Working Paper

OPTIONS FOR IIASA'S FUTURE AGRICULTURAL PROJECT: PRELIMINARY FINDINGS OF THE FEASIBILITY STUDY: START

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International Institute for Applied Systems Analysis
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FOREWORD

The feasibility study "Strategies and Tactics for Agriculture Reconstruction and Transformation" was planned to investigate the possibility of a new future agricultural project at IIASA. In order to specify possible options for research in this field and to discuss the NMOs' proposals, a seminar on sustainable agriculture was held in Sopron, Hungary, from 2nd to 5th March 1987. In this paper the authors summarize the preliminary findings of the feasibility study, including also ideas raised and discussed during the seminar. A more detailed description of these findings will be available in the Proceedings of the seminar to be published later in 1987.

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Options for IIASA's Future Agricultural Project: Preliminary Findings of the Feasibility Study START

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A. Introduction

IIASA's Research Activity Plan for 1987 includes a feasibility study about the interaction of strategical and tactical decisions in agriculture (STA). The general problem statement and outline of the STA can be found in the Plan.

An informal seminar was held in Sopron, Hungary from 2-5 March 1987 to

- discuss the NMO's proposals concerning a feasibility study,
- narrow the field of possible research,
- specify alternative research tasks,
- identify future possible collaborating institutions.

Seventeen representatives from 9 NMO countries (Austria, Czechoslovakia, Federal Republic of Germany, German Democratic Republic, Hungary, Japan, The Netherlands, USA and USSR) participated in the meeting and the round table discussion. 4 presentations made by IIASA staff, and 10 presentations made by non-IIASA participants, and the subsequent discussions showed that:

- An investigation of economic, social, ecological, and technological conditions of a sustainable agriculture and the integration of agricultural and environmental policies are of great importance for both Eastern and Western countries alike. To study the transition of agricultural systems to a more sustainable state is an appropriate interdisciplinary research for IIASA. Such a study is important for the analysis of the agro-industrial complexes as well as for the choice among development strategies.
- There are research results available in various countries which can be used as building blocks for the study. Long-run consequences of short-term management decisions, impacts of technical decisions on the natural resources, emerging new technologies and changing social and economic situations have all been subjects of investigation. All the NMO proposals ask for a complex approach and an appropriate methodology which combines these fields.

The following studies could be especially important as a starting point for IIASA's research.

- A West-German study on the long-term development of agricultural production in the FRG.
- Research concerning the effect of Conservation Reserve under the Food Security Act 1985 in the USA.
- International activities on the analysis of ways for integrating agricultural and environmental policies under sponsorship of the OECD Secretariat.

- Soviet studies devoted to problems of reconstruction and intensification of agricultural production.
- Japanese activities on studying the impact of extremely new technologies in agriculture.
- a Hungarian study on agricultural adaptivity.

To select appropriate topics for a possible future IIASA agricultural study we have taken into account several important criteria, such as methodological and financial feasibility, relevance to IIASA, interests for both East and West, and relevance to decision makers.

This paper contains the description of some options for an agricultural study at IIASA and it can be considered as background material for developing the final proposal.

B. Outline of Elaborated Options

During the meeting in Sopron the initial set of 11 possible options for a new IIASA study on sustainable agriculture, outlined in the paper by Donella Meadows, were discussed, refined, and extended to 20. Some new options were generated as a result of the presentations made by the participants, and others were elaborated during the round table discussions. For the sake of simplicity and clarity, a full list of the various options are given below. When analyzing the list one should bear in mind that the order has no particular meaning from the point of view of priority or significance of a particular option.

1. Clearinghouse for Sustainable Agriculture

IIASA should be considered as the "base" for the network, where extensive exchange of information and experience about sustainable agriculture would take place. The activities would include international workshops, review of literature and models, and dissemination of this knowledge by means of a Newsletter.

2. Comparative Studies of Technologies

A comparative analysis of the current state and tendencies of the application of conventional and alternative agricultural technologies, and their performance at the level of experimental plots in various countries is very much needed. Such a comparison could be done in a unbiased way by an international organization like IIASA.

