up this consistency. It is therefore necessary to understand the diverse uses of natural resources, the diverse conditions under which technical progress is adapted, and the diverse ways in which various actors adapt to an evolving, fluctuating environment. This cannot be achieved if the technical, social, economic, and political data are analysed separately. The geographic area studied

must be considered as a component of research: this is the concept that has been developed in this paper.

It seems clear that developing the ecoregional approach as it is currently being used is necessary to prepare for future issues recently spelled out in the report by Gordon Conway in "Sustainable Agriculture for a Food Secure World" This report shows that a new "Green Revolution"—agronomic and ecological—is necessary for productive agriculture that respects the environment, especially in regions with many constraints. In the prospect of this "doubly green" revolution, the ecoregional approach has a natural place.

Research institutes in countries of the South and the North and international institutes have obtained results which meet various needs of the countries of the South. But only in few cases have these results been integrated to promote sustainable development at the regional level.

This issue, of concern to most research institutes, requires attention to problems of organisation and content of research on development. The CGIAR, which founded the term of "ecoregions," research centres and universities in numerous countries in the North and, in the South, regional organisations stemming from the NARSs (National Agricultural Research Systems) such as CORAF (African Conference of Agricultural Research Organisations) all contribute to developing this concept.

In the face of the urgency, the complexity and the diversity of the problems to be dealt with, it is essential that these different forces be combined to establish the principles and conditions of more effective research, and hence contribute to helping prepare all research on development to better face future issues.

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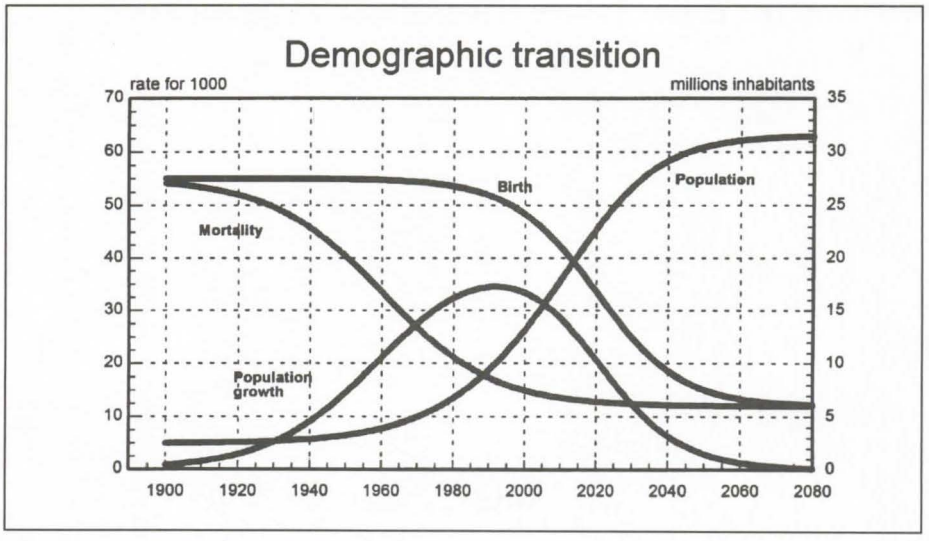
The geographic dimension of the Doubly Green Revolution

Michel Benoit-Cattin, Jean-François Ruas, Serge Guillobez, Brice Eychenie

To be operational, reasoning on the prospects of the Doubly Green Revolution has to be done mainly at the country scale. It is at this level that, agricultural, economic and political decisions are made in order to impel sustainable intensification of agriculture. General demographic and economic equilibria, have to be identified and preserved at the national level but for historical, climatical, pedological and cultural reasons, the agricultural and rural reality is heterogeneous. This heterogeneity is written in space and can be geographically approached.

The demographic challenge

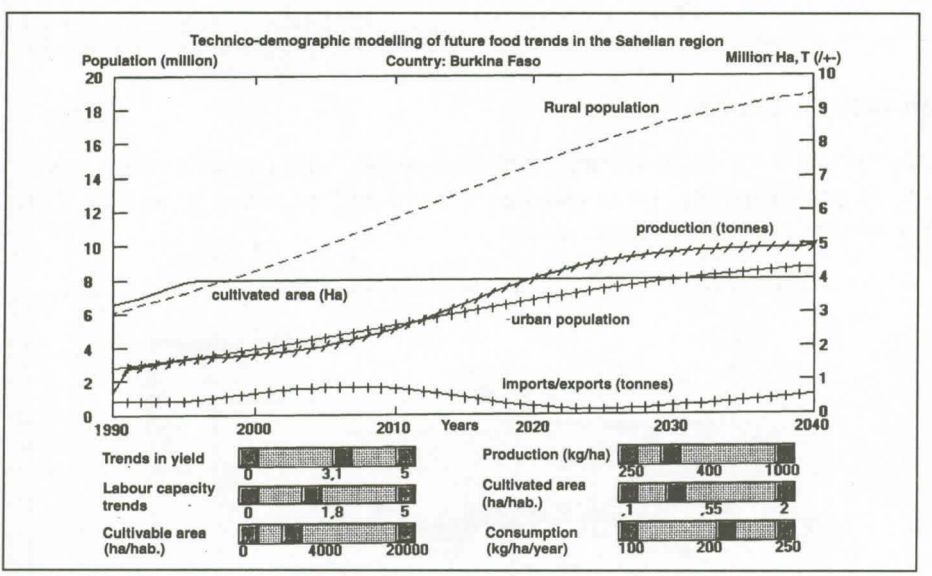
Population forecasts imply that agriculture has to be intensified. Demographers make their projections based on the theory of demographic transition. Since his



theory can be represented, it can be used to elaborate scenarios on the demographic futures of a country. What is known of death and birth rates in Burkina Faso, and the hypothesis of the beginning of the decline of the demographic growth rate since 1990 enable us to build this graph. On this graph, we see that between today and the year 2020 the population will be doubled with a trend towards 32 million (to be compared to the actual 10 million). Whatever the hypothesis, we have to remember that for the next 30 years, the population increase will be almost linear before starting to decline.

The agricultural challenge

Still reasoning at the level of one country, each additional inhabitant is an additional consumer but he can also be an additional agricultural worker if he can have access to arable land. To maintain the existing level of food per capita and the existing trade balance, as long as arable land is available, will require increasing the cultivated area at the same rate as the rural population working in agriculture. Labour productivity, like land productivity, has to grow at the same rate as the number of people to be fed by each agricultural worker. When all the arable land is under cultivation, the land productivity has to follow the demographic growth rate. These relations can be written like equations, and computers allow interactions. (Benoit–Cattin M., De Grandi, 1994).

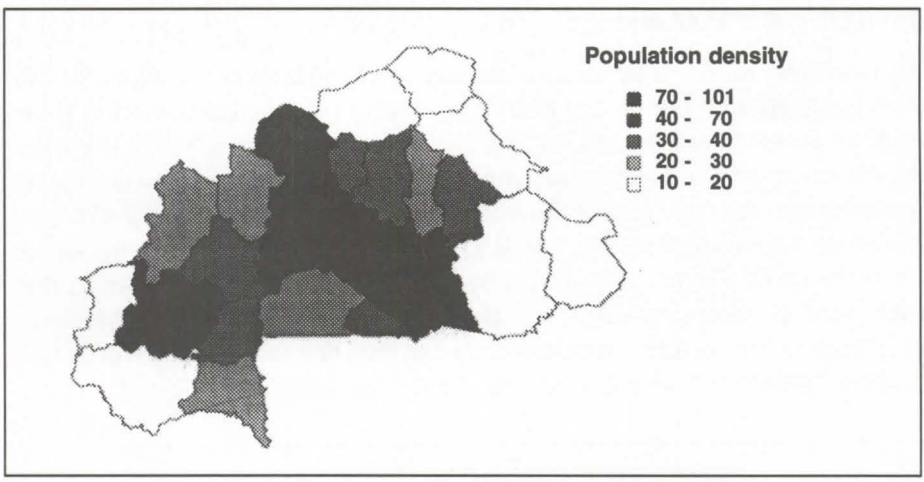


The evaluation of what is really arable is very important. If we accept the level of 8.9 million hectares of arable land (FAO and IBRD) for Burkina Faso and our demographical forecasts, the current system of extensive growth could continue as all the arable land will never be under cultivation. But if we accept our evalu-

ation of 4 million hectares, labour productivity will have to improve fivefold and yields threefold. Due to the heterogeneity of the actual world, these forecasts have to be linked with a more precise geographical approach to be operational.

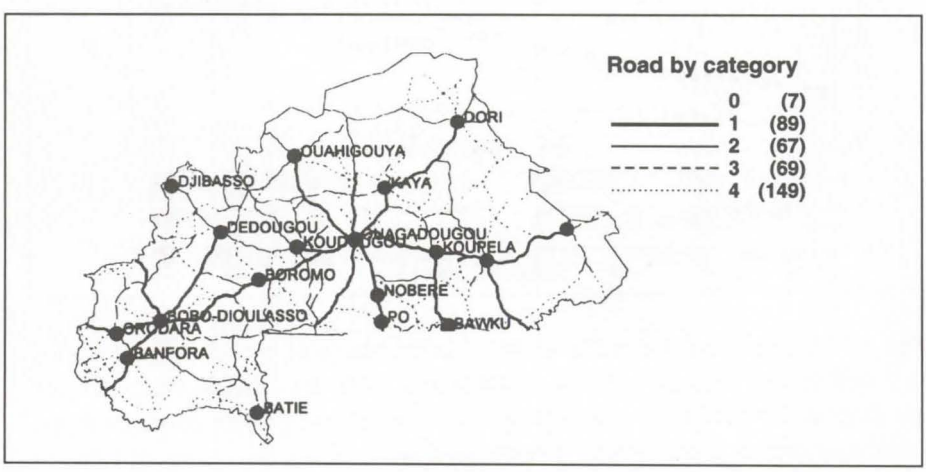
An unevenly scattered rural population

Even on the basis of rough administrative division (30 provinces), the heterogeneity of the rural population is evident and can be explained by the history of the population more than by the quality of natural resources.



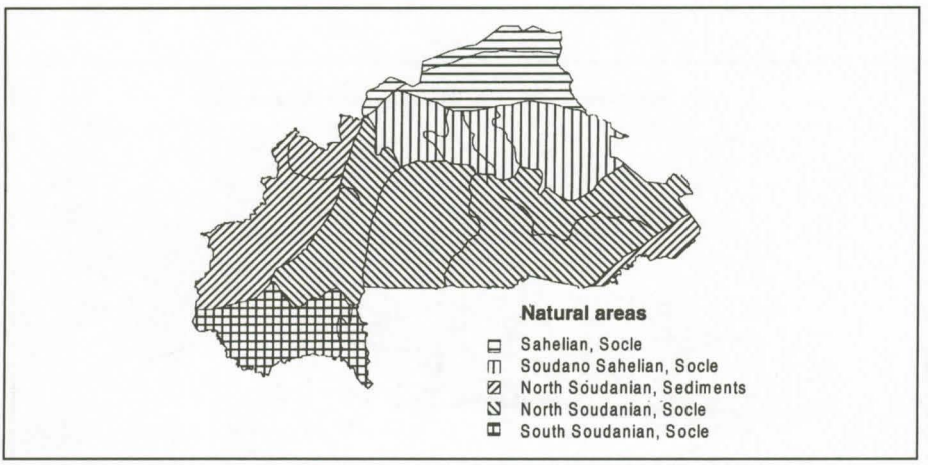
An urban network

Cities attract a rapidly increasing number of people, who consume staple foods without producing any. These cities grow more and more into a network that structurs the national economic space.



A heterogeneous natural environment

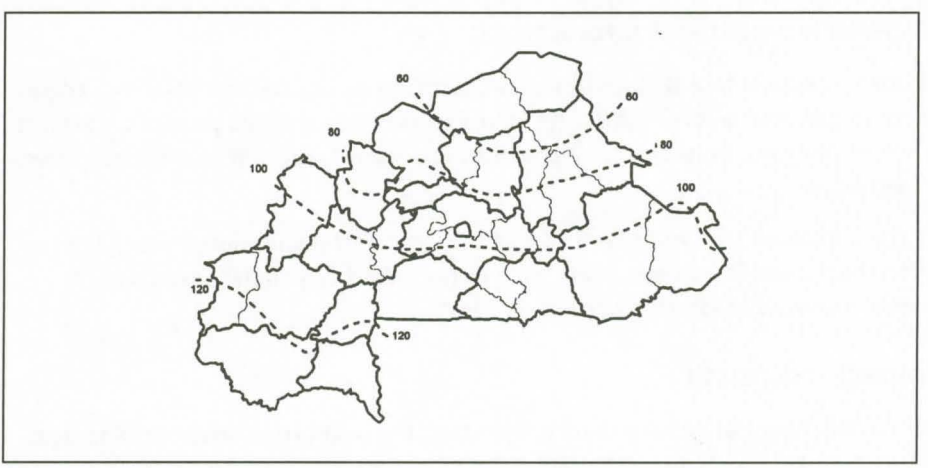
The natural environment is influenced by a rough north to south rainfall increase, like in all the countries of the sub-region. Interactions between climate and geology have produced different types of soils that support different types of vegetation. The resulting natural environments can be mapped. Zoning can be done by mixing administrative limits with maps of environments and populations.



Agronomic characterization of zones

Data from surveys, experimentation and remote sensing can be made coherent by using feeding them into bioclimatical, agronomical or zootechnical models.

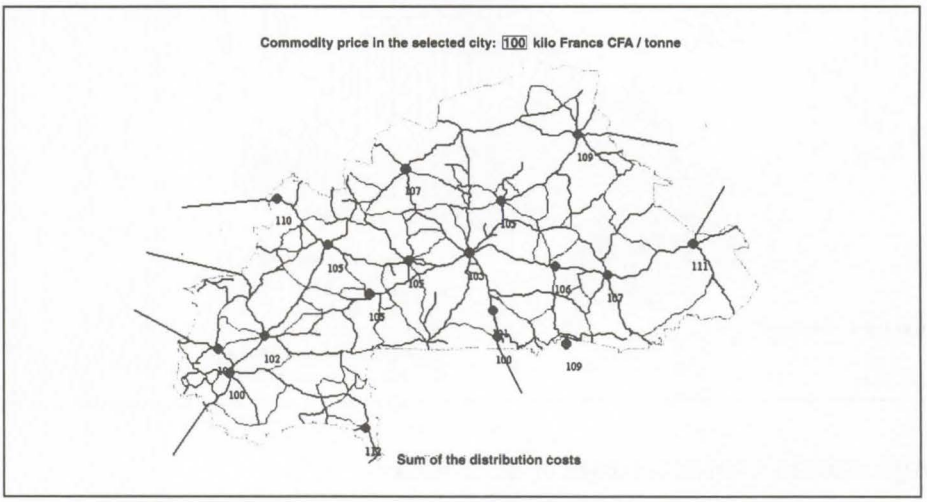
The results can be mapped individually or according to agricultural zones.



Above: growing cycle for sorghum, as proposed by agroclimatologists, and an example of zoning that aggregates the provinces in 17 zones.

Economic structuring of space

Relative prices change over space and time as affected by State intervention in price formation for agricultural products and inputs. Indeed, there are taxes and subsidies, for stabilisation (over time) and/or compensation (over space). Knowing the locations of the market places for the different zones makes it possible to calculate the market prices according to the hypotheses on policies, and to calculate the average for each zone.



Above: impact of the transportation cost for a product imported through Pô or Banfora at initial price of 100 CFA/kg.

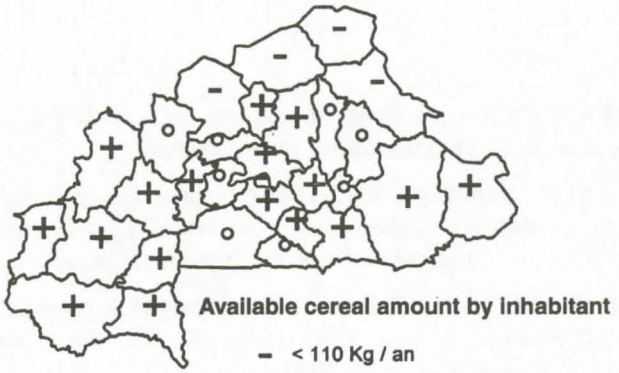
Agro-sylvo-pastoral interactions

A zone's pedoclimatical characteristics determine its agricultural potential, according to different levels of intensity linked to the demographic pressure. Farmers choices of crops, animals and techniques are market-dependent (relative prices, credit etc.).

These interactions can be handled with a technico-economic model, which is adapted to each zone to accommodate previously established parameters (soil types, potential productivity, labour availability, prices).

Impact indicators

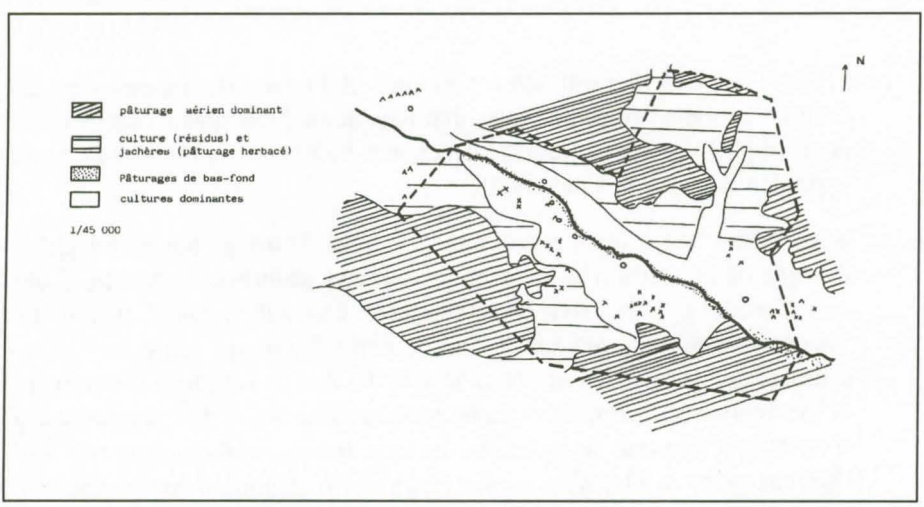
Within the range of validity of its parameters, the technico-economical and agro-sylvo-pastoral model can generate a lot of results that can be mapped for the impact evaluation of any policy. Policies are simulated according to different hypotheses on technologies and demography.



Above: level of satisfaction of cereal needs by zone.

Other geographical scales

The calibration of the technico-economic model is based on real, well documented situations, usually village monographs for which mapping land development can be very useful.



Above: different uses of Boukere villagelands in Burkina Faso.

Since on the other hand, boundaries are quite imprecise, it is important to think in terms of wider regional and subregional spaces.

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Comments and debates

Session chaired by Antoine Cornet, ORSTOM

F. HEIDHUES: I agree largely with the conclusions of the two papers, nevertheless I think that there are some issues that have to be highlighted. But before, I want to pick up one of Hubert Manichon's comments: is the eco-regional approach old wine in a new bottle?

When I first heard for the first time the term "eco-regional approach", I thought of my university courses in regional economics and, then, the "new" model of Thünen's "isolated state". One asks oneself: it is really Thünen's model that we are discussing here? There are some very interesting parallels to be drawn. Thünen was the first to introduce the concept of the economic factors in regional resource allocation. His revolutionary contribution was that he promoted the idea that regional development and regional resource allocation are not just a matter of natural factors like soil, climate or water and so on, but also of transport cost. But, in his model, he used very idealized regions eliminating the differences in natural resource endowment. His basic idea is that a region can be seen as a complex interaction between natural resources and economic factors, we might also add social and political factors.

The first question to ask is: what is an "eco-region" ? Both papers address this question in a very pragmatic way. When we discussed, research impact indicators in a USAID seminar a few weeks ago, I was assigned to a group on eco-regional indicators, and the first question we asked was "what is an eco-region?" One member of the group, a soil-water scientist, said that it could be a watershed. In another recent meeting on ecological zones, we saw slightly different definitions of eco-regions. And for an economist, we could have other definitions because in economy the main actor is the state and we are inclined to consider the countries as a key-element in the eco-regional approach. But it is not too clear, because policies can be taken at the provincial or international levels.

The second issue is the question of the manageability of an eco-regional research program. There are important lessons to be learned from the integrated rural approach mentioned by P. Pinstrup Andersen. That are certainly to the eco-regional approach. The first lesson concerns overloading the program. Rural development programs have suffered gravely because we wanted to do too much at the same time, within a single program; we all know that some of those programs were not manageable because coordinating costs were very high. Another lesson was the danger of overloading the non directly productive components. If we overload programs for example with educational infrastructure investments without having at the same time income raising activities, the problem of sustainability becomes difficult to resolve. A third one was perhaps the neglect of institution building because too much attention was devoted to coordination of operations, rather than institutions.

For the eco-regional approach, the same could happen; the more factors that are integrated into such a program, the more difficult it becomes to handle and to coordinate.

To the extent that we use models in the eco-regional approach, there is the issue that the more variables we endogenize into the models, the more complex it becomes. And the capacity to convince is possibly reduced because it is very difficult to trace cause and effect relationships. Second, the more complex these models are, the more time it takes to produce results. In rapid structural change periods, it is sometimes difficult to adapt the models in time. So, there is a question of whether we want to be perfectionists running behind the train, or whether we want to be in the movement and able to influence the direction with somewhat less perfect instruments. It is a difficult issue.

Let me conclude with the third issue relating to the eco-regional approach: accountability. In a time of scarce public resources for research, this is an im-

portant aspect. With the eco-regional approach, we get numerous actors and institutions involved in research programs (producers, farmers' organisations, NGOs, public services, governments, researchers). With the involvement of so many institutions and people, responsibilities tend to be blurred and with it, accountability can become difficult. The eco-regional approach has to be a framework within which individual actors can be assigned clearly defined responsibilities for which they can then be accountable.

What I like very much about the papers is that they do not try to define what an eco-region can be, but just present criteria that help us to define research questions and development orientations. These papers provide concepts that allow us to analyse of the interaction of the natural resource-environment complex, the technology-innovation complex and the socio-economic-political-cultural complex. Taking these factors and the interdependencies into account, in a participatory approach, securing real feeling of ownership on the part of those who have to carry out recommended action, we can hope that we will improve the region's management and development.

M. GILL: The word "actor" seems to become an accepted part of our vocabulary. And I wonder if perhaps it is something we should relook at. Think about what actors do; they follow a predetermined text, and have very little room for innovation. What we need for the Doubly Green Revolution is to allow innovation. A second point about actors is that they know what each other is going to say before it is said and to some extent, they don't need to listen to each other, while we need to listen to each other. Then, perhaps, we can think about using the word "player", which is the alternative word. With players there is room for innovation, and players need to respond to each other.

H. MANICHON: We see an actor not merely as someone who recites lines. There are in fact several forms of theatre, not just plays written once and for all. The actor is someone who acts, according to these objectives, within a group of limitations, and who, to do so, takes decisions. In this respect, some actors are players, because they have the means to be players, others do not have such means available. It is not therefore from a restrictive viewpoint that the term "actor" is used.

U. VERBLOW: The eco-regional approach, as presented, would appear to me to be a necessary approach in order to propose solutions to highly complex situations. There may of course be a danger of "overloading" this approach, as F. Heidhues said with regard to integrated rural development. However, what is mainly lacking in this approach is a place for the role of the environment outside the region itself. One cannot obtain a satisfactory response to a given regional situation without taking into account interaction with the rest of the world. Otherwise, the approach would only be valid for subsistence economy regions. One cannot look at the future for agriculture

in certain regions, for example, without questioning the future of the European Union's Common Agricultural Policy.

J-M. PRADELLE: The two presentations are remarkable as they put forward complementary methods, one which defines all potentials and limitations within a region and the other which offers more in-depth analysis and characterisation of development problems encountered. With the importance they put on physical and economical geography, the approaches presented are in line with the West Africa Long Term Prospective Study undertaken between 1993 and 1995 by the Sahel Club at OECD. This study demonstrates the role of peopling (location of populations) in periods of demographic growth, together with the rapidity of the division of work and the diversification of consumption patterns. Urban populations will multiplied by 20 between 1960 and 2020 (60 years). Agriculture is currently adapting to this phenomenon. It is increasingly faced with an urban demand for food products in a large number of towns which vary a great deal in size. This situation could give more intensity to local trading. The study also reaches the conclusion that countries will progressively evolve towards a regional economy by junctions between towns' economic influence zones, very often with national borders creating no obstacle to this phenomenon. The approaches put forward by CIRAD contribute therefore to a better analysis of these developments and, allow for better targeting of research and development operations. They also take into account both the urban and the rural aspect in the analysis of development problems, which is indispensable. However, should one not go even further in order to gain a better understanding of the nature of interactions between rural development and urban development?

Ph. LACOMBE: The points put forward by Hubert Manichon and Michel Benoit-Cattin provide part of the answer to certain questions which we have asked ourselves regarding the way in which a participatory approach to research and development could be organised.

First, the presentations put the accent more on procedures for organising research work than on the scientific problems to be resolved. This is understandable since it is necessary, however it arouses a certain number of concerns in the sense that it could encourage us to carry out descriptive research rather than research which provides answers to questions whose legitimacy has been proved. Are we not running the risk of accumulating case studies? It would appear useful to complete this representation by formulating of scientific problems to which the approach which you suggest could refer, and by elaborating scientific questions. This would enable us to demonstrate everything learned since Von Thünen. I am thinking of questions on the relationships between demography and production systems, or between transport efficiency and market efficiency, for example.

H. MANICHON: This is not at all a question of carrying out contemplative research! Of course one should not stop at the stage of eco-regional diagnosis and participatory diagnosis. The idea we put forward is indeed to define directions for research, a revolving process in which products could be supplied rapidly. If one starts with the idea that research must supply perfect products, lead times could appear unbearable for those concerned as production systems evolve very rapidly.

If one defines a regional typology of agricultural holdings and their development trajectories, one is then in a position to observe possible evolutionary prospects in accordance with easily foreseeable events (division of holdings and families, credit developments, etc.). One can thus easily update knowledge and rapidly adapt research to requirements.

Ph. LACOMBE: I want to come back to the participatory approach. I fear a little that "natural and spontaneous kindness" of agronomists may lead them to the quick support of these participatory approaches—which of course will give rise to our support, through generosity. But this may cause a certain degree of obscurantism (sometimes the price to pay for kindness?). In fact one tends to forget the profoundly contradictory nature of interests within local societies. Would the participatory approach naturally lead to omitting the contradictions which are present in these societies? Or will scientific activity resolve them (that I cannot believe!)? Or in fact, might one obtain a kind of "submission" in order to gain support for a joint development scheme? This would doubtless be the submission of the poor who would therefore be obliged to adapt to the new situation.

This outline of contention to the proposed method is not as radical as my presentation may lead to believe. To qualify my assessment, I would like to say that it is true that, based on a procedure, of confrontation participation rather than conflict can lead to negotiation and sometimes to cooperation, and learning procedures can be developed. It is perhaps based on these collective apprenticeships—which are stressed a great deal in economics and sociology as taught today—that new policies can be implemented using new rules and conventions. It would therefore be extremely useful to understand how these apprenticeships are established, rather than claiming to arrive rapidly at a participatory approach where everyone can enjoy the position he considers his own.

H. MANICHON: I do not always get the impression that agronomists are kind! Naive maybe! Everyone is outside of the world he knows well. I understand and share the arguments put forward by Philippe Lacombe, but we are not starting from a scratch in terms of the participatory approach and the eco-regional approach. We must, moreover, as U. Lele said, make a systematic analysis of experience acquired in order to learn from it. It is clear that there are contradictions within the rural areas. To deny that, or to replace knowledge and ex-

pression of these contradictions by "submission" procedures has never given good results. There are numerous examples taken from the past of actions said to be interventionist in the rural zones which can prove as much. What we are thinking of is rather to analyse as such the objectives of the various actors involved, without erasing diversity and contradictions. However, one can contribute to giving greater overall coherence vis-à-vis objectives which are greater than those of individual actors.

L. TUBIANA: I would like to continue on the theme of research practices, using an example. In a cooperation research programme in Mexico with geographers, agronomists, pedologists and economists, each individual sought to define a geographical unit which was as homogenous as possible. When each "discipline" had defined its zone, factors which would have called into question each of the zones were considered as exogenous to the system. Research is therefore itself confronted with a problem of managing conflicts which echo the conflicts existing in local societies. The resolution of research conflicts has—acting as an echo in a similar manner—allowed one to suggest resolutions to conflicts by seeking out actors capable of defining areas of coherence and giving overall coherence to developments.

G. CONWAY: It seems to me that there are three challenges that face the eco-regional approach. One is speed. The second is insightiveness of focus. The third is ownership.

On the question of speed, there is a real problem in that people using this approach want perfect information to produce perfect plans. In the 1970s and 1980s in Thailand, when we developed the techniques of agro-ecosystem analysis which was applied in many countries of South-East Asia, and relied on definitions very similar to yours, we used a small tightly organised multidisciplinary team, this was crucial. Second we said that every piece of information had to be described in a graphic form or in diagrams is to allow for good discussions. We obtained interactiveness by saying that at each stage you had to come up with key-questions, key-hypotheses or tentative solutions to a problem.

On the question of insightiveness, I think you have to have rigorous concepts. There were four measurable things in our research at all times: productivity, sustainability, stability, equity. We knew that they were being traded off in every situation whether we were talking about an individual field or a whole country. And that was the focus of the analysis.

The third challenge, ownership, is a very difficult one. There is the problem of an expert coming to a village, inquiring for information and taking it away. There is a contrast between the beautiful elegant diagrams on the computer, and the "beautiful messy" diagrams in the villages. And how you get to relay to the villages seem part of the process. This is crucial.

About conflicts, I think participatory research techniques are useful to deal with conflictual situations. Let me give you an anecdote. My good friends in USAID, once gave me a bullet proof car in Manila and told me to go into a rebel held area where there was a dam that was not being used because of all kinds of conflicts. Some people from the University of the Philippines and I went to the area. We were used to this kind of techniques with diagrams. We had everybody including the rebel army leaders and some government officials and the villagers use the diagrams as a point of analysis and conflict resolution. I think simple diagrams can be incredibly powerful in conflict resolution.

H. MANICHON: I too would like to see diagrams enable us to resolve conflicts between researchers! I am hopeful in this regard. When researchers put themselves resolutely in touch with reality, which does not mean, of course, that they cannot use models, their mentality always changes. They understand, at last, that farmers are capable of being innovative and that research does not have a monopoly over new ideas. Areas in which they innovate, moreover, are not necessarily the ones which the researchers have planned for.

One should not be idealistic either, and believe that farmers' innovations can always good in terms of the assessment criteria available to the researcher.

However, one of the major reasons for believing in agriculture in the South is that one very often observes an unexpected innovative dynamism, and when researchers take such innovations into account, they make quicker progress in their work at the service of development.

Future technology for the Doubly Green Revolution

Didier Picard

The next green revolution, referend to as the Doubly Green Revolution, will only exist if:

- emphasis is put not only on production, but also on the conservation and processing of the products, and it involve production and conversion processes which are viable: i.e. economically repeatable and harmless to the environment.

This note is mainly concerned with the agronomic aspects of the problem, other aspects being covered elsewhere. It aims to show that, like the first green revolution, the second relies on obtaining varieties selected to better exploit the potential of the growing environment. But that will not be enough. Much more than in the case of the first green revolution, which was implemented in potentially the richest environments, the Doubly Green Revolution will be based on the application of production systems better able to develop the potential of very varied agricultural regions, by integrating cultivated plots and livestock in a global management of the area. It will rely on the capacity of agronomists, through continuing dialogue with the players working on the production, processing, and marketing chain, and those concerned with land management, to identify factors limiting production and/or damaging the environment, be it in the short, medium, or long term, and to propose solutions to new challenges.

The Doubly Green Revolution will also need new methods, new research approaches, and new technologies to contribute to the development of the intertropical zone in the next thirty years, taking account of demographic considerations.

In the following text, the accent is deliberately placed on production, both plant and animal. A similar approach could be applied to product transformation.

New approaches for new production systems

The need to conduct detailed research under current conditions to tackle the problems of production and processing of agricultural products was hardly present

among the preoccupations of researchers during the period of the first Green Revolution.

The necessity to develop these methods was realised when it was acknowledged that, the problems to be resolved being complex, research in a partially controlled environment provided only a part of what was required to resolve them. In fact the environment of research stations (soil, climate) only represents a small part of the environment of a region: the experimental treatments themselves only correspond to part of the crop or animal husbandry systems practised; the cultural techniques are applied in optimal conditions, which is rarely the case on actual farms. Finally, the economic context is rarely considered. In environments subject to constraints, cultivated plants and animals suffer numerous stresses. To succeed in removing them in conditions which are economically profitable and environmentally friendly, one must resort to precise diagnostic methods and adapted solutions which can only be studied in the context of the actual production conditions.

For the same reasons of complexity of problems and multiplicity of possible solutions related to the farms and their environment, advice to farmers should not be prescriptive, but more of a decision support system for the producers, and more generally for all the participants in the chain of production, processing, and marketing of the products. Several forms of advice are possible under the heading of "decision support systems", from demonstrations, through research programmes involving the farmer, to the use of computer simulation programmes. But the objective remains the same: to leave the decisions to the end-users, to suit their own projects and environment.

The development of such research in real situations and the methods of transferring knowledge rest in part, but only in part, on the blossoming of biotechnology and instrumentation for diagnosis and experimentation, and on modelling, whose recent progress has been related to that of computer science.

Better systems of production fitted into their environment

The first Green Revolution was expressed as a strong artificialisation of the crop environment, often with disastrous consequences for the environment. In future one must turn to integrated management with rational control of all renewable resources, which takes account of the objectives of farmers and stockholders. This should depend on the environment of the production unit, in particular the economic environment, and on the project being undertaken by the leader and his family, and of the context in which the unit is situated.

The technologies which can bring new features into this area are very variable.

The new techniques of remote sensing and geographical information systems offer very interesting perspectives to better explain the phenomena of rural migration, the rules of land occupation and management, and resource management, such as woodland, pasture. They also lead to the formulation of decision aids.

For the development of animal husbandry in the Sahel, there is more to be expected from methods enabling the identification of globally available resources, the understanding of land tenure, and indeed the stockbreeders's own social organisation and place in the social structure of the crop farmers, and their methods of characterisating the individual performance of their animals.

As regards integrated pest control, tests capable of precisely characterising populations and their pathogenicity give a renewed interest to epidemiological studies and allow better characterisation of population dynamics and exchanges between the natural environment and crops, or herds and flocks of domestic animals. Such work is indispensable for achieving effective integrated control. This is even more true when forms resistant to pesticides appear.

New technologies for the management of crop systems

For the reasons indicated in the preceding paragraph, the new technical procedures proposed by agronomists to farmers are more and more diverse. They rest on a certain number of rules, which in turn relate to the necessity for the crop systems to be viable.

To establish the rules, agronomists start with the decisions farmers have to take, and the choices available to them. After choosing production systems, the farmer has to choose cropping systems and cultural techniques: rotation, choice of varieties, cultural techniques for soil preparation, sowing, etc. In such matters one must reason in terms of complete technical procedures rather than individual cultural techniques, bearing in mind the farmer's objectives, such as the intended yield of each crop.

As regards soil cultivation research is directed towards the application of techniques which are effective in limiting erosion, and which create and maintain a favourable soil structure.

In the humid tropical zone, where water is a factor that rarely limits yields, but where there is a high risk of erosion, the desire to develop cropping systems that limit erosion as much as possible leads to the adoption of intercropping, with both manual and mechanised cultivation.

Once a favourable soil physical state has been established, a cash crop is intercropped with a ground cover crop using zero tillage. Drilling implements are designed to sow directly into soils covered with living or dead vegetation.

As far as fertilisation is concerned, the basic rules are to limit applications as far as possible, and hence all losses except the amounts exported in the crop. This especially applies to leaching beyond the root zone. As regards fertiliser technology, numerous possibilities exist e.g. partially soluble phosphate, slow release nitrogen

The reasoning behind these technical procedures also aims to make better use of crop by-products.

Phytosanitary products will again have an important role to play in weed control, crop protection, and post-harvest loss. Much can be done to make their use less expensive and less risky for the environment. The range of control methods and products is increasing greatly. The main limitation is the high cost of new, more environmentally-friendly products, and the health of the users. All the diagnostic methods and thresholds for interventions should be developed to limit the use of pesticides to the very minimum necessary.

The application and refinement of agricultural diagnostic methods have led to a major reduction in the number of fungicide treatments against Cercospora leaf spot diseases in banana. By comparison with the strategy of systematic treatment used in certain Central American countries, the number of applications has been reduced from 25 to 6 for Sigatoka Disease (yellow Sigatoka) and from 45 to 16 for Black Leaf Streak Disease (black Sigatoka).

A great deal of work accompanies pesticide research, particularly on populations of insects and parasites which overcome natural or induced resistance, so as to avoid a too rapid appearance of such a breakdown of resistance, and to increase the efficacy of the products.

In the same way, vaccines and products for treating animals evolve rapidly. Biotechnology contributes effectively to this.

In the case of Newcastle disease in poultry, research is focused on finding an oral vaccine which is thermostable at tropical temperatures and can be easily stored.

New varieties, better adapted animals

For plants, research efforts in genetics and varietal selection have been mainly concerned with major arable crops, and less with species of local interest, forests, or natural pastures.

Obtaining higher and more stable yields remains a priority, as does resistance to pests and diseases. Knowledge acquired recently on the genetic structure of parasite populations and on mechanisms of variability of the pathogen allow us to better understand the use of resistance genes, which are better characterised by the molecular approach. The ability to resist stress, and the quality of the products, are becoming increasingly important.

Long-term analysis of the progress made shows that it sometimes results from leaps for major characters (semi-dwarf rice varieties) but more generally from a continuous improvement in a whole range of characters (rice varieties adapted to various water supply situations and resistant to diseases such as rice blast (Magnaporthe grisea).

Recently, progress in biotechnology has contributed to a renewal of selection methods and accelerated of progress. Future progress depends largely on genome mapping, selection assisted by use of markers, tissue culture, and genetic transformation. The use of transgenic plants in which a resistance gene is incorporated is required when, to control a disease or pest, no natural resistance is available.

For cultivated bananas, i.e. the polyploids (di-, tri- and tetraploids), and the natural hybrids of two species of Musa, acuminata and balbisiana, resistance to diseases is a critical problem. For a long time, because of the genetic characteristics of this species, selection of resistant varieties has been an almost insoluble problem, and many programmes undertaken with this objective have not succeeded. Knowledge acquired recently on the plant's genome gives hope for the future: by improving diploid varieties, and after chromosome doubling with colchicine, crossing with another diploid to give hybrid triploids, the first hybrid triploid varieties resistant to Cercospora leaf spot were created by CIRAD in 1994. They are now being tested. Very soon, it will be possible to produce new varieties by genetic engineering.

Arable crops should not be the only ones to receive attention. For rational and ecological use of land, one will resort more and more to species whose primary function is not production. They will have to fulfil several objectives, requiring special selection procedures.

In the realm of animal production, progress is expected in the use of natural tolerance and resistance to diseases and parasites. Knowledge of the physiological mechanisms involved, and of the genes responsible for this tolerance and resistance suggests augurs well for rapid increase in animal performance from this point of view.

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Comments and debates

Session chaired by Ndiaga Mbaye, CORAF Executive Secretary

J. PEACOCK: I want to further emphasize some points made by Didier Picard. You remember Per Pinstrup Andersen's comment that biotechnologies could be of value even in farming by and for the poor people of the world? I think this is very important because it is often brushed aside. It is now easier because DNA scientists can understand agronomists, economists and plant breeders. This is an important change for the development of these new areas.

There are two significant things. One is that we talk more about plants than animals. In plants there is a particular advantage in that the new science can actually interweave into the agriculture system. The most marvellous technology transfer package that is called the seed is in the hands of that subsistence farmer. And the farmer can rely on the plant. Another factor is that we are dealing with a new biology, and an unprecedented understanding of living organisms. It can also be leading to an unprecedented right in application of the new biology. The long lag from biology to agriculture is no longer necessary. In fact, one thing is challenging our research institutions, particularly in applied research: can our institutions keep up with the rate at which biology is changing?

What can be done? We can now add confirmed genes or gene constructs to virtually every major food and production plant. Even for rice, cassava, and banana, we now have the technology to add genes. The rice example was mentioned when there was real focus on a particular crop with very defined problems. We can expect that many laboratories in the world can add genes in the rice whereas three years ago, may be only one could. There is good robust technology now.

If we can add genes, what kind of genes? The biggest advances have been in genes which protect plants from pests. This is very significant, even in complex subsistence farming; it does not only have to be in the large uniform acreages that were used in developed countries. In-built insect proofing against a particular pest, even whilst encouraging beneficial insects, can have quite dramatic effects on yield stability. In many of the areas which we heard about today, yields may not double in the next few years!

This said, an increased yield stability, could be of great significance and lead to effective doubling. It is the better management that might lift the harvest value.

Against biotic challenges, there has been quite remarkable progress. One of the most exciting in plant biology is that many disease-resistant genes have been isolated in different laboratories. Since we are beginning to understand how the plant combats invaders, we will be able to change the essential gene so that robust invasion protection can be put into choice seeds. As you heard from Didier Picard, synthetic resistant genes are also being built particularly against forest diseases, against which they are very effectively.

Now for the abiotic or environmental challenges; they are not so easy. But there is a lot of understanding already in some complex areas of drought and salinity resistance. This emphasizes the absolute need for new technology to be combined with more traditional plant breeding.

There are some things that we never dreamt of that are already becoming possible. We are beginning to understand how a plant extracts nutrients from the soil. When you go into a new tropical environment, you see that the local plants have vastly superior abilities apparently to extract nutrients and utilise them. Why can not we learn what they are doing and give those new characters to the food plants? Once we understand the particular entry places in the roots at a cellular level we can know how to make an adjustment to those plants.

It is not only on the production level that the new sciences can help, but also as concerns storage, conditions of transport and response to transport. These problems are often overlooked.

It is important for us to have these new developments in biology focus on the problems of the developing countries. But only after the problem has been correctly defined at the local level, will it be possible to change the locally adapted seed and give it some valuable new technologies? It does not have to be the all powerful new hybrid. The right team of experts will be able to give biological answers to biological problems. We can thus participate in bringing about sustainability.

Insect proofing of cotton plant is spectacular. But it has to be done using integrated pest management and the ability created by working in multidisciplinary teams.

We can bring about these changes. There are now genetically engineered varieties for rice being tested in many countries. We now can put resistance genes in the banana, and this is a real feat and cassava has finally been "conquered".

We have a real chance to use the new power of biology. But one need carefully defined problems and new partnerships. You have a remarkable position here in France with CIRAD and INRA to bring some of this about.

Technological risks

G. PAILLOTIN: The example of biotechnologies developed by Dr. Peacock demonstrates why the insertion of scientific techniques in an economic and social system is more complicated than one is stating here. One alternates between the possibility offered by science for resolving problems, and the virtue of social demand. Research must be much better adapted to demand. With regard to biotechnologies, in developed countries supply is unlimited. It is consumer acceptance which counts, a fact which is limiting the development of such techniques in Europe. In the end, the only countries where these techniques would be more easily acceptable are developing countries. Why, therefore, are they not being used? Doubtless because there would be criticism in the name of ecology in the developed countries themselves. One day these complex questions will have to be addressed properly. Techniques, as good as they are, must be combined subtly with social demands as a whole.

B. CHEVASSUS: One aspect of the Doubly Green Revolution is its impact on the environment. We know that in our temperate eco-systems, with their monocrop production systems, this question is not easy. Very little is still known about the dynamic of gene flows towards wild species. The fact of replacing a plant which is sensitive to a disease or an insect with a resistant plant may give rise to host transfer on the part of either the insect or the disease; there may therefore be an incidence on other targets. We are also heading towards the introduction into tropical eco-systems, which are much richer in terms of bio-diversity and much more complex, of new biological creatures with new properties fertile biological creatures which are therefore likely to emit genetic flows in the direction of wild species. The Doubly Green Revolution presupposes therefore that one has acquired much greater knowledge about ecology and the dynamics of peopling in these tropical environments.

M. PETIT: The questions raised by Guy Paillotin and Bernard Chevassus warn us against excessive enthusiasm for biotechnologies. This is paradoxical: there is real potential but at the same time ecological dangers. Research into these dangers must go forward. And there is resistance from society which I tended to put down to resistance from economic pressure groups, but which would in fact appear to come above all from consumers. What do the geneticists think?

D. PICARD: In terms of biotechnologies, one often swings between optimism and pessimism. Here and now we can assess optimism shown at the outset by

saying that progress achieved is not that which was expected. F. Jacob's white paper foresaw in 1982 that very rapidly several transgenic plants would be grown in France. Ten years afterwards, land areas involved are almost non-existent. On the other hand, a great many transgenic plants are potentially available. Without being either optimistic or pessimistic, CIRAD must continue its research on transgenic plants, for instance on transgenic insect resistant or tolerant cotton plants. This could reduce the currently extremely high consumption of pesticides on cotton. In this specific case, the risk of spreading the gene into nature is extremely low. We must also remember that there are large scale ecological risks linked to techniques other than biotechnologies, for example the proliferation of the water hyacinth and *Chromolena odorata*. Risks must be assessed for all kinds of techniques, not only biotechniques.

J. PEACOCK: Regulatory affairs, of course are also. It would be absolutely foolish to introduce any transgenic organism into a country or a district where appropriate regulations and rules of introduction do not exist. But many organisations now (such as, OECD, CGIAR, Stockolm Foundation ...) are moving very quickly to provide help to developing countries to put together the appropriate regulatory packages. When you have a single gene with a particular character, in fact it is an adjustment to a plant that we might often achieve by normal plant breeding. We need to understand each and every case and what is being attempted.

Ecological and environmental considerations are very important. In Australia, for example, we are working on transgenic eucalyptus. We will have first to achieve sterility of the plantation trees, so there is absolutely no risk of gene transfer into the surrounding eucalyptus trees. In all cases, we have to be certain that the right care has been taken. Usually, it is not a major problem with crops. It can be in the centres of origin where there is still compatibility with native species.

We also have to consider that an insecticide delivered by gene transfer, is still a chemical, and we can still have the same drastic effects of selecting for resistant pests as we have with externally applied chemicals. So it is necessary to manage this procedure very well and very carefully. For example in cotton, the introduction of two independent transgenic methodologies at once gives dramatically different expectations with regard to sustainability and revertness of the system than introducing a single one at one time. These things have to be looked at very carefully indeed.

People like myself are of course enthusiastic about this technology. But science alone cannot work without a regulatory framework; this also applics to plant breeding.