3. Resources-Production Feedbacks

The problem of "endogenization" of many effects, regarded currently as externalities (like environmental effects in economic models), is likely to be the most promising way to clarify the interdependencies among basic natural resources (such as soil, and water) and agricultural production. Comparing the simulation results of a model with and without feedback effects between production and resources, the distortions caused by disregarded externalities can be quantified. Some of the already existing models could be used for such an analysis.

4. Adoption of a Particular Technology

Investigate possible ways of adopting a particular technology and project the dynamics of its implementation under various policies and various conditions. Calculate the long-run environmental impacts. This study could be based on a "historical case" (adoption of a currently widely used technology) or it can be focused on the implementation of a new technology (for example, biotechnology).

5. Investigating Particular Agroecological Problems

A long list of particular agroecological problems exists. This list includes nutrification of groundwater, soil compaction, etc, for which possible solutions are of interest to decision makers and social communities in both Eastern and Western countries. The necessary methodology should be elaborated in order to be able to handle these types of problems.

6. Problem-Oriented Illustrative Models

Lack of data about interactions among resources, technologies, and the environment make it very difficult build a complete scientific model which includes all the important causal relationships, even if some of them are properly described. Therefore a small illustrative model approximating complex processes of agriculture interacting with the environment, could be useful both as a pilot study for more sophisticated approaches (scientific objective) and as an information tool for policy makers, farmers, and students application. IIASA could develop, collect and disseminate such models.

7. Forecasting Ecological Effects of Conventional Technology

An analysis of likely future ecological effects and economic consequences of conventional agriculture could be done in order to make decision makers aware of the possible risks should present trends continue. This analysis could be done not only by using models but also by drawing on the experience of the experts. It is clear that a "comprehensive" forecast will be the result if a multidisciplinary and interdisciplinary team of experts is involved. Techniques for collecting, and analyzing these opinions and making a forecast could be considered as a theme for IIASA.

8. Consequences of a Large-Scale Shift to More Sustainable Technologies

In almost all the countries data are available on a small-scale or experimental usage of sustainable agricultural-technologies. These data show that they can have many advantages from the point of view of the economic use of natural resources as well as of their environmental and ecological suitability. A systems analysis of economic and ecological implications of a large-scale shift towards sustainable technologies seems to be of great interest to policy makers, farmers and industry. What will happen to the agrochemical industries? What will be the necessary flows of organic substances? Will there be sufficient organic fertilizers? What will be the implications on recycling of organic wastes, on new transportation patterns, on total crop production, and on food prices? How sustainable are these methods really over the long-run? What other industries will be stimulated? What will be the implications for all sectors of an economy?

9. Complex Economic Analysis of Alternatives

In order to make a decision, a comprehensive calculation of all economic consequences of conventional and of alternative agricultural methods, as well as of their possible and most likely combinations is needed. This calculation should include also externalities and long-term effects. In the case of uncertainty a possible accurate statement of the degree of uncertainty should be given. IIASA could elaborate a methodology for the comprehensive economic comparison.

10. Decision Support Systems

Prepare management-level decision support systems for the use of sustainable methods or the combination of sustainable and conventional methods, either at the level of the farm, or at the level of the national or regional planner.

11. Agroecological Cogwheel/Flywheel Examples

In various countries a cogwheel/flywheel phenomenon can be found in the history of agriculture. The short-run decisions responding to the day-to-day economic pressures, bring into motion long-run environmental and technical processes – like a high energy cogwheel brings into motion a flywheel. Once the flywheel (environmental degradation processes, a specific technical development) begins to move, it takes over the driving of the system and more and more short-run decisions will be determined by it.

A research activity could be started in order to analyze retrospective examples, to explore and simulate the dynamics of long-run/short-term interactions, and to find "new" examples. Is there a point where the flywheel becomes unstoppable or irreversible? Are there any early warning systems when thresholds are crossed? How real and how generalizable is the cogwheel/flywheel system structure?

12. System of Agroecological Monitoring

An integration of agricultural and environmental policies is the inevitable outcome of agricultural development. The pressure of conventional technologies on natural resources in developed countries is extremely high. Negative environmental consequences of applying current agricultural technologies were revealed in certain regions with highly industrialized agriculture. For instance, impacts on the quality of drinking water, due to overfertilization and the application of pesticides, have had negative effects on human life and for wildlife. The profit-seeking orientation of current agricultural policies can be considered as the main driving force for such a tendency. Most statistics about agricultural systems at various levels place heavy emphasis on data concerning the economic aspects of agriculture.