A. CORNET: It is important that problems arising from the spreading of biotechnologies are also the object of research. This may mean partially distancing from laboratory biotechnologies in order to look at biotechnologies in the field, with for example studies of genetic flows *in situ*. This is going to cause organisational problems.

M. JACQUOT: I would like to take the point of view of the selector. What do selectors know which would be of use to a Doubly Green Revolution? First they know from experience that this risks being a long job because genetic types are difficult to select. Obtaining lasting resistance to parasites or obtaining tolerance to climatic aggression is a difficult and often unspectacular task. Results are often obtained slowly and continuously whereas one gets the impression that genetics produces innovations which make large scale, or even exceptional, qualitative leaps. With the Doubly Green Revolution, the main change will be the clearer recognition of the role of plant breeders in obtaining genetic material which respects the environment better. More specifically, they will have to combat genetic uniformity for species grown on small areas but which are locally interesting and of use; the selectors must conserve study and improve these resources.

J-L. NOTTEGHEM: The management of resistance genes is definitely not a new problem. In the past, natural resistance has been bypassed by pathogens or insects. I am not very optimistic with regard to the state of discussions between biotechnologists, plant breeders and researchers working on pathogen and insect populations. At the recent International Congress on Rice Genetics in the Philippines, the weakness of inter-disciplinary discussion was evident. This may lead, for example, to transforming a variety of rice with a biotechnology gene with no concern as to whether there are risks of crossed resistance with other biotechnology genes, and not a great deal of thought is given to strategies for the use of the varieties. I hope that the Doubly Green Revolution will allow for more holistic of reasoning.

J. PEACOCK: With regard to the limits of biotechnology, we eat food, not biotechnology! We have to remember that it is just a tool for solving problems. I also think that there is a large potential to misuse biotechnology! But it can be of a great help in integrated pest management and in giving real new incentives to it, which often has been ignored with the use of widespread chemical insecticides. But I do not agree that the chance of cross resistance has been ignored. We know, for example, that with some of the biotechnologies you are referring to there can be cross resistance. That knowledge is extremely useful in avoiding some of the great mistakes that could be made.

J-L. NOTTEGHEM: I agree with your view.

Sharing biotechnologies

M. JACQUOT: I noted in Dr Peacock's presentation that the developments hoped for in biotechnologies will depend, above all, on the number of scientists who work on them and particularly on those who will transfer these techniques to teams working in developing countries. If we do not succeed in encouraging the setting up of such teams, our own work will no be very efficient.

A. CORNET: Indeed, the existence in this area of teams in developing countries is a necessary condition for progress. Even if initially the teams cannot undertake high-tech research, they will become capable of analysing local problems much more easily, translating them into research and participating in international discussions. There can be no Doubly Green Revolution without accelerated training for people in developing countries.

Orphan Plants

P. DUBREUIL: Will there not be a tendency to work on the most classic plants such as cereals and tubers for large scale consumption? What will be done for plants which are currently neglected by research and which are of interest? Is there any interest in working on these plants on a genetic level?

J. PEACOCK: We can actually look the transfer of some useful characters from wild plants into existing crop plants. It may be done with the help of breeders to domesticate it at a fast rate. We have begun to see that the genomes of these plants are remarkably conserved. Rice, for example, is the "Pierre de Rosette" for all the cereal plants, wheat, barley, millet, they all have the same order of genes. It is absolutely remarkable, and the new information that is largely coming from rice is going to help millet and sorghum breeding in Africa.

Complex cropping systems

P. DUBREUIL: There are many tropical crop systems which are based on crop associations. The Doubly Green Revolution would appear to leave room for crop association. Should geneticists work on crop complementarity?

D. PICARD: Of course the Doubly Green Revolution is not based only on the association of a cultivated plant and cover plants. This is a particular case of seeking out complementary crop associations with different objectives: water economy, maintenance of anti-erosion cover, spread of the harvesting seasons for food, and so on. I would underline, however, the particular interest of anti-erosion cover plants and complementary rooting crops and trees because their combination will doubtless be very useful for the promotion of efficient crop systems in hilly areas.

Demand-driven and systems research

M. PETIT: Didier Picard's presentation is an achievement. It marks the recognition by CIRAD, a agricultural major organisation, of the theses held in France on systems, which one might summarise as demand-driven and systems research. Is this orientation still in the future or is it already being applied?

N. MBAYE: In Senegal, researchers at specific disciplines were afraid that systems research would marginalise them. With time, and the explanations of J. Faye, fears disappeared gradually and the research dynamic is developing. The influence of social demand is felt to a greater extent, particularly thanks to research undertaken in the field.

D. PICARD: A certain number of concrete examples demonstrate that this approach, which arises out of demand, is tending to progress and interest a great many people. One could take the example of the "Office du Niger ". To begin with, the project was very ambitious and aimed to produce irrigated rice in large scale development schemes. The initial objectives in terms of surface area and yield were never achieved and developments deteriorated. There were successive attempts to rehabilitate them. Initial demand for research concerned cultivation techniques. The Office's intention was to rapidly introduce double-cropping. The reaction from research was to analyse of cultivation practices and their varieties. A typology of production units was created. This was used to adapt technical proposals to each type. The favourable economic climate created by the devaluation of the F.CFA then facilitated the adaptation of diverse techniques for the various production units. Here wen indeed started from an analysis of the producers'real needs.

The Doubly Green Revolution: economy and institutions

Michel Griffon, Jacques Weber

The Green Revolution has tried to fight against poverty and food shortages by selecting varieties and forcing systems of production on ecosystems, modified by massive use of fertilizers and pesticides. It has produced significant results but only in countries with high capacity production, water surpluses, and high population density.

The concept of a Doubly Green Revolution consists of shifting from one rationale of agricultural development based on a command of the environment to another, based on harmony with the ecosystems: working with and not against the variability of systems and putting the knowledge acquired from ecological sciences to use in agriculture.

It requires an interdisciplinary, intersectoral and spatialized approach. Current thought places agricultural development in an environmental vision of the sustainability of production systems.

It gives priority to local ecological, economic and social resilience[1] by rethinking the current relationships between central State and local institutions and by giving priority to a "bottom-up" approach in public choices and taxation schemes.

The Doubly Green Revolution aims to increase production without diminishing the environment's capacity or the bio-diversity for future generations. It adds to the objectives of the Green Revolution those of maintaining biological diversity and the resilience of ecosystems.

1 Resilience : capacity to return to the initial state after an external shock.

Issues and assessments

Poverty, hunger, deterioration of ecosystems

Currently, more than 700 million people live below the poverty line: three quarters of them live in rural areas. The most optimistic forecasts only predict a small decrease in this number by the year 2020.

In developing countries, 34% of the population were living in cities in 1990. By the year 2025, the figure will be up to 54%, with the total population more than doubling in the meantime.

The demand for food imports in developing countries could reach 400 million tons by the year 2025. It would take an additional 210 million tons of food to eliminate hunger.

Population growth combined with farming practices and the over-all organization of commerce and industry, the social structures and the property tax legislation can lead to the deterioration of ecosystems and their regenerative capabilities. Poverty and the institutional and economic organization also play a part in the process.

The economies of many countries are built on income from natural resources. They are extracted from the environment with no regard for the resilience of the ecosystems. The market favours this process because costs and prices do not internalise the deterioration of natural capital. Property legislation and authorities often worsen land tenure security for the poorest. In many countries, the State, guardian of renewable resources, lacks control capacities and cannot but rely on customary rights to limit access to public goods: the State ownership of resources often leads to the creation of de facto free access.

The virtues and limits of the Green Revolution

The Green Revolution is a rationale based on the command of the environment and the factors of variability. It aims to create a thorough artificialization of agricultural systems and seeks independence from climatic and biological variability.

It was mainly implemented in countries with water surpluses and high population densities—essential factors for its success in small farms. It has minimized the costs of gaining access to infrastructures, inputs and markets. After beginning with rice and wheat, it was later broadened to maize, groundnuts and cotton. The same rationale led to the intensification of herding in small farms and the development of aquaculture, also based on improving species and intensive production by bringing inputs into areas near markets.

The Green Revolution has experienced short-lived success in areas with water shortages and low population density. In such cases, and in the absence of limits

to land access, extensification seems less costly in terms of work and less risky than intensification. Though the Green Revolution was indeed technical, it was made possible by centralized incentive-based economic and institutional policies. Other factors of feasibility are the local existence of a market, high and stabilized agricultural prices, subsidies for inputs, large public services for supplying, marketing, extension and credit.

In areas where the Green Revolution achieved the success that was hoped, this very achievement has generated environmental costs not taken into account by the market: salination of soils and waterlogging in heavily irrigated areas, pollution by chemical inputs, loss of biological diversity particularly in local cultivars, decreased fertility and hydric erosion in areas ramfed agriculture.

Today, the Green Revolution has reached its limits. Not so much technically because it is still possible to improve crop varieties or input performance, but rather as a technical, institutional and economic system. We must find a new approach which doesn't only target areas of high density with water surpluses, but also agricultural areas where the Green Revolution has not taken place.

Towards a Doubly Green Revolution

Foundation and conditions of emergence

Another definition of the concept of intensification emerges. Rather than maximum yield under optimal conditions, we will be trying to achieve satisfactory yield at least economic and ecological cost under conditions of ecological and economic variability. The search for a least cost solution is consistent with the main objective of reducing poverty.

Advances in knowledge of ecology, economics, agronomy and the ethnological sciences, and progress made in modelling enable us to rethink the issue of rural development, based on the experience gained in the Green Revolution, taking advantage of what was learned, and going beyond its limits. This implies the total rethinking of rural development using a global approach and a "bottom-to-top"strategy.

Priority on social, ecological, economic and local resilience

In the Doubly Green Revolution, agriculture strives to manage an ecosystem in its entirety, including its relations with the human communities that live off it. It transforms this system irreversibly only if absolutely necessary. Priority will be given to low input techniques or the fight against risks by combining plants, and to the comprehensive management of local ecosystems, by moving away from the current dependence on a single plant such as cotton, rice or coffee.

Taking diversity and variability into account involves a "bottom-up" approach—from the local to the global level—made possible by advances in knowledge which allow us to move beyond the concept of production systems to a new concept of productive ecosystems. This change in basic concepts is necessary to take advantage of the diversity of local situations and to internalise the costs and the deterioration of "natural capital."

Internalising environmental costs

In a free-market economy, prices are not given *ex nihilo*. They are also management tools. Incorporating environmental costs in price systems is a necessary condition for the viable long-term management of ecosystems. Taking these costs into account will be all the more credible if it will be clearly perceived by local populations. Imposing taxes on resources extracted from the ecosystem can have the desired effect if it is accompanied by a turnaround in the traditional pattern of taxation: communities collect the tax, retain a percentage then forward the remainder to the State treasury.

A local tax, differentiated according to the fragility of the ecosystems, leads to a varying of prices from one market to the next which can spatially determine both demand and supply. For example, increasing the price of wood in peri-urban areas can encourage farmers to cultivate it. At the international level, only an agreement within the World Trade Organization (WTO) would allow environmental costs to be internalised into the price of export goods. Eco-labelling constitutes a necessary tool, although probably insufficient in the long-term.

The State and local institutions

The Doubly Green Revolution results in moving from an administrative rationale to one based on contracts between the State and local communities. Because of the obsession over property in economic thought, it was forgotten that customary rights can be secured and transferable in the framework of contracts with the State.

Projects have tended to ignore customary structures in order to stimulate groups of leaders who are supposed to spread innovations. The Doubly Green Revolution relies *inter alia* on customary structures, whether they are hierarchically or segmentally organized. It assumes that collective management of the access to resources and local collection of taxes are possible. It involves a major effort to ensure institutional representation at the local level. It acknowledges research and institutional actions as decisive sources of innovation. The bias against local adaptation condemns administrative development projects which bring local situations in line with general models. In their place, the Doubly Green Revolution provides for local co-manageed projects, governed by contracts between the State and local communities. The State becomes the facilitator and strategist of the development, thereby applying a principle of subsidiarity.

As concerns access to credit, in a context of liberalization, the State, as a facilitator, allows local forms of financing to become more widespread by ensuring the freedom of initiative and association. It spells out and enforces the rules of the game.

National and regional land use planning is one of the tools of this approach. The growth of cities, in a context of liberalization and elimination of administered prices, eventually generates a comparative advantage for urban hinterlands. Thinking in terms of locally viable development leads the State to play on local comparative advantages as the basis for its decisions.

- The risk is great to see regions far from cities shutting themselves off from the rest of the country and accepting subsistence, rural depopulation, or the over-exploitation of resources. In the rationale of the Doubly Green Revolution, a considerable part of research and development in these areas would be devoted to the cultivation of crops for food or industrial purposes. Comparative advantages within a country itself would be exploited in order to diversify production and markets which are economically, socially and ecologically viable.

- The construction of infrastructures, particularly those connected with transportation, is linked to development choices. A strategy based on the diversity of ecological potentials is in line with the integration of the national economy, if and only if goods can move about freely from one area to another. For this to be possible, many countries will have to continue to rely on foreign assistance.

Another approach of agricultural research

The local ecosystem is no longer just support for production, but becomes the foundation for productive choices. This change introduces more complexity into research and also provides possibilities to considerably diversify the supply of agricultural goods by utilizing genetic, specie and ecosystem diversity. The result of this could be putting into perspective the world food risk due to the small number of specie cultivated world-wide. Hence, numerous local plant and animal species could be domesticated. They have the same or better food, industrial and pedological properties as current species. Advances in research on bio-diversity must be exploited by agricultural research.

Current research defines scientific models in stations and asks farmers to test them under real life conditions.

In the Doubly Green Revolution, research begins with the farmers' knowledge base, tests and improves it, remaining in the perspective of global management of local ecosystems of which farmers are a part. Technical research models should be adapted locally and productive choices made first as a function of the capacity of the local ecosystem to be ecologically and socially resilient. These are two different ap-

proaches based on different objectives: controlling variability in the case of research and adapting *to* variability in the case of local varieties[2]. The Doubly Green Revolution calls for interdisciplinary research.

Towards viable long-term development

The approach provided by the Doubly Green Revolution takes advantage of the complexity, the diversity and the economic and social variability of ecosystems. It is rooted in research on viable long-term development which takes the greatest possible advantage of ecosystems under variable economic and social conditions without burdening its reproductive capacities. Thus the approach provided also aims to limit any irreversible effects.

The Doubly Green Revolution should be based on:

- Adapting technical models to various local situations. Local skills should be fully taken into account in scientific evaluation allowing their validation and the evaluation of their performance.
- Incorporating eating habits as a lever for crop diversification. The fact that more than 50% of the world's food is based on three plants cannot, in a context of probable climatic changes, be viable in the long-term. The Doubly Green Revolution opposes the growing homogenization in the way people eat and live around the world. Its goal is the diversification of supply and growth of local markets; globalization is not in contradiction with their diversity.

Furthermore, the Doubly Green Revolution postulates that cultural and social diversity are just as rich as biological diversity. It is not compatible with rationales based on centralized organization and uniformity. It is, however, consistent with the Universal Declaration of Human Rights, recognized legally by all the member States of the United Nations Organization. It has also been echoed in the president of the World Bank's "country focus" doctrine.

The globalization and liberalization of markets provides both benefits and risks for local producers and for the poorest:

- Benefits to the extent that they connect local markets into world markets and break down commercial monopolies;
- Risks to the extent that they result in important fluctuations in producer prices;
- Risks due to the standardization of eating habits based on a small number of species and genes.

2 In this respect, research tends to update short-cycle and water saving varieties. At the same time, local communities have chosen variable-cycle varieties as a function of the availability of water.

An alternative to the food risk and the instability of prices involves creating new, more local markets that reflect the diversification of crop and animal species, and are consistent with economic resilience and the upkeep of bio-diversity. The feasibility of diversification is more commercial than technical: it requires creating demand for supply to exist.

The globalization of markets is conducted in the context of a reduction of input subsidies and elimination of administered prices in the face of strong urban growth, the progressive impoverishment of rural zones and the deterioration of ecosystems. The Doubly Green Revolution constitutes a possible solution to the unprecedented challenge that the world now faces.

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Comments and debates

President : Saydil Moktar Toure

U. LELE: In order to stimulate the debates, I am going to try to be quite contrary. Michel Griffon presented an extremely comprehensive paper which covers a large number of areas. So it is impossible to discuss everything. I will pick out a few points.

I think the Green Revolution in Asia is only one case of a Green Revolution. I don't know if we can say that there is only one model. I don't even know what its significance is for Africa where the situations are so different from Asia. But to the extent that one tries to say "this is what happens in a Green Revolution" focusing on Asia, I as an Asian woman, hope that we learned the right lessons. We try to interpret history in a way which is meaningful for Africa, but I don't really know whether it is possible.

For the Green Revolution in Asia, we had the technologies which affected the scale economies; but in Africa for the Doubly Green Revolution, you don't. This has major implications on how research is organised.

Ironically Asia used to be described as a continent with "soft" states. But in retrospect, one would have to say that compared to what you see now in Africa, the State was very strong at least in India, Indonesia, Malaysia and the Philippine. And this so-called "soft" State had a very important role to play from the point of view of developing the political will to solve the food problem. But we don't know what it means to have political will to solve the very complex problems of the Doubly Green Revolution. We have to address the question of political will, which in the Asian context was driven by the fact that continuous shortages of food had very profound implications for

the political sustainability of the State because of urban riots and the impossibility of democracy to perform.

We have to ask ourselves what the role of the State is in terms of developing internal capacity. In that sense, Asia now is a much better place to deal with the complex problems of decentralised technologies because it has strong States which are able to put agriculture policies in place. I don't know what that means for Africa.

We have talked about the increasing role of the private sector. Again I don't know what that means in the African context empirically, because markets were very much more developed in Asia in the 1950s and 1960s. In my PhD thesis I showed how competitive the markets were in India.

Nevertheless, the State had to play an important role in helping to generate the Green Revolution. And it was not a straight "State monopoly us private sector" in the way that is being discussed now in the international community. But all over Asia, the State had to play an important role in stabilizing prices by being a last resort buyer and seller. It never was a monopolist. It was the blended balance between the public and the private sector. I don't think that Asia is going to make the kind of swings in policies that one has seen in Africa. It is much more stable. There will continue to be a strong role for the State in Asia regardless of what outsiders say.

Of course, the market role is essential in promoting development and food security, and one of the reasons of these high transportation costs that you see in Africa comes from the population and infrastructure densities. The MADIA study shows that Asia had population densities in the1970s which were similar to Nigeria in the 1980s. But India had five times the density of feeder roads, with the same level of population densities in 1970s that Nigeria had in the 1980s. Unless there is a State operating effectively at all levels, also at the local level, a State which has the capacity to build and maintain roads, it is very difficult to improve the transport network. The World Bank financed roads in Nigeria for instance, have been washed out every two or three years. I don't know what that means.

If you also look at the input-output price ratios, it is not correct to say that Asia had high prices because if anything India's prices were below international market prices before the Green Revolution. And the conditionality from the World Bank was to bring them up to the international price levels because there wasn't enough price incentive. There are a lot of comparatives studies between Asia and Africa which show that the input-output coefficients were far more favourable in Asia, but the price ratios between fertilizers and output were also much more favourable in Asia than they were in Africa. The profitability of technology doesn't exist in Africa for a

variety of reasons: markets don't function, the feeder roads are often not present, no strategic input from the State, etc.

That raises a lot of questions. If we are talking about a Doubly Green Revolution it suggests a far more organisational and knowledge intensive revolution than we have had before. When we say now that the first Green Revolution was easy to do, I desagree because I was a student when India was starving and I know how difficult it was to generate the first Green Revolution. There are several economists who worked on agricultural development in Asia who have said that if one can develop one's agriculture, a country can, in a way, do anything because developing agriculture is very complex and requires a tremendous amount of sophistication of an organisational nature and in terms of knowledge. What one achieves in achieving a high rate of agricultural growth is the work of a combination of institutions, not just Government, NGOs, or the private sector, but a blend of organisations all working as a symphony. I believe that it began to happen in Asia because of the Green Revolution. It contributed a lot to Asia organisational development that most outsiders do not even appreciate because they don't know what Asian countries were like in the 1950s.

So, thinking of Africa, I would personally learn far different lessons from the Green Revolution is experience in Asia, if there are any. Or even from the successful experiences within Africa developing of maize, cotton, tea and coffee. It has very different lessons, in any case, they go well beyond a mere distinction between what is centralized and decentralized, or private and public, or subsidied and unsubsidised, etc.

Having looked up numbers empirically, I personally feel very concerned. In the case of Africa, we have not been realistic. We are not facing the price incentive question and the technology incentive question in terms of what it means for the pace at which farmers can adopt technology. It calls for great amounts of comparative empirical research which countries in Asia benefited from a lot. Countries like India and Indonesia benefited from the comparative experiences of Taiwan and Japan. And we used to ask questions like given that these were the conditions in Taiwan and Japan, what did this mean for India, or for Indonesia? More of that needs to happen. A different type of collaboration is needed between industrial countries, developing countries and CGIAR institutions.

M. GRIFFON: I agree that it may appear contradictory to say that the State must be decentralised, giving rise to the loss of a certain number of functions, and to say that it is also necessary for the State to play a more important role, for instance as a development strategist. This is not contradictory, however. In Africa, it is precisely because the development of a Doubly Green Revolution will be complex and highly differentiated, depending on the location, that some public decisions must be decentralised and that those which fall under

the global strategy and the regulatory framework must be the State's responsibility. In many cases, this should give the State back the authority which it is tending to lose. The State is too big to be able to take care of local problems. Decentralisation is therefore unavoidable.

However, in Africa as elsewhere, the State is also becoming too small to deal with questions which increasingly can only be resolved at the international level. Most African countries cannot "avoid" coordinating their policies in view of the major economic interactions between countries. The State must therefore ensure that it has the capacity for analysis, reflection and decision which is essential to its role as an operator at the regional level and as the interface between external and domestic economies.

The Doubly Green Revolution should develop within a context of decentralisation, market development and liberalisation, but that does not mean that the State would lose its importance. I believe, on the contrary, that the State should play a determining role, and that it should not, therefore, in any way, be a "soft" or weak State. I distrust the use of the term "strong State". Where it should be unquestionably strong is in its capacity for producing, on behalf of and in agreement with society, a development strategy which allows all economic players to act in a forward-looking manner with long-term coherence.

Remember that the two African successes in the Green Revolution which Uma Lele mentioned, maize in Zimbabwe (as described by K. Eicher) and cotton in West Africa (called the White Revolution), were achieved against well-structured public institutional backgrounds with the State playing a directly operational role. However, I do not believe that the State can intervene in a similar manner in the future because, I repeat, the variety and complexity of problems to be dealt with, and above all the fact that they should be resolved at local level would prevent the State from being efficient at resolving them. At local government level, thus, the capacity for making the necessary public choices should also therefore exist in the future: the capacity for arbitrating in decisions relating to productive infrastructures (irrigated perimeters, integrated natural resource management) and service infrastructures (roads, public food security, stocks, etc.).

A. OOMEN: I would like to go, let us say, to the political level, and the need for some essential political decisions before entering the phases of policies and institutional development that are needed to start the Doubly Green Revolution. Michel Griffon gave two important political decisions: decentralization (this is beginning in some African countries) and equity. Equity would be the criterion for income distribution. In Africa, as far as I can see, it is not at all the case. So, at the political level, essential decisions need to be taken before this Doubly Green Revolution can really take off. That means that we need to find out how the political level can be addressed. The policy level follows.

Institutional development is needed as a part of the new green revolution. A lot of research needs to be done on the institutional development issue, with comparative and empirical approaches as Uma Lele said.

G. WINTER: This presentation is extremely attractive. It is not only a Doubly Green Revolution, it is, as I. Serageldin said, a Copernican revolution. What will make us undertake such a step? What will allow this turnaround to happen? By means of what development? Would such developments give rise to conflicts?

M. GRIFFON: How can a State be persuaded to accept the devolution of some of its activities on the one hand to local authorities and on the other to supranational bodies acting as arbitrators in regional problems? How can the State ensure that the economic situation is fairer and results in a reduction of poverty? Asking such questions, as A. Oomen and G. Winter have done, is to question the nature of the political game which would cause such decisions to be made.

At the risk of sounding naive, I must say that of course I do not have any simple response to this important question. I believe that several movements are underway and should converge into the institutional reforms which we are suggesting. Here again I would mention the case of Africa. In many countries the State is in crisis. A public finance crisis: tax is not anchored solidly in stable economic activities, public services are inefficient and sometimes are no longer performing due to lack of resources. A political crisis because the rules by which those who come to power are designated (constitutional rules) are not always founded on a lasting consensus. In this context, the role of local authorities may re-emerge to meet public service requirements (education, public order, rural planning decisions, and so on.). This situation should be an opportunity for governments to legislate on decentralisation, i.e. the distribution of power between the various geographical levels at which the public authorities have to act.

Another movement which is underway is the emergence of rural organisations of many types. They tend to occupy the space left vacant by public agricultural services and rural public services. These new organisations are often the first to request both decentralisation of public authorities and the existence of a solid State with which agricultural policies could be negotiated. I refer to the results of the Mèze Seminar organised by CIRAD in 1995.

Another argument is that the movement towards globalization and regionalisation of the economy makes the State the necessary seat for decisions regarding policies for adjusting the national economy towards a regional and global economy. This forces States to have an efficient capacity for analysis and strategic decision-making, without which the economic and social situation would go off course.

These institutional considerations already exist to a large extent in Africa, and numerous African researchers and intellectuals stand behind them. These ideas are becoming more widespread. They do not stop at borders. They will inspire, perhaps, the "re-founders" of democracies.

Finally, we can see that each proposal on the list we are making, has started to be implemented somewhere. Presenting them all as a coherent group gives the impression of an institutional revolution, while, presenting each proposal individually illustrates each of their operational, realistic and up to date characteristics.

However, these are just a few arguments among many. It is obvious that all of this should receive in-depth research.

G. WINTER: Does this proposed strategic development not imply, in the long run, "softer" growth which is therefore slower in comparison to what can be done in countries with intermediate or high incomes? This might risk preventing a reduction in income differences with the most advanced countries. In a world which is uniting and globalizing, would low growth rates for countries which undertake this development strategy not prove insufficient?

M. GRIFFON: The belief that taking account of the environment and of equity brings about slower growth, implies that the non-respect of the environment and equity bring about more rapid growth. Some would say this is preferable, but it is probably not sustainable. The Doubly Green Revolution seeks to promote more lasting growth. However, this hypothesis remains to be proven. One may consider, for example, that a more equitable distribution of income would encourage integration of presciously excluded social categories into the market economy, thereby contributing to growth.

There is another objective which must be targetted for growth, that is growth stability itself. We have seen many examples of highly unstable growth, for example when national agricultural income depends too exclusively on exports whose international prices are highly unstable. This instability increases financial risk and limits investment. Basing agricultural growth primarily on the correct functioning of local, national and regional markets could provide better stability, thereby permitting the country to profit from potential export income.

However, land-locked regions, regions with low ecological potential and few development initiatives will not see high growth. Here I am referring again to Africa. In these regions and countries, the Doubly Green Revolution will certainly not bring about an economic boom! It would no doubt be a good result if growth could avoid the populations concerned having to migrate towards more prosperous areas. The gain would be double: both for zones from whence migration starts, where a small amount of growth would be

restored and for reception zones, particularly the towns, because reception costs in towns increase with the size of the town. Part of the Doubly Green Revolution could thus be legitimised by internalisation of external costs due to migration.

This response is of course only partial. One cannot claim that the Doubly Green Revolution will reduce the gap between the incomes of developed countries and others. Its objectives remain above all to supply basic food in high demographic-growth countries and to eliminate poverty (3/4 of which is located in rural areas). However, in doing this, it can create the bases for rural development and more lively overall economic and social development.

L. TUBIANA: Very often in debates, State and government are confused as are the public domain and the State. We forget that local authorities can form an important part of the public sector. The proposal made redistributes roles between the State and local authorities and modifies the role of governments which are called on to play a more strategic role, at the interface between the national and international economies.

Moreover, this proposal also tends to redistribute the roles of the public and private sectors, both by suggesting privatisation and by proposing that account be taken of new public assets. This is the case for example when you consider that greater stability for agricultural prices is a public asset and that this is a legitimate area for intervention by the public sector. Moreover, the distribution of roles between the public and private sectors appears in the presentation as though it could be evolutive. This makes the principles which are normally used to liberalise the economy much less simple.

M. GRIFFON: This 'principle of mobility at the interface between the public and private sectors was shown to be necessary during the seminar on the privatisation of services to agriculture organised by the World Bank, IIAC (Inter-American Institute for Agricultural Cooperation), CIRAD and DANIDA in 1994 in San José, Costa Rica. Although one can easily identify criteria for the distribution of activities between the public and private domains, each society inherits a specific organisational culture and considers the public and private domains in its own specific ways. We must remain flexible therefore, but also keep in mind the elements within institutional theories which allow us to propose efficient distribution between the public and private sectors.

S. SNRECH: We have hardly questioned the contradiction which may arise between (laudable but exogenous) sustainability and equity objectives, and the fact that change will come from the market and from local authorities. It is true that, at least in West Africa, the closer one is to the market, the higher the average income per person. The further away one is, the more the society

operates in self-sufficiency. However, the market also creates inequalities and accelerates social differentiations. If one lowers the costs of transactions, one increases competition on markets and the producer ends up lowering production prices. This affects the salaries of farm workers, of which there are an increasing number in Africa. The question of fairness must be seen from this angle.

Moreover, to define the Doubly Green Revolution based on local factors when global parameters are permanently evolving, is to risk being extremely conservative since the perceptions of local actors always encounter difficulties in integrating global parameters and therefore in adapting to them. Local perceptions as a whole may give rise to a scarcely innovative social demand. It would therefore be preferable to see how local and central authorities can come to agreement. The existence of federated agricultural producers' organisations, capable of discussion with the State, is a means of avoiding the risk of disconnection between local and central levels.

M. GRIFFON: The market is a source of inequality where information regarding product prices and quality is asymmetric (i.e. where the odds are against one of the partners in the transaction), and geographically segmented, or where the situation is monopolistic or oligopolistic. The objective proposed is to create efficient markets which do not have these imperfections, or the least possible. Two conditions appear to be of importance: the existence of information systems for prices and transactions, which means that agricultural prices must be publicised (for example on the radio), and the existence of agricultural producers' organisations which are capable of defending incomes and having better control over supply. This would help achieve societies objective of equitable price establishment.

Local public authorities have not done enough to implement ecological viability objectives. The principle defended here is that solutions to local viability problems must be found locally within the framework of local government, and that subsidiarily, problems concerning larger areas are to be resolved by the public authorities with corresponding jurisdiction. This is both a principle of user-based management and of bottom-up subsidiarity, or from local to global. Work carried out by CIRAD on the management of resources and the environment shows that in many cases, the solution can be found in institutions and rules which can be drawn up locally. To achieve this, societies often have to be helped to establish the necessary mediation between those involved, to settle environmental or resource management problems.

Ph. LACOMBE: It seems to me that the institutional proposals presented within the framework of the Doubly Green Revolution should not be considered as a sort of ideal towards which one necessarily has to strive. One should beware of

the idea that in this domain there is a sense of history. I believe it to be wiser to consider this as an approximate framework, one which is provisional and useful for the orientations of research. This framework would gain in realism (and would maybe lose some of its attraction) if one were to underline within it the elements of contradictory relationships between those involved. One should not see it merely as an idyllic picture of pacified rural democracy and a group of public authorities operating under the subsidiarity principle of Leon XIII. Forecasters should do more than just promise paradise on earth. I believe therefore that in future one should undertake research programmes on institutions and organisations which could allow for agricultural and rural development in the direction of fairness and better management of resources and the environment. The field of research regarding organisations and the methods of coordination between actors is an extremely useful field of intervention.

M. GRIFFON: A presentation of the institutional aspects of what could be the Doubly Green Revolution requires something more like positivist rhetoric than scientific debate where ideas are kept at a distance, particularly when it is an oral exercise and one seeks to convince the audience, such as in my case. This has resulted in a rather inevitably standardised discourse that I feel demands reaction.

We should feel encouraged, as many of us are, to undertake new research into institutional issues. We should reverse the belief that development policies are only subject to macro-economic policies and incentives. Institutions and organisations play an equally important role.

Debate on orientations for research to be carried out

CONCLUSION - COMMENTS AND DEBATES

M. PETIT: I would like to make five introductory remarks before we commence our discussion on the research orientations which we must promote in order to continue what CGIAR and CIRAD have started.

First remark. I am making this comment because I have heard the following question: are there ideological presuppositions underlying the Doubly Green Revolution about which one would not wish to speak?

Personally I believe that if they exist and if they remain hidden they might hinder reflection. To be more specific, the combat against poverty has been placed at the heart of the discussions but the reasons for poverty have not been addressed. Some have said that economic development is perhaps itself the creator of poverty. We have discharged the question of social relationships which within societies may be extremely unfavourable to a scenario such as the Doubly Green Revolution.

Second remark. In this proposal preference is given to the participation of local populations as the leading actors in development. But let us not forget the internal conflicts within village societies. Participatory methods indeed have the objective of reversing the power ratio between those with knowledge (technicians, research workers, teachers) who are managers and those who are considered as ignorant (the villagers) and are managed. Is this evolution possible?

The third remark deals with the place within the Doubly Green Revolution given

to "new" biological sciences (molecular biology and biotechniques) compared with systems research. In the past, relationships between these disciplines have been difficult. Why should that change in the future?

The fourth remark bears on relationships between agronomists and ecologists. We have not dealt with this problem, but it is clear that no dialogue yet exists between the agronomic tradition and the world of scientific ecology.

The fifth remark takes up the comments made by Philippe Lacombe. The participatory methods presented to us leave a lot of room for work "procedures", that is to say the list of operations to be undertaken in order to carry out an eco-regional diagnosis, identify questions, define protocols, etc. But, more specifically, how is one to carry out this scientific research based on the principle of user participation?

Are there ideological pre-conceived ideas in the Doubly Green Revolution?

G. CONWAY: We still have a problem with this apparent contradiction between top-down and bottom-up, and centralization and decentralization. The key to this problem is the word in Michel Griffon's paper, the word subsidiarity. The principle of subsidiarity which simply says that when you take a problem, you look for the level of organization which is most appropriate to solve it. I believe that the way forward for the Doubly Green Revolution is to take the poor urban and rural in the well favoured areas as in the less favoured areas, and see what they need locally, nationally and then globally. Secondly, you take the whole set of environmental problems and again work on what level you tackle it. I believe that if you do that, you discover that participation is very important. It is not the solution to all of the problems, but it is very important. I am not an idealist, nor am I naive. But I have been working for 35 years in developing countries, and if I believe in participation it is simply because it is a pragmatic answer to many of the problems. We can use modern technology, of course, derived from genetic engineering, for example, but if we want to promote sustainable resource management and agricultural development, we have to use participatory methods. Otherwise, it doesn't work. I think that it is as simple as that!

M. PETIT: Participatory research, therefore, is not the result of ideological choice. It comes from the fact that technical progress can only be made by those for whom it is destined, which forces us to use a participatory approach.

L. TUBIANA: I would like to mention that one of the main objectives of research into institutions and development should be to propose ideas for resolving antagonisms and conflicts which may arise between actors within the Doubly Green Revolution, between users of the same joint resources, between agricultural producers and other agents, (particularly the State for prices) between the prescriptions of researchs and the objectives of producers, etc. It is a local democracy problem. In this sense, the Doubly Green Revolution does indeed have an ideological presupposition: that democracy is a prelude to development and that it must be an efficient means of arbitrating conflicts. This is a"pre-conceived idea" for which there should be no difficulty in obtaining consensus.

What themes do you see emerging from our discussions?

M. GRIFFON: During the 2020 Conference held in June 1994 in Washington Gordon Conway proposed that work should be carried out on what he called INRAM: Integrated Natural Resources and Agricultural Management. This means extending the concepts of Integrated Pest Management (IPM), and Integrated Water, Soil, Nutrient Management (IVSNM) and then integrating the two together.

In terms of plant improvement, I consider that the work carried out by CIRAD and the discussions we have had show that it is necessary to start considering "orphan" plants, i.e. plants which could diversify the food base of many countries throughout the world and which have not been the object of significant improvements.

F. CHALLOT: We often think of the Doubly Green Revolution as a group of changes involving agricultural production. However, the objective of increasing food supplies, improving food, and reducing poverty also involves everything which can be done in terms of research on food transformation and preservation and the production of new foodstuffs, based on various resources. Efforts we have made over several years are still insufficient.

B. BACHELIER: The transformation of products could indeed be a larger area of research which the Doubly Green Revolution could to some extent revive. This is an area which could bring together various research bodies into international programmes.

L. TUBIANA: I believe that the necessity for reducing price fluctuations, and therefore the question of stabilisation, is a theme which is returning to the research agenda. We have observed that international agreements do not always function satisfactorily and that price stabilisation by national public agencies is an expensive operation, but dismantling them does not resolve anything. The question must again be asked regarding the ways and means of limiting price fluctuations and the economic insecurity which they generate.

S. SNRECH: To say that agriculture must be the vehicle for development is not necessarily right. Mali, for example, has been self-sufficient for three years and even produces a slight surplus of cereals. How can that country produce more in order to have agriculture encourage other sectors? Of course the economy is becoming increasingly complex due to the division of work and that creates greater resistance. But can that be sufficient to ensure growth?

L. TUBIANA: Participatory research will involve local organisations (peasant organisations, local authorities, NGOs) and solidarity organisations such as

donor NGOs working with both local and international research. Such research can only be achieved if one first creates the conditions for fruitful discussion. A participatory approach means a partnership between the various parties. This relationship must have clear rules dealing, in particular, with the transparency of research objectives and on the nature of ownership results.

A. KOLHER: We agreed with the idea that the Doubly Green Revolution should start from the very beginning with a bottom-up approach. But I have the impression that sometimes the top-down approach comes back subreptitiously in our conversations. For example, all the information you can collect with Local Geographic Information Systems seems to allow somebody to keep control of these areas, not to favour a participative approach.

M. PETIT: I believe that the methods which have been proposed are aimed not at centralised control of the development processes, but on the contrary, at making them tools for control by local actors and in all cases tools for dialogue and participation.

M. GRIFFON: Progress must also be made in terms of the methods, models and theories of the Doubly Green Revolution. For a year, in our own modest way, we have continued studying the subject previously dealt with by the working group chaired by Gordon Conway within the framework of CGIAR. We need to take it further.

How can cooperation between the partners be organised in order to promote research into the Doubly Green Revolution?

C. NKWANYANA: Where do the regional research organisations fit in this Doubly Green Revolution? I understand that the decentralisation movement is necessary, but this movement could be contradict the regionalisation that we are promoting.

N. MBAYE: Regional research organisations should have an important part to play in the drawing up research priorities in order to ensure agreement between the national visions of member countries and the more global visions of donors. It is up to national systems (research bodies, universities, local organisations) to decide how to take account of the decentralisation of powers and the diversity of local problems. All too often national systems are nothing more than public research establishments, and have difficulty in creating a dialogue with local producers and organisations. We must start again with local problems in order to draw up national priorities and, based on these, draw up regional priorities. This principle of starting from local problems and working

up must be respected, rather than starting with exercises involving the definition of regional priorities which are then distributed between countries.

M. P. TOURÉ: I believe that national and regional food security involves recourse to varied solutions. The Doubly Green Revolution is one response, but a great deal has been said about it in terms of regions with medium to low potential. Production in high potential regions must also be increased, whilst respecting the environment and seeking a greater degree of fairness. Priorities are to be drawn up within each eco-regional programme, weighing efforts between the various types of zones.

B. BACHELIER: The research proposals for a Doubly Green Revolution lead us to think about the setting of priorities for research themes and financing. This meeting, like others, brings out various points of view on major objectives. However, this does not have much influence on research practices used by scientific bodies, whether in developing countries or in cooperating research institutes. We must go further in bringing together the points of view of those who draw up development or development aid strategies and the research workers themselves. Dialogue must be improved to ensure that research is better able to achieve its strategic re-orientations and to ensure that decision-makers take better account of the advice of research workers. This is true not only for developing countries, but also for donor countries and international research bodies.

J. LEWIS: There is clearly a problem in research priority setting. The local level participatory way in setting those priorities is not manifesting itself at the level of donor priority decision making. And yet there is enormous amount of agreement, when you go from meeting to meeting, about what constitutes participatory priority setting, how it should be done, and why it has not been done, at this point with donor resources being cut very drastically. But I suspect this is a temporary phenomenon because we have to fight with new global environmental threats for our own security. We have to give ideas to remobilise resources and researchers networks too. But as resources are scarce we have basically to fund those proposals that meet the criteria that have been presented here: ecoregional approach, participatory research, new techniques and new institutional framework.

M. PETIT: It is clear to me that there will be no international financing for research if the necessary forms of partnerships are not put into place at the various levels: between local and national partners within each country, between countries and regional bodies, and between regional bodies and bilateral and multilateral partners.

M. de VERDIÈRE: Very little has been said about governments, whereas it is they who take decisions relating to economic and environmental policies, often after discussions with international financial partners but these discussions

are often undertaken without input from research. Public decision-making is rapid, research takes rather longer. This also means that governments think in the short term and research workers in the long term. Consideration of the Doubly Green Revolution seems to be for the long term, so how can it inspire short term decisions? No doubt in order to achieve a short term perspective will requir simulation tools which project the medium and long term effects of public decisions, and thereby facilitate discussion of the various possible action hypotheses and negotiations with the various parties involved.

M. PETIT: This is an important problem. The methods proposed are participatory. They therefore mobilise local societies. This should be done in coherence with decision-makers who intervene at a more central level, and implies forward planning of research and of choices for public investment.

A. DEREVIER: Establishing a sort of count-down for the next 25 years would make it possible to define the key-programmes and the frame within which certain major problems must be resolved. This would of course be undertaken on a contractual basis with regional research organisations which are now becoming the privileged partners of international financial backers. In undertaking an exercise such as this, one must consider that national research and teaching organisations, together with agricultural and rural organisations will themselves have also changed in order to face up to the major food and environmental problems ahead. In negotiating with them today, we must therefore anticipate what they will become.

Who cares?

S. COURTOUX: Only rarely are analyses directed to the causes of poverty, very probably because this is a highly political question. Who really cares?

D. CARNEY: At the risk of being provocative, we need to make some hard decisions on how far we are prepared to go to reach the poorest people. What is the cost of reaching the poorest of the poor in those less favoured areas? How will we defend research budgets on the basis of the small rates of return we will have in those places? If we don't make an explicit choice and if we don't focus our research on the poorest we won't have any result. And in 2020 we might be sitting here talking about a triply green revolution to reach the poorest again!

M. PETIT: It is true that in our assembly we do not reply to the question "who cares"? Who must take the initiative? This is a challenge which scientists must face. It is up to them to take on this subject, to produce critical analyses of the functioning of societies which bring about the creation and maintenance of a part of the populations in a state of poverty.

Postface

In organising this seminar, CIRAD was seeking to continue the thrust given by CGIAR to the idea of a Doubly Green Revolution in the work group chaired by Gordon Conway. It is now up to others to continue with this major idea: CGIAR of course, the ESDAR unit of the World Bank, Uma Lele's GREAN initiative, the "European initiative" on agronomic research presided over by Bernard Bachelier and regional research conferences.

What have we learnt during this meeting?

In preparing this two-day debate, we tried to find the ideas which lie at the heart of the Doubly Green Revolution concept. Maybe others before us have already had similar intuitions. Since the Doubly Green Revolution demonstrates the will of societies to entertain relationships with nature so that ecosystems can be ecologically viable, and societies can be both economically viable and socially acceptable, and since the Doubly Green Revolution breaks with the Promethean myth that Nature can be totally harnessed by society, asserting that it is better to blend with than to batter it, we sought counsel from philosophers who discussed relationships between society and nature.

We encountered Sir Francis Bacon (1560-1626) who, at the end of the XVIth century, reproached monasteries (the research institutes at the time in the West) for studying nature too much in books and not enough by direct experiment. This mental attitude presupposed criticism of pat ideas and that which he termed "a purging of the intellect". That may be just what we are doing.

We found this beautiful quotation, to be a philosophical summary of this new green revolution:

"NATURA NON NISI PARENDO VINCITUR"

(Nature can only be ruled by obedience to her)

Appendix

Elements of technological prospectives for a Doubly Green Revolution

Results of the CIRAD Scientific Committees' Consultation plant improvement, crop defense, technology, economics-sociology.

Michel Griffon

The concept of a Doubly Green Revolution was designed (Conway, 1994) to face new emerging risks in food supply, poverty and the environment as identified by various forecasting studies (Rosegrant, 1995, Alexandratos, 1995, Mitchell, 1993, Griffon, 1994). We must now go beyond the concept of the Green Revolution. Although it has had positive results in terms of production on an exceptional scale, it is now encountering increasing limitations in Asia because of chemical pollution, salinity of irrigated land, levelling off of yields.

Like the Green Revolution, which was both a group of techniques and a strong economic and institutional policy, the Doubly Green Revolution will also have three major components.

The aim of this paper is to identify, and forecast the techniques involved in the Doubly Green Revolution. It has been inspired by discussions at CIRAD [1] Scientific Committee meetings in 1995.

Introductory definitions

The Doubly Green Revolution

To begin with, what is the Doubly Green Revolution? G. Conway et al. described its aims thus, "For the next three decades, it should repeat the success attained by the green revolution on a worldwide scale, in all the diversity of sites concerned. It

1 Scientific Committee of MICAP, the Mission for Plant Improvement, 6 April 1995; Scientific Committee of MIDEC, Mission for Crop Defense, 30 May 1995; meeting of Heads of Mission, 29 June 1995; Scientific Committee of MES, Economics and Sociology Mission, 30 June 1995; Scientific Committee of MITECH, Technologies Mission, 11 July 1995.

must be fair and lasting and must respect the environment. The first green revolution undertook to produce new high-yield varieties. It was only later that questions were asked regarding the benefit which poor people would obtain from them. The new revolution must overturn this logic by starting from the socio-economic demands put forward by poor households, and then seeking to identify research priorities. In substance, it names as its aims:

- food security;
- the creation of income and employment;
- the conservation of natural resources and the environment.

Specifically, this revolution is expected to improve the livelihoods of the rural poor households." (Conway et al., 1994).

With regard to the agricultural techniques, productive systems must show increased physical productivity in a way which is viable from an ecological, technical, economic and social point of view. We will also look at ecological and technical aspects of viability.