At the same time due to the lack of reliable information about changes in environmental quality there is little change in current agricultural policies. If such information were available then integration of agricultural and environmental policies would be possible. The first steps towards an analysis of the opportunities for such an integration have already been made in many developed countries during recent years. IIASA's experience in systems analysis, in environmental issues and in agricultural systems could be used to create a framework for such agroecological statistics.

13. Principles of Technological Choice

Technical development is heavily influenced by transient market pressures, by factor price changes and by short-term government policies. Therefore the choices among the possible technical paths seem to be random and arbitrary. It would be necessary to investigate past developments in order to derive some principles of technical choices for the future.

14. Effect of Changing Input Structure of Agriculture

Conventional agricultural technologies, especially in developed countries, rely heavily on the application of chemicals, big machinery, fossil fuel, and other purchasable inputs. Some of these inputs can be considered as non-renewable. If one or several of these inputs were in great scarcity, what impacts would it have on agriculture? What will be the response of other industries? Which subsectors of agriculture, and how, will they be affected? A comprehensive analysis of these effects can be done on a national and global scale, for a particular input, (for instance fossil fuel,) or for several inputs.

15. Possible Ecological Disasters

In the history of agriculture there are a lot of examples showing how mismanagement of natural resources and ignorance of ecological "laws" led to ecological disasters. The pressure on natural resources and on ecological systems is increasing over time. Surveys of soil fertility, of the organic content of soil, and the quality of the water table in regions with intensive agricultural production, show this tendency. Several surprise-rich scenarios, describing possible ecological disasters in agricultural regions can be constructed. Consequences of these disasters on the global or national economy, on social welfare, on various sectors of economies could be investigated.

16. Social Consequences of Technological Changes in Agriculture

Introduction of new technologies in agriculture lead not only to increasing inputs and productivity but it creates also social problems, because of changes in the rates of unemployment, in the income formation, the structure of the labor force, etc. Such consequences are sometimes painful for the rural communities. Possible social consequences of drastic technological transformations in agriculture (for instance, transition from conventional to alternative practices) will be observed not only in agricultural but also in the industrial sectors of the economy. Their investigation is of primary importance.

17. Institutional and Organizational Structure for National Agro-Industrial Complexes

In many developed and developing countries agroindustrial complexes have been established during the last 5-10 years. This subsectoral breakdown, institutional and organizational structure and management procedures are different. An analysis of these differences could be a worthwhile exercise for comparative international studies. On the basis of this analysis the interaction between the main components of agroindustrial complexes, like "input" industries, agricultural sectors, food processing, distribution and trade could be described. Bottlenecks in management procedures could be revealed and recommendations for improvement made.

18. Impact of Industrial Development on Agriculture

Both industry and agriculture are very complex, interdependent and interconnected sectors of an economy. Therefore changes in the industrial development, in any country, will induce a "wave of consequences" in agriculture, and vice versa. An analysis of such impacts, an investigation of past examples with both positive and negative consequences, and a study of future paths could also be considered of interest to the NMO countries.

19. Changes in the World Market under Sustainable Agriculture

If conventional agriculture is substituted by more sustainable practices on the national scale then the world market will be heavily affected. Of course the scale of the disturbance will be determined by the speed and scale of such a substitution. This will induce changes in the world market for purchasable resources, such as mineral fertilizers and other chemicals, machinery, etc. It will also influence the structure and proportions among corresponding industrial sectors. Some shift in usage of fossil fuels in agriculture will have an impact on the energy sectors of the economy. These and many other changes will definitely have an influence on the prices of agricultural commodities, patterns of consumption, demand and supply, income formation and distribution, and trade, etc. IIASA's experience in macroeconomic modeling of national and international agricultural market interactions could be useful for such an analysis.

20. Environmental and Social Effects of Extremely New Technologies

Results of many investigations made in various countries about future agricultural technologies show that technological progress in this sector of the economy is connected with developing biotechnology, genetic engineering, computerization of management procedures and robotization. When applied on a larger scale, some of these new technologies will have a strong impact on agriculture and will lead to a change in the structure of interrelations influencing labor, levels of productivity, educational background of farmers, etc. Apart from these social consequences new technologies will also change the relationships between agriculture and the environment. Developing a methodology to investigate the new technologies and their social and environmental effects, as well as its application in case studies could be done at IIASA.

C. Options Revisited, Evaluated and Combined

We have arrived to these 20 topics described above by several brain storming sessions. As it has been mentioned, very important inputs were provided by the different presentations and by the discussions following them. However at the end of the discussions it turned out, that the big number of options as well as the various formulations of the different topics make the choice among them extremely difficult.

To overcome this difficulty we have tried to introduce an ad hoc evaluation system. To find out the relative importance of the topics assigned to them by the individual participants, we asked them to answer certain questions. These questions were related to the feasibility, the uniqueness, the urgency, the East-West nature of the topics and to their relevance to IIASA as well as their potential for the advancement of science.

The lists of options and criteria for their evaluation were given to participants of the seminar. Each of them was requested to evaluate each option with a separate criteria by using 4 as the best and 0 as the worst estimate. Two examples of data received from the 18 participants are given in Tables 1 and 2. Table 1 contains individual judgements about the methodological feasibility for the options and Table 2 judgements about their relevance for the problematique of IIASA.

In trying to formulate the collective wisdom, we have applied a simple procedure to add up the numbers for each option. On the basis of these estimates all options were ranked. (In order to avoid any misinterpretation of the results we will not provide these results in this paper.) From the rigorous point of view of mathematical statistics, our procedure might well be criticized, yet it gave us a feeling about a consensus of the participants of the meeting. We have found that significant preferences were given to certain topics like e.g.the methods to forecast ecological consequences of the currently used and sustainable agricultural technologies, the exploration of the highly complex feed-back loops between production and environment, the social consequences of the technological development in agriculture, etc.

There was another lesson which we have learned from this "voting" procedure. It turned out that because of the various interpretation possibilities

- certain evaluation principles were ambiguous,
- sometimes not the topic was important, rather its formulation made it "unique", "relevant", "feasible" etc.

Accordingly we have decided that in addition to the approach used to arrive to the maximum consensus we shall try to ***combine*** the revealed interests of the participants. This procedure helped us also in reducing the number of topics into some combined research tasks which then became equally interesting for a large number of participants.

Looking at the list of the 20 options one can see that they cover not only a very wide spectrum of possible themes but many of them can be studied at various levels (farm, regional, national, global). Furthermore some of them could be considered as intermediate stages for the implementation of a more complex study.

It is clear for instance that at least the options numbered 4,7,13,16 and 20 could be studied at each of the above levels. Options 6 and 10 could be the final product of almost all of the other options. Options 2,3,7,9,11,13,14,16 and 19 could be considered as either theoretical exercises or systems analysis studies that are important preliminary steps for implementing a more integrated investigation. The main conclusion to be drawn from these examples is that one should try to define an appropriate combination of the above options.

Careful analysis of the options and of the available NMO proposals has enabled us to outline 3 possible combinations for the purpose of investigating long-term consequences of agricultural development. Because each of these combinations accentuated a particular side of a study these were named as follows:

- macroeconomic analysis
- ecological and environmental study
- strategical technological investigation.

A "macroeconomic" combination includes ideas which were formulated in options 2,3,6,8,9,12,14,16,17,18 and 19. The "ecological" combinations could be compiled with the problems that were outlined in options 1,2,5,7,8,9,11,12,15 and 19. In this paper we would not like to specify the details about all of the combinations, except the last one. It is our opinion that further studies and discussions will help us to