The viability of a production ecosystem can be defined as the functioning of all biological cycles in conditions where permanent renewal of its structures and its functions ensures that production potential is maintained and future production is not hindered. Evolutions in the production ecosystem may not be viable due to a deterioration process which may or may not be reversible. The extent of viability of the system's dynamics depends on the whole group of states for which the renewal regime is assured for a given period and for which there is a capacity for resistance to known risks (Griffon, 1995). Ecological viability indicators are therefore, first and foremost, indicators of renewal of the elements that make up the biological cycles which characterise production ecosystems. This concept means that the production system is not isolated from the ecosystem. It means that agronomy and zootechnics are considered as part of the more general operational ecology framework of reasoning.

The ecological environments of the Doubly Green Revolution

The Doubly Green Revolution, like the Green Revolution must have its own geography.

The areas involved in the Green Revolution are mainly areas with high potential, above all the irrigated plains of Asia but also the tropical savannah areas of Central America and Africa. It has been extended to more marginal areas from a production potential point of view, but without success; these areas include lower rainfall and hilly areas.

For the Doubly Green Revolution, geographical priorities are defined by the criteria of poverty amongst populations and environmental risks. Three major types of areas are concerned:

- extensively use
- overuse and hence
- new land areas and forest margins, where populations have a natural tendency to deplete the existing natural productivity capital; this is the case for forest margins in the humid and sub-humid tropic.
- areas where the Green Revolution has never been implemented and where the increase in food demand requires increased productivity. In a large number of cases, the problem will involve a reduction in fallowland.

This concerns the humid, sub-humid and dry tropic and the Mediterranean areas:

- areas where the Green Revolution or a similar approach has been used, with negative effects on the environment.

There are also three types of cases involving livestock production:

- Extensive rearing with non-renewal of fodder biomass, particularly in areas like the Sahel and woody-pastoral Mediterranean areas.
- Stock-rearing integrated into agriculture which is being intensified, particularly in sub-humid and dry tropical areas.
- Intensive stock rearing detrimental to the environment, particularly in peri-urban areas.

The geography of areas encouraged to produce and intensify production is determined by transport costs. In the absence of a nationally standardised prices. In areas close to consumption and storage centres, farmers and animal breeders can obtain good prices for selling their products and purchasing inputs. Areas under urban influence where intensification is the most probable, but also where one comes up against the greatest risks. On the other hand, in areas further afield products are sold at low prices and the cost of inputs is high, which motivates farmers exploit the capital of the area's fertility, with the risk of exhausting it (Ninnin, 1994).

Fertility management

Fertility means the productive potential of production ecosystems. This potential is compatible with a given domain of viability and a given regime for the renewal of structures and functions within the production ecosystem. Fertility is the result therefore of the state of viability of the area and its functioning regime. It cannot be explained merely by the stock of nutritive elements contained in the soil, since it is the product of all elements within the production ecosystem.

Different sub-domains for the management of fertility can be identified:

- soil preparation and occupation

- management of crop profile
- management of nutritive minerals
- management of organic matter
- management of competition between plants (ecophysiology)
- management of the pathosystem
- management of the working calendar.

As we shall see, in each of these areas there exists a management concept specific to the Doubly Green Revolution which, taken as a whole, creates a specific agronomical concept.

Agronomy for the Doubly Green Revolution

The Green Revolution seeks to build up a production system which replaces the existing ecosystem thus making part of the original environment artificial. The aim is tight control over the production system by seeking yields which are both the most efficient in terms of the outputs/inputs ratio and the highest possible. This means that, at the interface between the production system and the surrounding ecosystem, the pressure exerted by the latter has to be contained, for example, emissions of weed seeds, local-based parasites, water shortage and flooding. This is "nature substitution" which leads to "confrontation" in search of "containment" (Henry, 1987).

The Doubly Green Revolution seeks, on the contrary, to get the best from existing ecosystems by modifying them progressively, as and when needs arise, and respecting the laws of resources renewal. We no longer seek, to establish a simple production system as a substitute for the ecosystem, but to use the existing ecosystem which we then consider as a production ecosystem. This is a reasoning which no longer seeks to "confront and contain" but to manage nature and its way of functioning intelligently, "conniving" with it so as to "put it to work" (Henry, 1987). This has been done by numerous societies throughout history, because they did not have the means to create artificial ecosystems very rapidly and massively; such endeavours did not always meet with success however[2]. Therefore the idea of managing agricultural production in coherence with ecosystems is not new, but it can be "renewed" by adding a scientific concept.

2 One often cites for the sterilisation of the irrigated land of Mesopotamia and the desertification of areas close to the Nile, at the beginning of history and the difficulty encountered by the Romans in avoiding the desertification of the Maghreb and, more recently, ecological regression in Yucatan Maya.

This concept should have important consequences in environmental management.

Soil occupation

The principle of soil occupation responds to the necessity of combining different crops on surface areas and over time, each with different aims:

- species are required for their direct usage (production) and/or indirect usage (beneficial effect on the environment, e.g. nitrogen-fixing plants). This eliminates the need for managing the weed control problem.
- associations must be synergetic: recycling leached nutrients in lower parts of the root systems of trees, creation of shade with a favourable micro-climate effect, maintenance of a certain level of humidity, etc.
- permanent ground cover helps to limit soil erosion.

Land preparation

The installation of sole crops often requires the overall preparation ofbare land, by burning, clearing or ploughing. The modelling of plant cover, used in association with a crop, on the contrary requires selective treatment.

Soil profile management

Traditionally, tillage aimed at creating a crop profile is undertaken using instruments which:

- create or restore water retention
- facilitate root growth and penetration
- destroy causes of compaction
- plough in organic matter
- reduce weeds.

To limit artificialisation oil tillage is kept to a minimum.

Water and humidity management

In traditional irrigation methods, the principle is to secure a maximum amount of water, using the rainwater only as a supplementary source. In the opposite hypothesis, water from irrigation are meant to complement the climate.

Traditionally, in rainfed agriculture the formation of water reserves is achieved by tillage (ploughing, hoeing to break soil capillarity). Other methods may be used

to retain ground humidity: maintenance of plant cover, use of natural or artificial mulches.

Mineral fertiliser management

Priority can be given to the use of mineral fertilisers, but diversifying sources is preferable:

- recycling harvest residue, composting by products, adding composted urban waste and animal manure.
- fixing plants
- use of nitrogen and phosphorus fixing plant (see inset 1), use of new industrial fertiliser and formula: reprocessed organic fertilisers from industrial stock farms, fertilisers released according to temperature and humidity (micro-encapsulation).

INSET 1

Sources of biological nitrogen from the symbiosis of plant and micro-organism.

- Annual nitrogen-fixing leguminous plants using rhizobium: pisum, medicago, sesbania, phaseolus, anichis.
- Leguminous trees: acacia, parkinsonisa (in dry areas) using rhizobium.
- Azole in ricefields using anabaena
- Non-leguminous plants using frankia
- Sugar cane using azospirillum

- inputs in small doses in order to avoid leaching and atmospheric losses (nitrogen).
- recuperation and recycling of nutrients sinking deep into the root system.

Management of organic matter

This can be done using the traditional method of complementary inputs, but this is often expensive due to volumes to be transported. One can also progressively reconstitute organic matter by encouraging humidification; humid conditions and favourable temperatures can be obtained using mulches or agro-forestry production ecosystems.

Weed management

The trend in modernised agricultural methods is to use herbicides or mechanical hoeing. Another approach would be to avoid the advent of weeds by competition with other cultivated plants, although herbicides still have their uses.

Management of pathosystem (parasitic biotope and biocenosis)

Modern trends have, over many years, increased the number of chemical treatments used. However, much work has also been done on the search for alternative methods:

- biological methods: use of predators and parasites which are the enemies of pests;
- genetic methods: production of varieties resistant to diseases and pests;
- integrated pest management: a combination of all methods, maximum reduction of biocides (inset 4).

Management of work calendar

The main trend is towards mechanisation in order to carry out crop-related activities in the shortest possible time, and at the most opportune time. Monocultures have, moreover, created peak working times in the calendar which result in the need for mechanisation.

In systems with multi or associated cropping, the working calendar is more spread out and work on crops is less easily mechanised, although research may prove otherwise. This option is coherent with the maintenance of high numbers of farm workers in rural areas.

A concept integrated around the crop system concept

The idea of integrating, on the one hand, soil and fertility management (inset 2), and on the other, integrated pest management leads to a more global concept of integration thanks to the crops system concept and the technical itinerary concept (inset 3) his integrated management of operations can be made coherent with the local ecosystem (inset 4).

Livestock adapted to the Doubly Green Agricultural Revolution

Stock-rearing systems which strive for highly artificial production processes (foodstuffs, animals living conditions) are no longer given priority. Other stock-rearing systems are put forward which are more compatible with production ecosystems and are thereby better integrated. Numerous channels exist already: animals as part of the work-force, manure as a source of organic matter or proteinous foodstuff for fish-farms, animals as income or daily food source with the aim of offering security in the same way as using animals as a form of savings offers security for the owners. New types of low-labour intensity stock-rearing could surely be invented to use the presently wild fauna in the humid tropics (large rodents, tortoises, fish) or in the dry tropics (flightless birds).

INSET 2

Integrated soil management

1. Working the soil without endangering its biomass and structure.

Aim:	to retain as much residue as possible on the soil (mulch)
Means :	to avoid erosion

2. Recycling nutritive elements

Aim:	to avoid the loss of nutritive elements
Means:	appropriate crop rotations and successions crop associations (and agro-forestry) in order to occupy the various levels in the soil through the roots system
	mulches

3. Combating weed-control

Aims:	to reduce the use of pesticides
	to make the working calendar more flexible
Means:	mulches
	crop associations

4. Managing territorial units

Aim:	to integrate interventions within the framework of the local cultivated ecosystem
Means:	ecological works: hedges, erosion control, etc.

From: C. Piéri 1995. Soil fertility management for intensive agriculture in the humid tropics Draft and Integrated soil management for the tropics - IBRD/AGRTN, no.7, Nov. 1994

INSET 3

Crops system and technical itinerary

Crops system: all elements within the system (soil, water, nutrients cultivated plants and weeds, diseases and pests) and relationships between these elements (of the eco-systemic type) at the plot level, which the decision-maker manages using a technical itinerary.

Technical itinerary: all crop operations ordered over time.

A technical itinerary is a succession of crop operations in a given time period (types of tools, technical characteristics of operations).

New directions for plant-improvement genetics[3]

The majority of cultivated tropical plants are traditional, apart from palm oil, rubber trees and Robusta coffee plants which have been grown for approximately a century. Through widespread and age old dissemination crop varieties have become very adaptable. This adaptation has been somewhat eroded but not reversed. Overall, the use of selected varieties still remains an exception, exemplified by palm oil, rubber trees and cotton plants, whilst local varieties dominate most crops like cereals, coffee, cocoa, coconuts.

3 Summary of "Plants from yesterday, today and tomorrow". MICAP File (Knowledge and Improvement of Plants Mission), written by M. JACQUOT, CIRAD, 1995.

INSET 4

Doubly Green Revolution

Technical Principles for Rainfed Agriculture

	Trend "Green Revolution or modernisation"	**Trend "Doubly Green Revolution"**
Soil occupation	Sole crops	Associated crops
Environmental preparation	Obtention of bare land by burning, mechanical clearing, herbicides	Retaining selective plant cover
Management of crop profile	Tillage in order: - to constitute water retention capacity - to facilitate root establishment - to plough in organic matter - to reduce compaction - to form a seed bed - to reduce weeds	Minimum tillage in order to economise energy and work time
Water management	By tillage	By retaining humidity using bush cover and mulch
Fertility management	Mainly mineral additives	Diversification of sources: - recycling residues - animal manure - N and P fixing plants - recycling of nutrients migrating duply e.g. through roots system - effects of mulches and management of soil's micro-fauna - "new fertilisers": urban waste, etc.
Management of weeds	Mainly herbicides Mechanical hoeingcrops	- reduction by competition with associated weeds - herbicides used as a complement
Management of pathosystem	Mainly by biocides	- biological pest management - integrated pest management
Management of productivity	Mechanisation and motorisation to reduce intervention times	- spread of calendar in order to maintain employment - mechanisation by risk reduction
Risk management (climatic, economic)	Specialisation Search for optimum productivity	- diversification - search for an intermediate aim in varied environmental hypotheses
Management of stock-rearing in the production system	Stock-rearing not necessarily integrated into agricultural systems Search for optimum productivity	- stock-rearing integrated into agriculture e.g.: • as a work force • as a source of fertility • as an activity to optimise available working time • as a means of saving

Present selection objectives

Research for maximum yield has until now been the overriding objective. Resistance and tolerance to parasites came as a priority at a later date: coffee plant rust as from 1900, Phytophtora in pineapples in 1914 and citruses in 1920, cercosporosis in banana trees in 1940, etc. Physiological and architectural improvements were researched later on: reduced-height palm trees, dwarf rice and coffee varieties, upland rice, etc. For commercial crops, quality has always been an important criterion: length of fibre for the cotton plant, taste and presentation for citruses and fruit plants.

In order to improve knowledge of intra-and interplant variability and its spatial breakdown, research has developed polymorphism studies using biochemical and molecular markings on numerous species: rice, cane sugar, sorghum, cotton plants, cocoa plants, rubber trees, and so on. This has led to the conservation of genetic resources.

The main improvements for yield potential were obtained by the achievement of hybrid varieties and the mastering of plant multiplication (especially in woody species). Future projects are expected concerning genomic mapping, selection assisted by markers, in-vitro plant multiplication culture, haploidisation and genetic transformation.

The Doubly Green Revolution objective

The objective of the Doubly Green Definition is defined by various criteria: higher yields with lower production costs and respect for the environment in a lasting, viable manner all the while focusing on ecologies and areas where poverty is rife, by working mainly on the crops grown there. Plant breeders should include a multifactorial approach.

The supply of varieties to poor farmers in regions with limited production potential implies the use of hardy, species. In reality, these species are genetically more sophisticated as greater efficiency is required of them in a poor area, and they have to resist stress and abiotic environmental factors over which the farmer has no control. Areas concerned are numerous and varied; likewise plant solutions must be multiple.

Furthermore, research should focus on more numerous species [4]. Research's natural tendency is to work on a small number of species in order to capitalise

4 For example: cereal crops in dry areas, fonio and quinoa in the Andes, tropical fodder crops for a tropical forage, cow-peas, taros, yams, lipped-tubers, plants for new usages: marrows which produce fibres for packaging, polymer-producing potatoes, trees for pastureland and ecological objectives, sand-fixing grasses, etc.

scientific innovations upon each of them. In intensive agriculture and high-production areas where just a few high performance species are present, this approach is undoubtedly efficient. In marginal areas with vast ecological diversities and low-capacity investment power, research could be directed towards other species and in particular towards local farmers' needs. Initially the same botanic family could be retained in order to reduce development time.

Efforts to conserve of genetic diversity are essential when faced with the need for foodcrop diversification and the introduction of useful genetic properties.

Varieties to be offered should have durable stability (e.g. varieties of sorghum whose cycles vary according to water availability) and spatial stability when taking into account the vast heterogeneity in the area and even micro-heterogeneity in small plots of land. They should therefore be able to resist poly-genetical types of aggressions, and have inherent resistance against destructive abiotic factors, in particular, wind and drought (inset 5).

INSET 5

Doubly Green and Genetic Revolution

	Usual objectives	**Doubly Green Revolution Objectives**
Species		Focus on orphan plants Diversify species
Varieties	One or several species given priority	Seek multiple plant solutions Use local varieties
Criteria	Maximum yield in good climatic	Multifactorial approach conditions Yield stability in time and space when climatic conditions vary
Resistance to abiotic stress	No research	Very important objective since essentially beyond farmer's control
Transgenesis	Frequently used	Caution: dissemination occurs in areas where related species grow together
Conservation of resources	Indispensable in the long-term	Rapidly indispensable in order to restrict erosion of adapted variety

Finally, the necessity to continue research to increase food crops yields in high production areas should not be forgotten. The fact that the ever-increasing demand for food is met by these areas reduces pressure on low yield and more fragile areas.

Therefore, genetics should be simultaneously orientated in two different directions: producing varieties which respond better to high-imput intensified farming and varieties which are less demanding and more stable in their environment.

Confirmation of crop production research: integrated pest management [5]

Crop growing systems can be considered as artificial ecosystems when populations of cultivated plants are genetically standardised and thus vulnerable to parasites and pests. Damage which can be considered acceptable in the maintenance of a wild species population, is not acceptable in a commercial harvest. For these reasons intensive farming has used all available means: crop growing systems which restrict the development of related plants and pests, plant resistance, antagonistic or parasitic organisms which act on destructive weeds and plants, and the use of increasingly efficient biological and chemical products. The optimisation of these methods leads to environment-friendly integrated pest management.

Limited scope for research into new products

The use of chemicals has become widespread in most farming practices in order to ensure commercial viability. Scope limitations are: costs, eco-toxicological risks, the absence of products which can be used against bacteria and viruses, and resistance build-up in targeted organisms. Copper sulfate was first used a century ago, organo-chlorides and organo-phosphates were introduced approximately fifty years ago, and since then numerous, more efficient families of products have been created and constituted the number one research objective until 1980. At that time the major objective became the research for molecules with greater respect for the environment. Products corresponding to these objectives now exist, but their cost is often high. This can be offset by seed treatment applications. The cost and necessary duration for the development of a new product is presently estimated at approximately 400-500 MFF on average over 14 years. Because of this, research has focused on a limited number of objectives which correspond to large, present or potential markets for chemical products used in farming. A very small number of pests or tropical parasites are specifically researched (this question to be related with the objectives of the pharmaceutical industry's research programmes). A slightly higher number of the aforesaid subjects will benefit from offshoots of test results on new products concerning organisms which were not initially the research target. Furthermore, the cost of commercial approval and standardisation continuously increases due to constraints brought about by legislation. This imposes serious scope limitations (S. Axiotis, 1995) [6]

5 Summary taken from "Domaine de recherches stratégiques pour la lutte intégrée" (Strategical Research Field for Integrated Pest Management) of the Doubly Green Revolution. Report from the Scientific Committee of the Crop Defense Mission (MIDEC), prefaced by J-L Notteghem.

6 Summary taken from "Domaine de recherches stratégiques pour la lutte intégrée" (Strategical Research for Integrated Combat) of the Doubly Green Revolution. Report from the Scientific Committee of the Crop Defense Mission (MIDEC), prefaced by J-L Notteghem.

Research has for a long time been based entirely on the screening of families of synthetic products. Development of research into molecular aspects of parasitic pathogeny is contributing to new knowledge. This approach which has been widely developed for viruses and bacteria, presently has numerous applications on fungi (Lebrun M.H., 1995) [7] As far as fungi are concerned, results are expected relating to the identification of new fungicide targets and the possibility of using new genes to increase plant resistance.

In 1990, more than 500 species of insects were reported as resistant to insecticides. This type of resistance often leads to the use of higher dosages and more frequent applications. Assessment of resistance levels is a necessary first step in the management of populations of parasites. The growth in mechanisms of resistance now even entails genes and their very functions: studies carried out on Culex pipiens (Pasteur N., 1995) [8]. The example of Culex, pipiens complex mosquitoes raises new study prospects for resistant populations. Mutants rarely exist, but they spread to numerous territories due to migration, encouraged by human activities and selection pressures which favoured the multiplication of resistant populations leading to their expansion around the world. These studies find obvious applications in the management of arthropods, fungi and weeds which are resistant to pesticides. Similar research is useful in the management of resistance to all products used, whether chemical or biological (Bacillus thuringiensis).

The use of genetic resistance

There is tremendous similarity between the studies on the dynamics of populations resistant to pesticides and those of populations of parasites or pests which defy plant resistance. Analysis of populations of phytopathogenes is necessary for designing strategies using resistant varieties. Analysis of the genetic structures of these populations shows frequent links with pathogeny variations (M. Peterschmitt, 1995) [9]:

Variability of pathogeny in phytopathogenic viruses. Analysis and prospects - E. Roumen [10]: Analysis of the European population of M. grisea and the management of resistance genes. Studies carried out on epidemics in present crop growing systems indicate a need to avoid the accumulation of resistant genes in a plant. The latter method can lead to an increase in the frequency of virulent strains and increased persistency whilst methods permitting temporal or spatial associations of resistance genes lead to long-lasting management of effectiveness (C. Pope, 1995 [11] Analysis of populations of phytopathogenic fungi and management of resistance genes).

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7 MIDEC conference: M. H. Lebrun: Pathogenic capacity of fungi, molecular analysis of pathogeny genes in M. grisea

8 MIDEC conference: N. Pasteur: Factors controlling the development of resistance to insecticides

9 MIDEC conference: M. Peterschmitt: Phytopathogenic viruses. Analyses and prospects.

10 MIDEC conference: E. Roumen: Analysis of the European population of M. grisea and management of resistance genes

11 MIDEC conference: C. Pope : Analysis of phytopathogenic fungi populations and management of resistance genes

These studies require powerful population analysis tools with high-detection capacities. Immunoenzymatic tests are now applied to a great number of organisms, mainly viruses and bacteria. The generalisation of their use in tropical areas is a current objective. Molecular tools give access to the greater specificity and sensitivity needed to understand the cycles of viral and bacterial diseases. Research to find these tools is under way in numerous laboratories (P. Rott, 1995 [12] : Diagnosis of bacterial diseases, prospects of using molecular methods).

The management of resistance genes can be achieved through improving knowledge concerning these genes. The identification of a new gene and its assessment represents considerable work. Further, methods which give access to in-depth knowledge of them are now being developped. Research is centred on both resistance genes and corresponding virulence genes which are associated in a gene-to-gene relationship. The results of resistance gene cloning have recently met with success, and some ten genes are presently being cloned (M. Dron, 1995[13]: Monogenic resistances to plant diseases). We also expect gene mapping to lead to simplified identification methods for new resistance genes. These studies will help in the development of strategies for use in monogenic resistance. An analysis of links between molecular markers and resistance could facilitate the assessment of the role of genomic segments in partial resistance (QTL) (C. Lanaud, 1995 [14] : Mapping of resistance genes in tropical perennial plants - B. Clerget, 1995 [15]: Corn resistance to tropical viroses). The major objective of these studies is undoubtedly to acquire further knowledge of genetical control over the aforementioned resistances. If the use of the marker method becomes simpler, thereby lowering its price, the usage of QTL in plant improvement could become general practice.

The possibility of genetic transformation of a growing number of species introduces the possibility of creating cultivars with built in resistance genes. This strategy has been most widely developed for viral resistance; now attempts are being made to include resistance against phytopathogenic bacteria and fungi. In the latter case, published results are not conclusive, but the diversity of studies should rapidly lead us to promising research channels. As far as viruses are concerned, following the viral protein envelope approach, one may now observe many experimental methods, are being tested including the use of other viral genes, and animal genes with antibodies against plant viruses. (T. Candresse, 1995 [16]: Strategies to produce transgenic plants resistant to viruses). There are two scope limitations involved here: biological risks, especially the possible increase in recombinant viruses, and the sidestepping of new resistances. Discussions concerning strategies for the use of transgenic resistant plants are vital, and fit in with those on the use of monogenic

12 MIDEC conference: P. Rott: Diagnosis of bacterial diseases, prospects and uses for molecular methods
13 MIDEC conference: M. Dron: Monogenic resistances to plant diseases
14 MIDEC conference: C. Lanraud : Mapping of resistance genes in perennial tropical plants
15 MIDEC conference: B. Clerget: Corn resistance to tropical viroses
16 MIDEC conference: T. Candresse: Strategies to produce transgenic plants resistant to viruses

plant resistances, the analysis of pathogenic and pest populations, and weeds in crops. These are probably the most important fields of research for the years ahead.

Upstream and downstream agricultural techniques

The objectives of the Doubly Green Revolution are not just aimed at the crop-stock farming stage in the food chain. Agricultural supplies are also affected: agricultural machinery, fertiliser production, plant health treatments rural equipment. Similarly the stabilisation, conservation and transformation of products must not be forgotten. These upstream and downstream sectors contribute to increasing the availability of food and diversifying the agricultural supply as well as creating jobs in rural areas and limiting environmental damage.

The mechanisation of agricultural activities

Intercropping systems (including agro-forestry) cannot be mechanised in the same way as mono-crop systems. Work in rows remains the main research channel through which work productivity can be increased, but crop associations probably do not permit the use of high-powered traction machinery. In the same way as machinery exists to work on gradients and narrow roads of land in mountainous farming machines also exist to cater to the ageing farming population (Japan). This leads us to believe that specifically adapted machinery for inter cropping could be developed. Mechanisation would have to include small, easy to handle machines. Since farming interventions are staggered throughout the year high-powered traction machinery (which do the job quickly and are needed for peak time chores should be avoided). The example of manual low-volume sprays for cotton plants illustrates the possibility of mechanising certain selected functions. Hauling remains manual and is acceptable where low volumes are involved. Spraying is electric in order to achieve the correct size of micro-drops. Important research efforts should be made towards transport within the farm as this is often a major obstacle when bringing in inputs and harvests. The mechanisation of seeding under mulch is also a major objective.

Upstream Agriculture

The Doubly Green Revolution could change the nature of demand towards other agricultural supply sectors: fertilisers, land developement companies.

As far as fertilisers are concerned, the need for organic matter should increase. In addition to internal on-farm resources, other sources should be explored. This is the case in Japan where research is underway to produce low weight organic fertilisers. Animal manure from large industrial stock-breeders could be dehydrated

using hydraulic pressure, liquid slurry could be transformed into solid fertiliser and the remaining liquid de-polluted ("transfilter" process) for irrigation and methane gas could be produced for energy. Considerable commercialisation networks for these offshoots exist already in Europe (Truong Binh 1944). Compost made from urban waste emanating from large tropical towns also constitutes a tremendous source of fertiliser.

As far as nitrogenous mineral fertilisers are concerned, there is presently no industrial alternative which would give low-cost local production. For phosphates, solubilisation using sulphuric acid phosphates with low water solubility constitutes an important breakthrough Africa.

Innovations in packaging pesticides so as to restrict skin-contact are extremely welcome: self-spreading granules in self-dissolving sachets for paddy-fields, "jumbo" size granules, drop-by drop-insecticides.

Rural development companies (dams, irrigated plots, anti-erosion works) are generally in charge of entire operations. New systems are presently emerging. Local populations are becoming involved in manual labour combined with machinery (sub-soilers, bulldozers, trucks) for work that cannot be done dealt with manually. The work of local populations is an investment subsidised with food-aid.

Reducing post-harvest losses

Losses are often estimated to be as high as 10% of the harvest. This can be due to bad harvesting and poor biological stabilisation of the product. Other causes are attacks from diseases and pests during storage, poor transformation, commercialisation, and at times consumer handling.

Local knowledge concerning storage has been ignored too often in the past. This valuable information should be heeded as it is based on years of experience.

On this basis, research could be undertaken in different fields to improve:

- drying and stabilisation of cereals and oil-proteinous grain in humid tropical conditions,
- the protection of perishable food stocks,
- the conservation of products obtained by grinding grain,
- drying, dehydration and conservation of fruit.

The transformation of products by small companies

In poor and landlocked areas, developing the local economy by diversifying transformation activities contributes to job security. These small transformation units

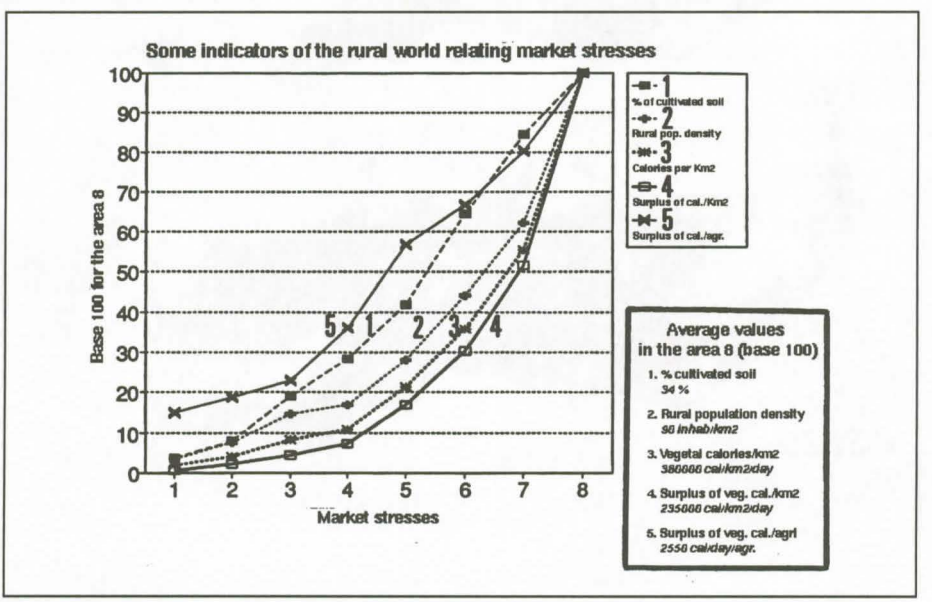
serve the local market and include grain mills and oil presses which also produce cake and animal feed, etc.

In the future new techniques could be offered to local companies: dehydration-impregnation by osmotic immersion, canning, edible or biologically degradable packaging, bread making with manioc starch, new fermented foods for sauces.

New agricultural productions for industry: energy, fuel, timber.

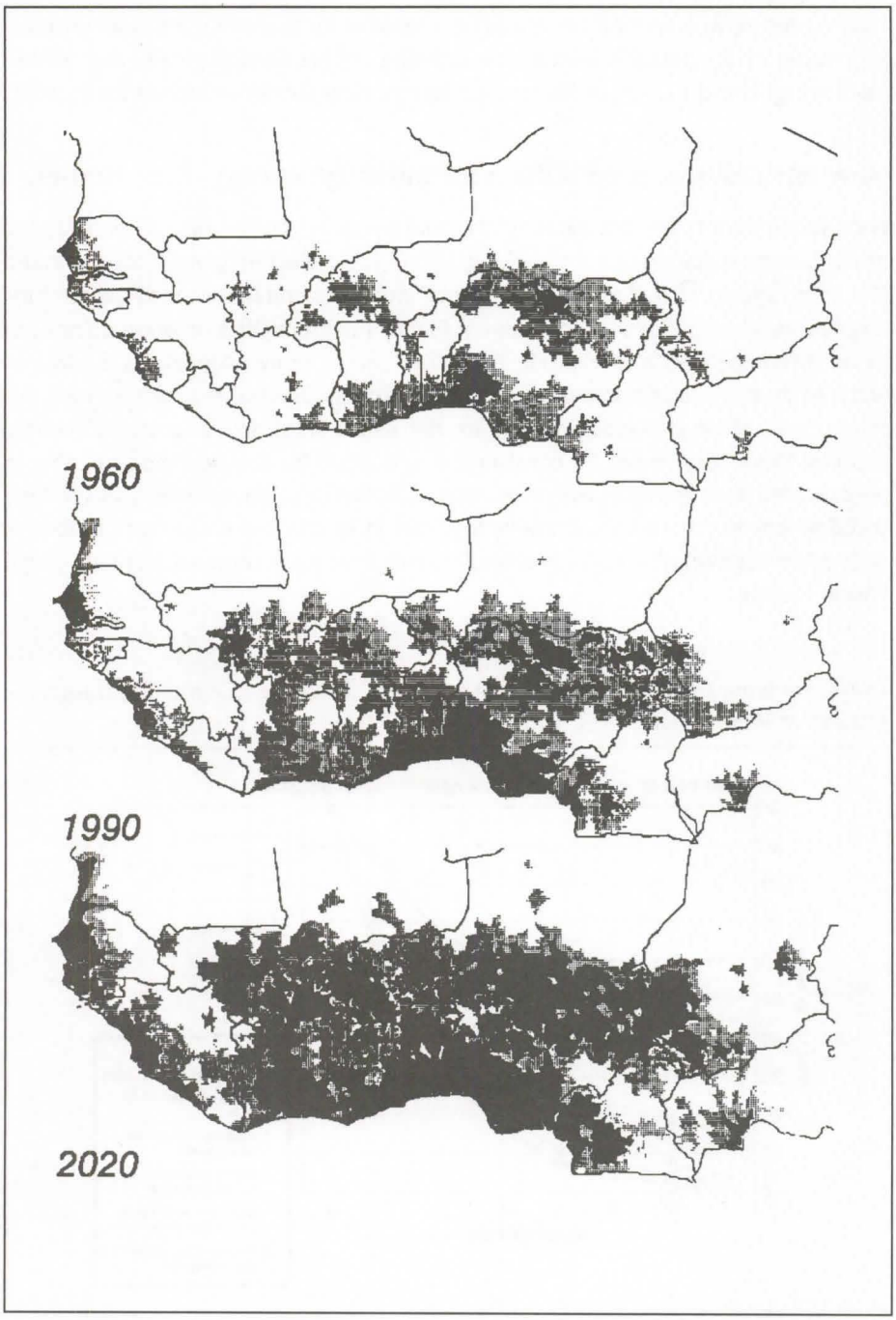
Food requirements are not the only essential needs which increase as populations grow. Energy requirements for cooking, lighting and electricity are also important. The same applies to fuel for transport, small industries and for producing electricity. Biomass production for the extraction of fuel or the production of wood do not necessarily compete with food production. They can be in synergy within the framework of cropping systems (agro-forestry, oil-proteinous seed production with different uses). These non food products are also useful in the diversification of income sources. Producing timber for construction and wood for fuel become profitable in areas where trees are rare. The production of biofuel (alcohol, ethanol, gas, oil, fuel) could be envisaged as an alternative to diesel in landlocked areas (remote towns, poor infrastructure) or in areas situated far away from main commercial roads (small Pacific islands).

Graph showing the influence of the proximity of towns upon agricultural intensification in West Africa.



Source: Ninnin B. (1994). Economic Geography of West Africa ; Markets, Settlement patterns, Agriculture, Roads: Modelling for 1960-1990 - OECD-WALTPS, Paris.

Map showing the influence of the proximity of towns upon the motivation to produce in West Africa (Market tension).



Source: Ninnin B. (1994). Economic Geography of West Africa; Markets, Settlement patterns, Agriculture, Roads: Modelling for 1960-1990 - OECD-WALTPS, Paris.

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Economic and institutional aspects of the Doubly Green Revolution

Michel Griffon, Jacques Weber

The Doubly Green Revolution aims to increase agricultural production to meet societies requirements. This will be achieved mainly by increasing yields (Rosegrant et al., 1995). The new revolution must also avoid harm to the environment and ensure viable management of natural resources and bio-diversity, i.e. without jeopardising the development capacity of future generations. Last, its principal objective is to reduce poverty.

This is, therefore, more than just a technological revolution aimed at integrating ecological concepts into agriculture. The Doubly Green Revolution also calls for large-scale economic and institutional changes in order to meet future risks associated with growth in agriculture and related sectors.

The fight against hunger is not yet over

"The fight against hunger is as old as the world. It is not yet over" (Malassis, 1994). To feed themselves, societies undergoing demographic expansion have to choose between using more new land or intensifying exploitation of land already in use with intensification there is always a risk of harming the ecosystem's capacity for renewal and production. The maintenance and increase of this capacity for renewal requires new technology and knowledge. Therefore, agricultural history is a succession of evolutions and revolutions both techniques and in the patterns of social organisation connected to these techniques. Not all have been successful. The ancient civilisations of Mesopotamia and of the Yucatan in Central America, for example, were not able to prevent damage to land fertility. On the other hand, in many developing countries, there are agricultural systems which use ecosystems intensively and which enable societies with high-density populations to subsist.

However, hand in hand with population increase goes a constant increase in demands made on ecosystems, to a greater or lesser extent. In most tropical countries, the fast population growth and high population figures force societies to accelerate

the use of ecosystems in conditions which, in many cases, do not ensure their long-term viability.

In comparison with earlier agricultural history, the end of the twentieth century is marked by two radically new phenomena: the acceleration in the pressure of use of productive areas and the massive spread of this phenomenon in tropical and Mediterranean countries. The result is a number of risks, especially the most well-known recurrent risk of food shortages. This is associated with the risk of environmental damage.

The risks, as we see them today

After three decades of development aid, including structural adjustment, the world still numbers between 300 million and one billion people affected by food deficiencies. Around 150 million children have weights deficiencies and around half a million women suffer from anaemia due to iron deficiency. It is estimated that around 20 million children are born with low birth weights and 40 million suffer from vitamin A deficiency. Finally, one thousand million have iodine deficiency (Von Braun et al., 1992). This situation reveals, first and foremost, the incapacity of societies to reduce poverty and food insecurity, particularly in the poorest populations. Since any of the poor are agricultural and livestock producers, they are the first to suffer from food production deficiencies. Research studies indicate an impending increase in food shortages over the coming three decades, mainly in Sub-Saharan Africa, South Asia and South-East Asia (Alexandratos, 1995; Mitchell and Ingco, 1993; Rosegrant et al., 1995).

The least pessimistic forecasts show, for 2010, a demand for imports of 160 million tons from developing countries. This demand could reach 400 million by 2025, to which 210 million should be added in order to eradicate hunger and malnutrition. Total supply will doubtless not exceed 355 million tonnes resulting in large scale deficit and therefore no significant reduction in the number of malnourished people (Conway, 1994). Food shortage is a real risk.

The second risk is of an environmental nature. Population increases will inevitably result in the conquest of new land, and experience shows that in many cases this gives rise to regressive ecological evolution: rapid reduction in forest cover, changes in water patterns resulting in land desiccation, loss of fertility and biological diversity. In areas which have already been cultivated, population growth results in a reduction of fallow land which can also lead to decreases in fertility if not compensated by nutrient imputs. In both cases, there is no renewal of natural resources and of the productive capacity of ecosystems. Ecological risk is therefore high.

Finally, risks connected to rapid economic globalisation should be taken into account, particularly with regard to the agricultural economy. One cannot be certain that all the food-deficient countries will dispose of the necessary foreign currency to pay for their food imports. In some countries, moreover, one can no longer be

certain that basic food production can survive competition from lower prices imports. The risk of increased dependency and food insecurity cannot be excluded.

When faced with these risks, the Green Revolution, banking on earlier successes may still be seen as a satisfactory solution. Indeed, it aims to intensify land exploitation by using inputs to substantially increase yields quickly, and thus reduce food deficits. It also aims to create a modern agricultural system which can be economically competitive. But, in reality, the Green Revolution is no longer a sufficient response.

Limitations of the Green Revolution

The Green Revolution was born in the 1960s when it was observed that famine risk in Asia was recurrent, due to demographic increases and the limitations of existing production systems. It was believed that this food risk could lead greater social and political troubles. In order to avoid a spiralling situation of this sort, resources were devoted to developing technology for rapid yield increases. Now thirty years later, production levels are very high throughout irrigated Asia.

The Green Revolution is often presented as being the result of the introduction of high-yield wheat and rice varieties, together with high-level fertilisation and plant health protection techniques. Contrary to general belief, the Green Revolution involves mainly small agricultural holdings, which represent almost the whole of agriculture in Asia. The concept was spontaneously widened to include corn, particularly in Mexico and Zimbabwe (Eicher, 1995). It could also be enlarged to include other crops such as groundnuts and cotton which are not food crops but are grown on vast areas of small-scale agricultural holdings. In the case of cotton, one speaks of the White Revolution (Fok, 1995) and for rapeseed the Yellow Revolution (Dorin, 1994). Intensification of stock-farming on small-scale farms also comes under a similar approach.

In Asia the Green Revolution was also benefited from economic policies based on high incentives: agricultural prices which were both high and stable (at least throughout a period of start-up and installation of the technical change), subsidies for the purchase of fertilizers and plant health products, purchasing facilities thanks to the creation of large public departments for extension services, the provision of inputs, the sale of agricultural products and credit facilities for the purchase of inputs and equipment. The Green Revolution was therefore simultaneously a technical revolution (selected plant varieties and inputs), an economic policy (incentives) and an institutional policy (public departments).

In many cases, the Revolution saw only fleeting successes, either because the techniques proposed were unsuitable, or because prices were not lastingly motivating, or because producers had used the incentives provided to extend the land area used (increase in surface areas) rather than intensifying. This was notably the case in sub-Saharan Africa.

In place where a long-term intensification process established itself, the Green Revolution encountered other problems, mainly negative external effects: salinity, and waterlogging in intensively irrigated areas, pollution due to chemical inputs, decrease in fertility and erosion in rainfed agriculture. More recently, structural adjustment policies have contributed to

reducting incentives to use fertilizers and plant health products. In India, price increases for fertilizers provide part of the explanation for the reduction, and for yield stagnation (Pingali, 1994). Similarly, in Senegal, in the same situation, cotton producers have reduced their purchases of fertilizers and have attempted to compensate for yieldergo income losses by an increase in the surface areas given over to cotton, with a risk of rapid deterioration in fertility (Anon, 1993). The Green Revolution is therefore encountering limitations in its application at the same time as population increases are requiring continued performance improvements.

How can Green Revolution limitations be surpassed?

The challenge is not only to continue with the Green Revolution by resolving the problems which it is encountering in environmental terms; it is also to increase production in the many regions where no Green Revolution has taken place and where increasing demands are being put on ecological areas. In these areas, the risk of ecological damage is added to the food risk. Deforestation, followed by the installation on forest margins of annual crops or pasture land, can give rise to irreversible damage to water regimes and to the biological diversity of species. In savanna areas, shorter fallow periods, without investments for the renewal of fertility, may provoke erosion. In dry areas, risks of desertification may be amplified by unsuitable agricultural practices. Finally, densely populated areas where societies have for a long time been managing productive ecosystems in a viable manner, are not exempt from problems related to ecological fragility.

Therefore, most agriculture when heavily pressured by society to produce more, whether or not they have experienced the Green Revolution, are confronted to a greater or lesser degree with problems of renewal of fertility, natural resources, ecosystems and biological diversity. These agricultures must therefore find intensification methods which are viable in ecological, economic and social terms. All these necessary technical, ecological, economic and social changes taken have been together termed as the Doubly Green Revolution (Conway et al., 1994).

The conceptual bases of the Doubly Green Revolution

As indicated by the CGIAR Panel, entrusted in 1994 with proposing long-term directions for agronomic research, we must produce more without damaging the environment, nor violating the principles of social justice. The Doubly Green Revolution

therefore responds to the objectives of sustainable development, and the principle of equity is one of its main components.

The production objective

Food production is the principal objective. But food is not the sole aim of agriculture. Agriculture is the source of numerous industrial products, some of which respond to basic requirements which increase along with populations: textiles, timber, biomass, for fuel, recreation. Reflection must also be continued with regard to the future of agriculture and of the ecosystems cultivated for food purposes only, particularly as energy requirements could constitute an increasingly important outlet for agricultural production. Account must also be taken of the whole food subsector, manufacturing and upstream industries, support services and, more generally, all activities which relate to the development of rural areas.

Important gains in productivity are possible within the food chain, from agricultural production to the consumer's plate: reductions in harvest and storage losses (the largest source), improvements in technical efficiency for artisanal and industrial processing, reductions in wastage at the consumer level. However, it is still expected that future needs can best be met by growth in agricultural production.

Growth in production may be achieved by expanding cultivated surface areas and by increasing yields, through intensified exploitation of cultivated ecosystems. In each region, the relative contribution to growth resulting from increases in surface areas and yields will depend on available land, its productivity potential, the cost of access to resources and the cost of exploitation. It will also depend on the potential for intensification of cultivated areas and on the cost of intensification. Producer preferences for extending surface areas rather than intensifying production means that the cost of access to new areas probably constitutes a key variable in the choice between the two methods of production growth. Access costs are closely connected to the existence and state of transport infrastructures which depend almost entirely on public policies. The latter are very different from one country to another, and future developments may be extremely contrasted.

Conclusions as to the geography of agricultural development, based on past trends indicate that the proximity of large consumption centres contributes to lowering transport and transaction[1] costs, to increasing incomes of hinterland producers and therefore to an incentive to increase their production and yields since agricultural areas are limited (Von Thunnen,1994; Ninnin, 1994). It is in the hinterland of cities that incentives to intensify should be the strongest, particularly since pan-territorial[2] pricing mechanisms have disappeared under the effects of liberalisation policies.

1 Transaction costs: set of costs which are necessary for a given exchange: costs of information on partners and prices, costs of negociation, eventually costs of contracts design, control costs.
2 Pan-territorial price: single price in force across a national territory

One also observes that rapid deforestation on forest margins is often the result of a race to appropriate land rather than the result of a migration of populations arriving from high-density areas. In this latter case, the progression of the pioneer front is slower. Therefore, where governments do not incite populations to penetrate heavily forested areas through infrastructure and tax incentives, or indirectly by means of forestry exploitation, the progression of cultivated agricultural areas is slower because access costs are higher. Correspondingly, incentives to intensify in hinterland areas are greater.

There is, therefore, a geography to the Doubly Green Revolution, which is mainly centred on areas of intensification and pioneer areas.

The objective of respecting the environment

Intensification areas experience the same problems encountered in high-imput farming, in industrialised countries and in areas involved in the Green Revolution: pollution of ground water tables, rivers and estuaries by nitrates, phosphates and chemical residues; flora inversion (invasion of herbicide-resistant weeds), drug-resistant pests, varietal sensitivity new diseases, salinity of badly-drained land, reduction in the diversity of ecosystems and countrysides. High-density stock rearing, particularly in peri-urban farms, also gives rise to large scale pollution. These external effects result in important social costs. Techniques used by the Doubly Green Revolution must "internalise" these negative effects.

In areas on the forest margins, the Revolution must limit risks of irreversible ecological damage. In zones with low potential, it should also limit risks of deterioration.

Overall, the respect of the environment, within the framework of the Doubly Green Revolution, prioritises fertility renewal, the functioning of ecosystems without affecting the potential for genetic diversity, and the avoidance of irreversible ecological regression.

The objective of social justice and equity

It is not enough for development to be ecologically viable, it must also be something humanly bearable[3], i.e. something which is socially acceptable. This brings us back to the idea that wealth distribution, income and possibilities of access to higher living standards must be socially equitable. Beyond certain levels of inequality and wealth concentration, social consensus for development is not possible. It depends on the representations which the various social categories make of one another.

3 As indicated by J. Poly in 1982, one of the major future objectives of agronomic research is to propose development which is both viable and "liveable", something which "modern" agriculture has not succeeded in achieving.

Equity has therefore been put to the fore as one of the principles within the Doubly Green Revolution. A society which recognises the principle of equity is a society ready to recognise the rights of everyone. In extremely non-egalitarian societies, equity must lead public authorities to work using "positive discrimination" in favour of the poorest citizens. The level of acceptance of inequalities, or of the mechanisms of social redistribution therefore depends on the individual society. This makes it difficult to define a criterion for universal equity. The only principle of universal law that could be used comes from the Universal Declaration of Human Rights. It implies equality of rights, and therefore more equity in the distribution of wealth.

The respect of the environment and the principle of equity in fact go back to a more general principle: the principle of sustainable or viable development, which is itself based on the concept of viability.

The concept of viability

The viability theory (Aubin, 1994) describes living systems - and therefore ecosystems and societies - as being the result of different variables such as variables of state and regulation (*regulons*). In the systems' leeway in evolution is restricted by viability constraints. If these viability limitations are violated, the system exits from the domain of viability, goes into crisis and may evolve according to irreversible trajectories leading to states which may or may not be viable. This case excluded, systems may be viable and stable or undergo stationary evolution or tend towards greater viability.

The concept of viability applies to the domain of agriculture and to agricultural and rural development (Griffon, 1995). For ecosystems, viability implies functioning of all biological cycles in conditions that provide for continuous renewal of structures and functions, and in such a way that production potential is maintained and future production is not affected. The functioning of cycles results in balances which may be in equilibrium or in surplus. These balances concern resources and their uses for elements which define the state of the physical environment and those which define economic and social situations. The domain of viability of an ecological, economic and social dynamic is, thus, characterised being the whole range of states for which the renewal regime is assured for a given period of time. The group of viability states as a whole shows, moreover, the property of resilience[4] to known exogenous hazards.

The system is viable if, at any given time, its state allows for later renewal, i.e. if its evolution does not result in a tendency to leave the domain of viability and to enter into more or less irreversible deterioration trajectories. The pressure of requirements

4 Resilience: capacity of returning to initial state after external shock.

which the growth in human populations exerts on ecosystems is therefore continually calling the viability regime into question. The concept of viable development must therefore integrate the necessity of transforming systems (under the exogenous constraint of having to increase production) in such a way as to continually enlarge the domain of viability and its possibilities for future development, whilst preserving a capacity for resilience to known exogenous hazards.

This representation of systems as a group of uses-resources cycles and balances does not allow for the inclusion of "social acceptability". However, one may attempt to define indicators with regard to key areas for equity within the agricultural field: indicators of capital concentration (*capitalis*), be it in terms of real estate, finance or equipments, or conditions of access to natural resources, land, credit, information, education (*capabilis*), and indicators of knowledge as capital (*capacitas*) on which depends the possibility for accumulating the other forms of capital. Viable development must encourage relative redistribution over time of these three types of capital to the advantage of those who lack them more, and this must be undertaken in a socially acceptable manner. Let us note that any redistribution process is doomed from the outset if the parties to it reason in terms of acquired positions, in a no-win situation, whereas, on the contrary, it may succeed if one negotiates in terms of future positions, jointly sought, within the framework of an out-to-win situation.

This representation of ecological-economical systems does not prefer ecological viability over social viability, or vice versa. No hierarchy is established in the creation of viable states. Viability is not divided into sub-groups according to scientific disciplines.

Application of the concept of viability in the Doubly Green Revolution

The variable which provides the essential direction to the evolution of systems is demography. The need to extract more products from ecosystems is the element which determines the necessity of introducing replacement elements which will ensure the renewal of cycles and of modifying the ecosystem's structures (agricultural plans) in order to maintain their viability. Another key variable is poverty which may cause populations to damage ecosystems because they have no other choice in order to survive. Here, poverty should be understood as being insufficient capital, insufficient access to resources and production factors and insufficient knowledge (see above).

The Doubly Green Revolution must therefore guarantee ecological viability (viable intensification of exploitation of the ecosystem) together with the economic and social viability of the societies concerned (eradication of poverty). One must therefore endeavour to define techniques which will ensure ecological viability (Picard, 1995; Griffon, 1995).

Agricultural techniques in the Doubly Green Revolution come under a new concept of agricultural optimisation. Normally speaking, modern agriculture consists of setting up production systems which are partial substitutes to the ecosystem which harbours them. This substitution triggers feed-back effects on the production system: pressure of earth land-based parasites, sole crops invaded by weeds, etc. These effects bring about the introduction of corrective techniques, e.g pesticides, herbicides, to contain external pressures on the production system. Similarly, since the land had been transformed, nutrient cycles, water cycles and cycles relating to soil structures are modified. The maintenance of viable functioning of the soil-crop system necessitates recourse to fertilizers, tillage and, if required, modifications to water flows (irrigation, drainage). The use of inputs (fertilizers, chemicals, irrigation water) may give rise, in turn, to pollution and other external effects.

In the Doubly Green Revolution, agriculture aims to manage the ecosystem as a whole and not to transform it except where necessary and therefore, only very gradually. A production system no longer replaces an ecosystem; the ecosystem is exploited using its own law of functioning. In theory, one is therefore no longer subject to the negative effects of a barrier between the production system and the overall ecosystem. And external effects no longer exist, since they are internalised by the method. Where fertility was insufficient, fertilizers were added; now, on the contrary, better management of nutrient cycles will be sought. Where crops were attacked by pests, chemical products were used; now, one will seek to limit treatment within the framework of an integrated pest management (IPM) and by the use of plants' genetic resistance. Formerly weeds were destroyed in order to protect pure crops; now through inter-cropping it should be possible to obtain better ground coverage and water retention, thereby increasing fertility by means of selected plants. Agriculture was mechanised for better control over cropping operations, but this required more energy. Now emphasis is on saving energy, particularly by means of minimum tillage. Gradually, IPM is being achieved in the form of integrated management of soil fertility, water, diseases, weeds, etc. One could use the term total or holistic management. Simultaneously, therefore, the "production system" is leading to the "production ecosystem concept".

Contrary to the Green Revolution, which was interested in areas with high productivity potential, the Doubly Green Revolution should be interested in all areas where the risk of non-viability exists. It should therefore be interested in a great variety of situations, particularly those which are ecologically fragile. It will be interested both in areas where the intensification of the use of the ecosystem has become inevitable and where it has not taken place, in areas where the movement towards intensification has started but where it is not viable, and lastly in high--imput Green Revolution areas where a different intensification concept needs to be used.

Repercussions on directions taken in agronomic, genetic and crop protection research are enormous. In agronomy, important research should be concentrated on

integrated fertility management, particularly in rainfed agriculture, and in systems which are marginal in agronomic terms. In genetics, the accent will be put on the adaptation of plants to more difficult environments. Rather than maximum yield in optimum conditions, one will seek to obtain satisfactory yields in environmental conditions which are subject to variability. One will also concentrate on "orphan plants" and on animal species which have as yet seen very little improvement. In terms of crop protection, IPM, which is nothing new, has a real place within this new logic. The holistic concept for the management of soil fertility, water, the pathosystem, breeding, the work calendar and the necessity of finding operational methods for production ecosystems with sufficient resilience, will lead researchers to strong interdisciplinarity which will include reasoning from economic and institutional angles.

The institutional conditions for a Doubly Green Revolution

The diversity of agricultural situations and the complexity of the phenomena involved prevent any centralised concept for public management of a policy to encourage and accompany a Doubly Green Revolution. Faced with this diversity and complexity, in a context of liberalisation which, in addition, deprives it of power, the State is no longer in a position to conceive and manage the transformations which wherever needed. State decentralisation, its de-concentration, privatisation of activities which are not at all public, and the internal liberalisation of the economy are conditions which are necessary for viable national and local development. The Doubly Green Revolution presupposes deep institutional changes. In many countries, they are already happening and indicate the direction to be taken by economic evolution after the structural adjustment phase.

The State : from implementor to facilitator

In terms of agricultural and rural development, in many countries the State initiates the development which it carries out and manages. By means of administrative bodies, state-owned companies and projects, the State has become all-powerful and has left very little room for the civil society, which has often sought refuge in activities seen as being informal since they resist fiscal influence and State.

The Green Revolution and attempts at Green Revolution have often been undertaken in a centralised context: national equipment policies for irrigation, public services for the provision of credit and for trading, public extension services, price regulations, etc. These centralised public mechanisms were coherent with the fact that the Green Revolution was a standard model which could be used by a very large number of producers.

Such a centralised system functions properly and has functioned in countries where a centralised administrative culture has been in existence for a very long time - in Asia for example - and where, over time, the authorities have been able to create a real expertise. However, in spite of these successes, there is a permanent risk, and malfunctions are inevitable. Centralised decisions can never be based on sufficient information since the cost of data collection is high. They may therefore be in contradiction with general interest at a local level. For this reason, centralised public decisions which have local consequences can rarely be optimal. Moreover, the existence of empowered State officials who lack precise capacity for social control, creates conditions that favour corruption and abuse of power.

Everything combines to suggest that a top-down conception of the State should be replaced by a bottom-up conception, where the State creates the frameworks for action, defines incentives, and facilitates initiatives, but is no longer implementor or manager. Initial application would involve the fuctioning of the agricultural marketing.

Facilitating market functioning

Internal liberalisation of economies must lead to less State participation in trade, and to fewer obstacles to the circulation of goods, particularly local taxation, whether the result of legal corruption. Liberalisation measures usually take their inspiration from the model of perfect competition which functions under the following hypotheses: trading partners identify each other, prices are always transparent and inter-connected markets form a complete system.

In many developing countries the reality is very different. Market channels are geographically segmented, e.g. cereal crops; it is often difficult to get surpluses to the areas in deficit. Prices are not transparent, and States are frequently opposed to their publication. Information is therefore asymmetric and detrimental to the interests of agricultural producers. The various markets are poorly inter-connected, e.g. African cereal markets are rarely connected to rural financial markets or to livestock markets. The fact that fluctuations in one market are not therefore absorbed by an other market, contributes to maintaining unstable prices and income levels. Finally, the State or private agents are often in a monopoly situation.

State withdrawal from trade and price setting, will not be sufficient to create a satisfactory situation *ipso facto*. Some necessary preliminary conditions must be in place to ensure correct functioning of the markets. One of these conditions is the existence of a public information system, that is accessible to all concerning markets and prices. Producers, intermediaries, manufacturers and consumers will then have information concerning the distribution of margins among agents within a sector, and on individual expectations.

Price-fixing conditions must be equitable, i.e. powerpull on markets must not be asymmetric. Confrontation between fragmented supply from agricultural produ-

cers and oligopsonic demand from traders or processing companies has always been to the detriment of the former. Where producers are organised in order to negotiate transactions collectively, the market force becomes more equitable. The same is true of consumers, with their segmented structure, when faced with the oligopolistic supply from trade and food industries.

Competition for shares of margins within a sector may create group situations which are not necessarily optimum, particularly where there is asymmetry of information coupled with adversity among agents. In this case, the risk of market failure is increased. Here the loss of earnings can be much greater than coordination costs.

Recent examples show that information on prices and markets widely distributed amongst agents within the sector, efficient representation of the interests of the various agents, and consultation - in many cases negotiation - between them can greatly reduce market risks, bring about synergy of expectations and, last, considerably reduce transaction costs (Bourgeois, 1995).

Improvements in market functioning, their fluidity and efficiency are often obtained through coordination between agents: public information systems and interprofessional bodies for coordination and negotiation. These types of coordination are sometimes called quaternary services to the economy, because they allow other sectors to perform more efficiently, particularly the services sector. Quaternary transaction costs are inferior to the transaction costs for market imperfections and to the loss of earnings which these imperfections cause the economy as a whole.

It should also be recalled that the reduction in transaction costs is facilitated by the construction of transport and communications infrastructures which connect complementary economic areas. In every country there is always a geography of transport infrastructures which is often characterised by export (sometimes import) requirement and by the need for communication between towns and their hinterland. The rapid increase in urban populations will create an increased requirement for transport, on the one hand between towns and their hinterland, and on the other hand between the towns themselves. This evolution should lead to integrating areas of urban economic influence into single economic areas and thereby progressively limit unitary transport costs. This phenomenon should be of particular importance to spontaneous regional integration in West Africa (Snrech, 1994).

An institutional policy which aims to improve market functioning, other than being highly encouraged by an appropriate transport and communications network, must be based, *inter al...*, on the distribution of public information on markets and prices, the structuring of producers into organisations to defend their own interests, and the existence of bodies for consultation and mediation between all concerned. This is only possible if business laws and conventional forms of trade guarantee satisfactory conditions for agents to exercise their activity. Actually the improvement of market efficiency implies progressive implementation of agree-

ments[5] which is only possible in a climate of mutual loyalty. Further more the State, except for its natural role as a provider of public goods and services, must limit its role to that of facilitator.

What can be public, what can be private

Is privatisation necessary for the creation of an institutional environment which is favourable for the Doubly Green Revolution? This question concerns above all the services activities in the agricultural sector. It is asked because of the poor performances in numerous countries in supply, commercialisation and credit services, and in terms of quality of service. It should be noted, however, that these services have not always been poor and that in the past they have kept with important technical and economic changes in agriculture and continue to do so. The necessity for economic stabilisation plans and for State financial equilibria leads to the question, for the future, of what should be public and what should be private, what are the various possible types of public and private bodies and, lastly, what are the conditions for the correct functioning of these services.

First, it may be considered that there are enough satisfactory criteria to establish the public or private vocation of a service (Petit, 1994). A service can be public when it has the nature of a public good (indivisibility of consumption, non-restrictive access), when it produces external effects, and when by its very nature it could be the object of fraud with regard to quality. One may also consider that it may be of public interest to help create a service by allocating public funds to its start-up phase (infant industry). All of these criteria allow for correct distinction between services of a public or private nature. However, the public nature of a service does not necessarily imply that the entity which performs it be public. For example a vaccination in the public interest may be performed by private veterinarians surgeons. Reciprocally, a state-owned company may, in some cases, offer private services; this is the case with research. The public aspect of a service may also be reduced to a simple role of inspection (for example, quality control of seeds, seed production being private), or regulation (setting vaccination schedule). In all, it is not always easy to draw the line between public and private, particularly if one takes account of another criterion, that of the institutional culture of societies.

Some societies have an institutional culture which provides public services with a great deal of efficiency, particularly those where the State has long experience in organisation. In this context, it is not shocking to retain certain services within the public domain, where quality and efficiency are equivalent with the private sector. Similarly, some societies have a highly deficient institutional entrepreneurial culture since it has only recently come into being. In this context, it is difficult to pri-

5 Agreements: relations between partners in economic exchanges based on routines or traditions or customs in trading practices, mutual expectations, near-contracts or more formal contracts.

vatise some services rapidly. The rate of transfer must be dictated by the obligation not to break market circuits unless credible private alternatives can take over. It takes time to ensure that efficient, stable commercial networks exist and that competition can exist without difficulty.

The main problem is access to credit. The disappearance in many countries of agricultural banks or projects which ensured credit functions, is leaving producers to face traders with limited lending potential and high interest rates. Intermediary costs charged in banks in the formal sector are so high that loans are only extended to the richest, most credit worthy farmers. Various forms of credit are appearing little by little to meet the needs of small-scale producers: local banks with very low intermediary costs and mutual credit organisms. These new credit institutions are not unlike institutional bodies found in rural financial markets: mutual guarantees in tontines, family-backed guarantees, local loans guaranteed by trust between lender and borrower.

For the credit function, as in all other areas of service to agriculture where traders cannot offer a sufficient level of service, producers have to create groupings to take on these functions. However, an authentic cooperative, mutualist sector can emerge if it is free at direct State authority. This movement would doubtless be all the more forceful if an association to defend producers' interests emerged in parallel to it. For this to be possible, States must allow freedom of association and freedom of collective, private economic initiative.

Decentralising ownership and management of natural resources

In many countries, particularly in Africa, the State owns the natural resources: land, forests, water, fauna. In fact, State ownership coexists with customary law which offers wide scope for joint ownership, whilst a nascent market for land and land tenure may lead to private appropriation of land.

In reality State ownership creates free access situations. Costs of administrative control are far too high for the State to ensure easily that regulations are respected. This results in free access, particularly with regard to the cutting down of forests, the use of pasture land or access to non-colonised forests. Moreover, the few guards paid by the State are of course readily corruptible by those seeking access to natural resources.

As a reaction to this situation, the idea of privatising land areas was born, based on the principle that it is in the owner's interest to apply viable, durable management techniques. This proposal mainly concerns Africa. Many examples taken in areas on the forest margin contradict this principle. They show, on the contrary, that owners "race to take land", in order to affirm their right of ownership, and that their agricultural and stock rearing methodes cause rapid deterioration of environmental fertility. Moreover, in Africa, rapid generalisation of private ownership in areas where many farmers live on small areas of land may cause the latter to sell their

rights to large scale operators. In this way very large estates were constituted during periods of drought in the Sahel. If such a movement was extended, it would create the basis for a high degree of social injustice similar to that which results from major disparities existing in Latin America between the *latifundio* and the *minifundio*. Is it necessary to recall that these inequalities are the source of the enormous rural poverty on that continent, numerous social disturbances and important limitations to economic growth due to the large number of insolvent households?

There is without doubt no need to privatise. Customary law is applied to agricultural land and rangelands in the major part of Africa. As these are common resources, there are institutions which regulate access. They do not ensure full long-term viability of environments and societies, but they constitute the basis for a entitlement which no public reformer can afford to ignore.

States do not have the capacity for correctly managing local resources, and since the latter can be more easily managed locally, States are decentralising ownership to the local level. Initiatives of this kind have been made in numerous countries. In Niger, for example, forests are managed by villages which, thus control tree felling, collect taxes and assign this income to forestry renewal (Bertrand, 1944).

Decentralisation follows the principle that resources can be better managed by their closest users than by distant public decision-makers. Being close to the resources, they have more precise and fuller information regarding the state of resources. They are in a better position to make decisions. The resources are owned by them jointly, and in their position as direct users they have an interest in managing them in a viable manner (Weber and Reveret, 1993; Bertrand, 1995)

Generalisation of this principle results in the definition of subsidiarity. This principle states that resources are to be managed by the public authority which has the geographical jurisdiction closest to that of the resource involved. Thus, for example, forests used by villages are managed on a village-scale, forest areas which govern the hydrology of several areas must be managed at the level of an equivalent public authority, and forests of national interest must be managed by the State.

In conclusion, rather than State ownership, it is without doubt customary law which must be the source of future laws since it provides for decentralised management using the principle of subsidiarity as applied to public natural resources.

Poor producers' access to resources

Impoverished producers have limited access to natural resources, credits, inputs and education.

Local public ownership or common ownership can provide a guarantee of access to natural resources (agricultural land, grazing lands, wild animals, irrigation water), for the poorest members of the community. However, where the regime of individual ownership is established, it is very difficult for society's poor to become owners or to

increase the size of their farms except by migrating, and where possible, occupying land on the pioneer fronts. In other cases, reduction of rural poverty involves redistribution of land to the poorest members of society. Such redistribution often gives rise to conflict. In many cases (particularly in Latin America) it has led to increased political instability and civil war. Land reform therefore is no longer the order of the day. It will, however, be indispensable to return to it, but methods of redistribution must be found which do not cause major social upheavals but which could have expeditiously positive economic effects. To achieve this, land reform must be permanent mechanisms and not simply splirts of hyperactivity. It must allow for very long term financing for the purchase of land which is little used, and resale under highly concessional terms to small scale owners. Fresh capital and incentives could encourage sellers to invest in growth sectors.

However, in many cases poverty in rural areas is such that people do not automatically have the capacity to modify their farming practices, to progress from subsistence farming to market-oriented production, and to learn new methods. The transfer of land should be combined with a transfer of knowledge and the capacity to obtain access to credit, markets and information.

Decentralisation of public choices

Decentralising the State is not just transferring part of public ownership of natural resources to local authorities. It is also the transferring management of certain locally important public services. Here again, reference must be made to the principle of subsidiarity.

Many locally useful public services can have a strong effect on agriculture: education, health, the legal system and the police (for minor transgressions of local regulations). Decentralisation must be used to bring these services closer to users and citizens. The state education system in rural areas, for example, could be better directed towards specifically local requirements in the fields of ecological planning, economics and civic affairs.

However, most decentralisation must be focused on public choices. Each village must be in a position to collect local taxes and to assign the income to local uses of general interest. The amount of tax and the choice of allocations is everyone's concern; these are public choices. The method of choosing must therefore be such that public interest is respected, whether it involves direct consultation or a decision delegated to a representative, whether it involves a decision-making method by majority vote or by consensus. The existence of a local public decision implies the existence of a democratic local decision-making processes. Democracy is one of the main conditions for ensuring that decisions are fair.

Local decisions can play an important role in terms of economic development and environmental protection. They involve road and communications infrastructures and thus the structure of costs and prices. They involve water supply lines

and purification (which play an important role in health) and production infrastructure (irrigation, landscaping such as terraces, hedges, reforestation, and erosion and desertification control, etc), which play a decisive role in local production, food security for households and villages and local employment.

The end of administrative projects

Agricultural and rural development projects have always been relatively large and have brought together a group of service functions: supply, trade, credit, extension work, construction of equipment, etc. Integrated projects added numerous other functions: the construction of infrastructure, education, health, etc. In any case, these operations contributed to the creation of public authorities at local level. The power of these bodies came from the State and since the State had large powers, nothing obliged them to negotiate with populations. Decisions were generally imposed. Projects concentrated initiatives and some time later sought the participation of the main beneficiaries. They therefore often replaced local capacity for decision-making and initiative, and at times forced local populations into a kind of active or passive resistance. Project managers were often badly informed and did not understand the complex realities surrounding their actions. By offering simple ideas to complex environments, these projects only rarely achieved their objectives or generated lasting results all, the more so since they were short lived by nature, and depended on international aid which is, by definition, unsystematic. These types of projects therefore are not permanent institutions.

Since micro-projects obviously have far less ambition they more readily give over control to local populations. However, the same shortcomings are possible, although with a lesser degree of influence. NGOs which perform micro-projects may also act as substitutes for local authorities by means of extensive intervention in decision-making processes. They become lasting economic operators and accumulate powerful functions to the detriment of existing public authorities, whereas NGOs are supposed to be private bodies.

Clarification is therefore necessary. A new institutional landscape may be born of liberalisation and privatisation on the one hand, and decentralisation on the other. Private operators working in associations should distinguish themselves clearly from public bodies and from municipal management. These bodies should be in a position to take the initiative necessary for managing local development.

This does not exclude projects, however. It is useful to introduce a player to facilitate local transformation: encourage private agents to take initiatives (investment, organisation), inform local players of the consequences of their decisions, and encourage them to be permanently aware of the criteria of equity and viable management of resources, facilitate the functioning of trade and markets by mediation between the various' interests, facilitate achievement of a consensus in public choices, and mediation between interests, systematically propose a view of the future in or-

der to enlighten today's decisions. Projects could play the role of quaternary institutions, that contribute to efficiency in economic and social functioning. Thus, projects would form part of the trend towards liberalisation and decentralisation, and could remain timebound.

Local knowledge as a basis for change

Like projects, research has also for a long time been organised according to the "top-down" theory. The Green Revolution in principle made all agricultural transformation depend on one scientific innovation - high yield varieties - together with related technology. This inevitably encouraged the notion of the transfer of technical knowledge between research centres and producers placed in the position of users. Extension services aimed to persuade producers, and projects supplied the necessary support services and motivations.

The problem-oriented approach of the Doubly Green Revolution reverses the situation. It will be applied to areas and conditions which are extremely varied from an ecological, economic and institutional point of view. It will be impossible for researchers to develop only one mode. Each situation would have to be analyzed in all its ecological and social complexity in order to propose solutions which will also be complex and lengthy to develop if the usual sequence was to be used: on station tests, followed by multi-location tests and then on-farm trials before the extension phase. We have long known (Tourte, 1978; Benoit-Cattin, 1984) that this process is only suitable for specific situations.

In order to save time in the diagnosis and development of solutions, research must be based on local ecological knowledge. This knowledge, reinterpreted by researchers, will enable rapid access to a detailed knowledge of the resilience and other properties of the production ecosystem, the constraints under which producer decisions are made and the steps in intensification to which they intend to give priority. On these bases, research has hypotheses to teston station or with producers in their fields. If farmers are involved with experimentation they are all the more interested by the results. Research can accompany trends in local evolution, bring out related risks, anticipate future problems and questions, and seek new methods. This way of operating redefines the linkages of disciplines in agronomic research by connecting them to specific local situations. This presupposes an approach which one may qualify as eco-regional (Manichon, 1995) and which may be inspired by the eco-regional idea put forward by the CGIAR.

The economic conditions for a Doubly Green Revolution

Most of the poorest in society live from farming and are therefore the first ones to be concerned by under-nourishment. One should therefore start from the principle that

agricultural policies must deal with the problem of rural poverty. Access to land, access to credit and access to knowledge cannot be resolved by institutional measures alone. Economic support measures are also required. The same is true for the adoption of the techniques involved in the Doubly Green Revolution. Economic motivations must encourage intensification in the use of production ecosystems without hindering their capacity for renewal. This is the definition of a multi-facetted agricultural policy for which the internal coherence and coherence with economic and social development policies must be specified.

From extensive to intensive growth

In many countries with abundant natural resources (thick forests, oil, ores), economic growth is encouraged by exploitation of natural capital. Exports feed the State's budget which, through spending, creates the impetus for the functioning of trade. The same growth phenomenon created out of the consumption of resources is observed in rural areas where agriculture is developing extensively and projects are pouring in money which only generates a small amount of capital creation. Extensive growth results in the use of resources for consumption only; very little is saved, and none is invested (Naudet, 1994). In reality, natural capital is consumed. In agriculture there is loss of fertility, loss of forests, loss of water resources; other sectors, lose stocks of fossil resources.

On the other hand, intensive growth is characterised by a preference for saving and investment in comparison with consumption, resulting in capital creation and productivity increase. The State stimulates economic functioning more by means of investment flows than by the distribution of income.

Intensified farming can be traced back to limitations in natural capital that force societies to produce more, on smaller areas, with less labour, and less chance of producing a surplus. In agriculture, societies with fast growing populations, limited by geographical space, have invested their workforce in transforming the environment and making it more productive. The stock of physical capital and knowledge acquired for the transformation of ecosystems can be considerable: irrigated terrace farming, complex mixed wood and pasture—"bocage" in french—ecosystems, agro-forestry ecosystems, etc.

In many developing countries, the switch to intensive growth has become inescapable. When a State has very large debts, can no longer rely on external capital flows and must greatly reduce its current spending, it becomes unable to support extensive growth. This is the result of economic stabilisation policies. Moreover, structural adjustment, by changing relative prices, reduces household consumption, particularly the consumption of imported products. Consumption then falls back on domestically produced goods, thereby stimulating local production. This switch to intensive growth only occurs if recourse to extensive growth has become impossible or if one can dissuade its promoters. For example, currency devaluation

may relaunch massive timber exports and encourage candidates seeking land to colonise forests. They will do this faster if they do not have the means to control weeds because of high prices for herbicides, and will inevitably be forced to compensate by moving on and clearing other areas more quickly. Depending on its political will, the State can assist or arrest this trend (Castella, 1993).

Structural adjustment, by increasing the price of fertilizers, can also cause producers to reduce amounts used and to compensate for decreases in yields by an increase in the surface area cultivated or by a decrease in fallow land, which risks dangerously hindering fertility reproduction. Intensification is inescapable. The alternative is a decrease in fertility, which may be irreversible. Ratios between agricultural prices and fertilizer prices may, in this case, play a determining role in making production ecosystem viable again.

Finally, in addition to stabilisation and adjustment policies, liberalisation policies also affect intensive growth dynamics. This is the case in particular with the disappearance of administered pan-territorial prices establish by geographical compensation mechanisms. Producers located close to trading areas benefit from advantageous transport costs for their inputs and can sell their production at attractive prices. On the other hand, those who are further away are penalised by transport costs for their inputs and have to sell their output at lower prices. The discontinuation of pan-territorial prices concentrates supply and collection areas. Those in the first category will be motivated to intensify production: the market makes demands on them, and margins enable them to invest in order to improve land productivity since there is no other choice for increasing production due to dense land occupation. There will therefore be more intensive growth in peri-urban zones and the hinterland close to market and consumption centres. Producers further away have to continue extensive farming or, seek ways of reducing transport costs and for transaction costs, or work more to compensate for loss of income.

Overall, the State must remain highly attentive to changes in producer behaviour during periods of changing relative prices. Although in certain cases economic policies encourage farmers to go in the direction of more intensive growth, and although this movement is inescapable due to the limitation of wealth issuing from natural resources, it is nonetheless true that the poorest producers and those the furthest away from markets will spontaneously tend to draw on natural capital reserves.

A system of food supply at reduced costs

The main dilemma faced by agricultural and food pricing policies is that the problem of the rural poor and the urban poor has to be dealt with at the same time . Therefore high prices paid to farmers have to be reconciled with low prices charged to urban consumers.

Providing poor urban consumers with tickets to buy food at low cost is a common solution. It has the advantage of alleviating the problem over agricultural prices. However, it also has disadvantages. Firstly, the supply of tickets is a source of illicit trading and corruption. Further, this solution can only be envisaged if the number of urban poor is limited, which is rarely the case. Moreover, it is useful for both growth and development to have food prices lowered so that some urban income is spent on other consumer goods thereby stimulating growth in other sectors and providing urban employment. Treating poor farmers with "positive discrimination" also raises major problems when the poor are in contact with others. It is easier when exceptional measures cover whole areas. However currently, in the majority of countries, the State can no longer intervene in pricing policies since it is no longer a buyer. Aid must be limited to inputs (subsidies), credit (bonuses) or to the work force (distribution of food for work). This aid may also, however, lead to trafficking and corruption. Moreover, ensuring that agricultural prices are high in order to guarantee sufficient income for the poorest producers would present the major disadvantage of limiting diversification of urban consumption and the possible boom in other sectors. In addition, since most of town-dwellers' incomes go to food, high prices for food would maintain a high price for work, thereby limiting the competitiveness of manufactured goods for export (Delgado, 1991). On the other hand, high agricultural prices may, in some circumstances, bring about an accumulation of capital in the countryside and growth in productivity and employment (Mellor, 1993).

The conclusion of these observations is that State intervention, which aims to influence prices by applying special measures to certain populations, must be limited as far as possible, even though such intervention often remains inevitable and indispensable. The result is that two classically opposing development strategies are possible. One is based on a rapid transformation of the economy in the urban environment, by means of a low-cost urban work force and urban consumers who have potentially diversified spending power. This strategy is facilitated by low food prices and therefore limited agricultural prices. It tends to maintain poverty in the countryside and to condemn part of the rural population to remain excluded from growth, except by migrating to towns, (rural exodus), or migrating towards more prosperous agricultural regions. The other is based on agricultural growth made possible by satisfactory agricultural prices, creating growth in productivity and therefore, in the longer term, a decrease in food prices, which in turn will facilitate economic diversification. This strategy encourages rural populations to seek prosperity in the countryside and not to swell the mass of insolvent urban populations. This second strategy is often favoured by agricultural development economists.

Every developing country encounters this pricing dilemma and has to make choices between the two methods of capital accumulation, urban and rural. Decisions made depend of course on local conditions. Indeed, the success of the "rural method" depends fundamentally on the response capacity of producers to price ri-

ses, in terms of agricultural productivity and ecological viability. In some cases, price increases may bring about a stagnation in production, particularly if the market functions badly due to a lack of possibilities for purchasing consumer goods (Berthelemy, 1989), or if the market economy is in its infancy, and producers do not seek greater gains once assured of food security through their own production. In this case, prices have no effect on the growth of productivity. Conversely, it may happen that a slow decrease in prices causes producers to improve productivity in order to maintain their production and income levels. This was the case, for example, over a long period with cotton production in Mali. As for the "urban method", this is fundamentally based on the existence of real dynamics for industrial diversification and diversification within consumption. If these dynamics do not exist, the relative lowering labour costs permitted by the lowering of food prices will have no effect other than drawing ever more rural poor into towns. The urban economy, in particular the informal economy, has a real capacity for receiving poor people (Cour, 1994) but it is limited because it depends principally on the extensive growth of the urban economy. Furthermore urban growth entails major costs: the marginal cost of urban equipment increases with its size [6] together with social costs linked to environmental damage.

There is a method of reasoning which partially reconciles the two strategic directions mentioned above. First, account should be taken of the fact that growth linked urbanisation is greatly limited by economic stabilisation policies which, in many countries should curb the rural exodus and benefit agricultural and rural development. It should also be recalled that many poor people are from rural areas and failure to deal with rural poverty potentially adds to urban poverty. Hence the main objective of a policy which modifies the terms of trade between the rural and the urban worlds, particularly an agricultural and food pricing policy, must firstly benefit agricultural prices and then ensure that food prices do not increase too sharply. This leads one to seek maximum reduction in transport costs by means of an infrastructure policy, and in transaction costs by means of an institutional policy which facilitates market functioning (see above). In view of producer behaviour with regard to prices, agricultural prices must provide a signal that encourages farmers to produce more and to increase productivity by facilitating investments financed by own resources. The difference between urban food prices and what the urban poor can afford to pay for their food could then be covered by food-aid.

In regions where agriculture is marginal, where populations seek to survive rather than produce for the market, prices have no signalling effect. To stem the rural exodus and capitalise gradually on production capacities (rehabilitation of damaged environments, construction of infrastructure...), will require social transfers and aid programmes. Recourse to the work force being absolutely necessary, food-aid distri-

6 Ancey, 1991.Cit. in: L'avenir de l'agriculture dans les pays du Sahel.Actes du XI séminaire d'économie et sociologie.Montpellier, CIRAD-Mission d'Economie et Sociologie.

bution in return for work has, in this context, an important economic effect: capital formation, production and productivity growth.

Agricultural growth based on national and regional demand

Food requirements, one the one hand, and consumption increases population growth on the other, make up the basis for growth in the agricultural sector. The increase in the urban/rural population ratio implies increased production per rural worker and contributes to the creation of lasting agricultural growth. Food supply improvements for the poorest in society also contribute to increased demand (on condition that adequate policies are implemented). Last, diversification in food demand, a major phenomenon in Asia and noteworthy in Africa, constitutes another stimulating factor.

Food demands made on agriculture, livestock production, and other indirect rural productions have repercussions on the productive system in terms of effects created by demands. These linkages must be maintained through appropriate economic stimulations (Delgado, 1994).

The first linkage involves employment. Doubly Green Revolution techniques require work and create new activities: the use of supplementary fertilizers and chemicals increases the demand for inputs; in peri-urban areas, the demand for urban waste compost should see an increase, as should demands for products issued from livestock production wastes. These activities create employment and generate income.

Other activities may also be stimulated. The demand for meat, particularly white meat (poultry and pork) should encourage the offer from non-land based animal farms close to towns, which will then increase their demand for animal feed, particularly cereals roots and tubers (cassava) and oilseed-protein cakes (groundnut, cotton, soya). The price of local grain crops therefore must not be too high for it to be used in animal feed. The demand for fodder grains entering into competition with the demand for food cereals should also be avoided as this brings about an increase in price. When cereals, roots, tubers and cakes supply the local meat production sector, the multiplying effect of the demand for meat on agricultural demand is extremely large. This is one of the main growth impetus links in agriculture.

Meat may also come from draft animals, confined stock (pork, mutton, goat) and grazing herds (beef, mutton, goat). The creation of a sustained supply of beef would be facilitated by better interconnections between the cereals market, rural financial markets and the livestock market (see above). In the Sahel area of Africa, animals are often seen more as a means of saving than as productive capital. They are often sold during intercrap periods when food is difficult to obtain, thereby pushing sales prices down whereas recourse to borrowing, which would be easier if savings were in monetary form, would be more appropriate. Animals could then have an essen-

tially productive role. Food requirements for fish are rarely satisfied. Fish farming should also be stimulated by demand and play a dynamic role in the cereals supply. Lastly, new breeds may perhaps see the light of day, such as the agouti in Africa, deer, or flightless birds.

Food diversification also includes pulses and leguminous plants, fresh vegetables and fruit. Production is mainly peri-urban but may also involve supply areas which are further away (for example onions from Niger are sold in the Golf of Guinea and cowpeas from the Sahel in Nigeria).

Food processing can participate efficiently in the reduction of product preparation costs. Increasingly in Africa, large processing plants can be replaced by village units: rice and oil mills, cotton ginning. New techniques can be offered for drying and dehydrating products. It is in these processing sectors, just like at the farm level, that important efforts can be made to limit storage losses.

New productions may also be envisaged, e.g. energy from biomass, methane from harvest waste, alcohol and above all biomass fuel oils in relatively landlocked areas where they are competitive with imported oil products. In some countries, agriculture also becomes a source of timber, using fast growing species to meet large urban demand.

Giving incentives to economic agents who open new product markets is an essential element of support for internal growth in the food sector. Incentives of an institutional nature are also needed to sustain the new trade channels.

Growth in the agricultural and food sectors, together with connected activities must not be considered on the urban scale only, although towns are the mainspring of diversification in their hinterland or the country as a whole. Very often, the geography of communications determines regional market areas which extend beyond national borders and as the seat of productive dynamism, is pur growth through increased demand. For this reason, and in view of the effects of comparative regional advantages, customs tariffs should encourage the regional integration of agricultural markets.

Internal growth should not be thwarted by imports

In Africa and the Middle East, competition between national production and imports mainly involve cereals. The substitution of wheat or rice for local cereals, tubers and plantain in African consumption is gradually unifying the market for starch products. Therefore, over many years, cereal exports subsidised by the European Union and the United States were able to compete with African products. Competition also exists for meat in these regions, to which the European Union has, for a long time, exported low-grade quarters of red meat and towl carcases, and in Asia where meat production is increasing but remains insufficient to cope with demand. Competition also exists increasingly among oilseed crops due to interchangeability of oils used in

cooking. Therefore, soya production in Asia is in competition with imports from the American continent.

The protection of national production is therefore necessary in some cases. However, this must not become a rigid dogma. Although designed as the prelude to a national growth policy there is a very great risk that protection has no stimulating effect on national production (lack of satisfactory productive response). It then penalises growth since food prices remain too high, and it slows down the growth rate of productivity in agriculture. Over time, other countries may become more competitive, which makes agricultural producers bring all their weight to bear to maintain protection in order to avoid competition and the subsequent crisis. Moreover, States which protect their agriculture by imposing taxes may have an interest in maintaining protection for as long as possible because of the resources which it procures for the State budget. Here again, the inescapable market liberalisation is postponed, thereby increasing the size of the potential crisis.

Protection must be the last means used to preserve national productive systems, applied only after all measures have been taken regarding the reduction of transport costs (infrastructures), the reduction in transaction costs, the fluidity of market functioning (institutions) and increased productivity. Protection may be useful where it preserves and supplements growth dynamics.

Protection can be justified where competition with national production results in such a volume of imports that it creates dependency and strategic vulnerability for the country. Too great a dependence on external markets can result in food insecurity. There is a risk of price rises should international food stocks decrease, or increased value in the currencies in which purchases are paid for, or in interrupted supply lines, particularly for landlocked countries.

Protection may also be considered where international prices are so low that, in order to resist competition, national production would have to lower its costs such that it would endanger the renewal of its natural resources, particularly land fertility.

Finally, protecting cereal sales was understandable for a long period during which international prices were maintained abnormally low export subsidies granted by the European Union and the United States.

Regional integration of national agricultural economies could teach the national agricultural sector how to avoid getting too far behind in productivity and competitiveness. One may hope that regional protection, in the same conditions as those presented above, could then have the effect of a stimulant. However, in conclusion, evolution towards greater commercial freedom in the world should lead governments to think in terms of controlled liberalisation rather than protection, even if the latter is only residual.

Agricultural exports as the subsidiary driving force for growth

Agricultural exports constitute an important source of income for countries and may strongly stimulate growth. However, growth based too exclusively on exports puts the agricultural economy at risk for various reasons.

First, it is frequently observed that the State obtains an important share of national added value, either through export taxes or by being a monopoly operator itself. International agreements on products with national quotas have for a long time encouraged this State presence in export circuits. Consequently, producers often only received a small part of the total added value. This practice can lead to extensive growth in production, and damage to ecosystems: accelerated deforestation in order to set up coffee and cocoa plantations, extension of cotton production (West Africa) or cassava production (Thailand). Experience in Côte d'Ivoire, for almost 25 years after independence has, shown however how a favourable farmgate pricing policy (high and stable prices) was able to create strong growth.

Another danger is that of the succession of booms and crises tied to international prices and variations in exchange rates. The result is "stop and go" movements which penalise growth and development. With the end of international agreements on price stabilisation, growing instability in exchange rates for major currencies, and the disappearance of national price stabilisation mechanisms in many countries, price fluctuations will probably be even greater in the future. It should also be added that ever keener competition between exporting countries will force the national production sectors to invest in improving competitiveness and productivity.

Such instability leads one to believe that export earnings cannot be counted on as the basis for lasting growth. Such income, however, can constitute be an important subsidiary driving force for growth, but as such it must be used to finance priority investments which in turn support lasting sources of growth in agriculture and the food industry, i.e. finance growth in productivity.

The pricing system: the main incentive in the economic policy

The pricing system must permanently aim at a large number of objectives: encourage sustainable intensification in agriculture, ensure that the food prices continue to trend downwards, maintain terms of trade which favour agriculture in order to trigger agricultural growth, facilitate relays of growth within the sectors concerned, protect agriculture (without excess), whilst helping it to fit into the regional economy, encourage products for regional consumption and, subsidiarily, export. Such controls will always be sophisticated, and have to be based on-going, clear information as to the action taken by those involved, permanent consultation with them and clear messages from the State to the agents. Tools which simulate the effects of pricing policies on the various sectors and types of agents will be very helpful to the decision-makers. Indeed, the combined overall effects of the detailed sectorial decisions concerning taxation, subsidies and credit bonuses, investment

aids, interest rates and the foreign exchange policy should be measured. It is less and less possible to isolate the agricultural policy from economic policy choices.

Another major pricing characteristic should be relative stability. It is known that as concerns the effects of agricultural prices on farmers' behaviour, variations over time have often had more influence than variations in levels (Boussard and Gérard, 1991). For farmers to accept important technical changes, a certain degree of price stability is necessary, or at least a limitation of instability. On the other hand, prices which are too stable prevent producers from learning how to adapt to demand. Without returning to costly public mechanisms for permanent price stability, it will be necessary to aim to reduce the most significant fluctuations in prices.

However, pricing policy cannot give signals that are strong enough to direct behaviour. Public investment can perhaps play a more determining role. Indeed, in countries with rapid population growth, the localisation of infrastructure investments, in other words the physical planning policy, will no doubt have a strong influence on the localisation of populations. The level of pressure put on natural resources by rural populations will therefore be influenced, together with the speed of evolution in the relationship between urban and rural dwellers which controls the evolution in agricultural productivity requirements. It is probable that in a large number of cases, policies such as this can only be financed by international aid. The State also has to learn to work with territorial authorities in order to make investments geographically coherent

The State should therefore increasingly become a development strategist as well as an element for regulating the conditions for fixing prices and incomes. One may consider this to be an ambitious role since many States are almost bankrupt, some are in the hands of warlords, and others are led by corrupt elitist politicians. The decentralisation of public authority and the liberalisation of markets are therefore necessary to guarantee a certain resilience in growth and development mechanisms, so that fluctuations in the real capacity of States to govern their countries do not compromise the essence of the movement.

Livelihoods for the poorest in the community: priority to local ecological, economic and social resilience.

Reducing rural poverty is first and foremost ensuring that rural populations can obtain locally the means of existence which at least allow them to benefit from adequate food security. The means of existence are the whole range of resources and products to which they have access and the activities which they can carry out. With regard to resources, this could mean timber, firewood, plants, fruit and wild animals. With regard to activities, it could mean opportunities for employment or local income obtained through the processing of agricultural products, the sale of craft items, employment in farm work, etc. (Conway, 1990).

These local livelihoods must be permanent, i.e. be based on viable production ecosystems (satisfactory management of common property), on institutions which give the poor people access to resources and power over them (rights), and on economic channnels with a certain regularity. In other words, these activities should allow for a certain local resilience in local ecological, economical and social systems so as to ensure that poverty is not aggravated by economic and social disturbance.

Such local resilience should encourage resilience in the same systems at more general geographical levels; this is a new application of the principle of subsidiarity. This concept should make it possible to minimise the risks of generalised imbalance in ecology and societies during the period of rapid population growth.

Conclusion: Political will

There is no reason for the Doubly Green Revolution to be able to impose itself on societies even where it is necessary. Yet this is revolution inevitable. How can agriculture stay isolated from the laws of ecology? And how can such complex changes be permanently controlled by governmental decision-making centres? Ecology and the decentralisation of decisions will make societies evolve towards new methods of organisation. However, in this evolution, the State will retain a decisive role which will dictate the speed and fluidity of the transformation processes. But above all, the fairness of this process and, finally, its social viability will depend on the State. Therefore, nothing will be possible without the political determination of the political leaders.

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Acronyms

AKRSP - Aga Khan Rural Support Programme

ARO - Agricultural Research Organisation

CGIAR - Consultative Group on International Agricultural Research

CIAT - Centro International de Agricultural Tropical

CIMMYT - Centro International de Mejoramiento de Maiz y Trigo

CNRS - Centre National de la Recherche Scientifique

CORAF - African Conference of Agricultural Research Organisations

DANIDA - Danish International Development Agency

FAO - Food and Agriculture Organization

GIS - Geographic Information System

IARCs - International Agricultural Research System Centres

IBRD - International Bank for Reconstruction and Development

IFPRI - International Food Policy Research Institute

IIAC - Interamerican Institute for Agricultural Cooperation

INRA - Institut National de Recherche Agronomique

INRAM - Integrated Natural Resource and Agricultural Management

IPM - Integrated Pest Management

IRRI - International Rice Research Institute

ISNAR - International Service for National Agricultural Research

IVSNM - Integrated Water, Soil, Nutrient Management

MADIA - Managing Agricultural Development in Africa

NARs - National Agricultural Research System

OECD - Organization for Economic Cooperation and Development

ORSTOM - Institut Français de Recherche Scientifique pour le Développement

PRA - Participatory Rural Appraisal

SADCC - Southern African Development Coordination Conference

USAID - US Agency for International Development

WTO - World Trade Association

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"Natura non nisi parendo vincitur"

Nature can only be commanded by complying with it
Francis Bacon, De dignitate et augmentis scientarum

The Green Revolution has tried to fight against poverty and food shortages by selecting varieties and improved production systems, by the massive use of fertilizers and pesticides. Its impact was very important but only in countries with high production capacity, water surpluses and high population density.

The aim of the Doubly-Green Revolution consists of changing the agricultural development rationale based on the control of the environment to another based on the harmony with the ecosystems : working with and not against the variability of systems and making agriculture profit from the knowledge acquired by the ecological sciences. It aims to increase production without depleating the environment nor affecting the bio-diversity for future generations. It also seeks to alleviate poverty and decrease food insecurity guaranting economic viability and social equity. Thus, Doubly-Green Revolution requires an interdisciplinary, intersectorial and spatial approach which was discussed in the seminar.

Organized by CIRAD and the *Innovation et Prospective* Foundation at Poitiers (France) with scientists and decision makers from developed and developing countries, it allowed a better understanding of the challenges related to food security and renewable resource management in the world.

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