Table 1: Individual Estimates of Options of Methodological Feasibility

Options	Experts																	
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Clearinghouse for sustainable agriculture	0	4	4	3	-	4	4	4	3	4	0	4	2	0	0	0	4	1
2. Comparative studies of technologies	1	4	4	4	-	4	2	4	4	2	0	3	2	1	2	2	3	3
3. Resources-Production feedbacks	3	3	3	4	-	3	1	3	3	2	3	4	4	3	3	3	4	1
4. Adoption of a particular technology	2	4	2	3	-	3	3	4	3	3	0	3	3	0	2	2	4	1
5. Investigating solutions of a particular agro-ecological problem	2	3	3	3	-	4	3	4	4	3	1	4	3	1	3	3	4	1
6. Problem-oriented illustrative models	0	4	3	3	-	4	4	4	4	4	1	4	4	3	3	2	4	3
7. Forecasting remote ecological effects of conventional technology	2	4	3	2	-	2	2	4	3	3	3	3	2	2	3	3	3	2
8. Consequences of a large-shift to more acknowledged technologies	2	4	3	2	-	2	2	4	3	2	3	3	1	2	2	3	3	1
9. Complete economic analysis of alternatives	0	3	1	3	-	4	2	2	3	2	3	2	0	3	3	2	4	4
10. Decision support systems	3	2	3	3	-	1	2	2	3	3	2	3	3	4	2	1	3	3
11. Agroecological cog-wheel/flywheel examples	0	2	3	4	-	2	1	1	3	3	1	3	4	-	1	1	4	2
12. System of agro-ecological monitoring	0	4	4	4	-	4	4	1	3	4	2	4	2	2	2	2	3	3
13. Principles for technological choice	4	4	2	3	-	2	2	2	4	2	2	3	3	2	3	4	2	2
14. Effect of changing input structure of agriculture	3	4	3	3	-	2	4	1	4	2	1	2	1	2	1	3	4	3
15. Possible ecological disasters	0	3	3	4	-	2	2	2	2	2	1	2	2	0	1	2	4	1
16. Social consequences of technological changes in agriculture	2	4	2	3	-	2	3	2	4	2	3	3	2	0	2	0	2	2
17. Institutional and organizational structure for national agro-industrial complexes	0	4	2	2	-	1	2	1	3	2	2	2	2	0	2	2	3	2
18. Impact of industrial development on agriculture	2	2	2	2	-	2	2	1	4	2	3	3	2	1	1	2	1	2
19. Changes in the world market under sustainable agriculture	0	2	3	3	-	4	3	2	4	3	3	3	2	2	1	2	3	2
20. Environmental and social effects of extremely new technologies	3	4	2	4	-	3	3	1	4	1	3	1	0	0	1	3	3	2

Note: (-) means that an expert did not estimate an option for this criteria

Table 2: Individual Estimates of Relevance of Options for IIASA

Options	Experts																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. Clearinghouse for sustainable agriculture	0	4	1	4	-	2	3	4	3	3	3	4	3	4	3	1	2	4
2. Comparative studies of technologies	1	4	2	4	-	3	0	3	3	1	1	2	2	1	2	0	3	4
3. Resources-Production feedbacks	2	2	2	2	-	3	4	3	3	2	2	2	1	3	4	2	3	2
4. Adoption of a particular technology	3	4	1	3	-	2	2	3	3	1	1	3	0	0	3	0	3	1
5. Investigating solutions of a particular agro-ecological problem	2	2	3	3	-	3	2	4	3	1	2	2	2	3	4	0	2	4
6. Problem-oriented illustrative models	0	2	2	2	-	3	4	4	3	3	1	1	2	4	2	0	3	1
7. Forecasting remote ecological effects of conventional technology	3	3	4	2	-	4	4	3	3	3	3	3	3	4	2	1	2	1
8. Consequences of a large-shift to more acknowledged technologies	3	4	4	2	-	4	4	4	3	3	3	3	2	4	4	1	4	3
9. Complete economic analysis of alternatives	0	2	4	2	-	4	4	2	3	4	2	2	3	4	3	0	2	1
10. Decision support systems	3	2	3	4	-	4	4	1	3	1	1	3	0	4	2	0	3	3
11. Agroecological cog-wheel/flywheel examples	0	3	4	2	-	4	4	1	3	3	2	3	2	-	1	0	3	1
12. System of agro-ecological monitoring	0	4	4	4	-	4	3	1	3	3	2	3	3	0	1	0	2	3
13. Principles for technological choice	4	4	3	3	-	4	3	2	3	2	1	3	1	0	1	4	3	1
14. Effect of changing input structure of agriculture	2	4	3	2	-	2	3	1	3	3	2	3	2	2	2	3	1	1
15. Possible eco-logical disasters	0	2	4	4	-	2	2	1	2	3	1	3	3	0	2	2	3	2
16. Social consequences of technology changes in agriculture	1	4	3	3	-	2	3	2	4	3	3	4	0	1	2	0	2	3
17. Institutional and organizational structure for national agro-industrial complexes	0	4	2	3	-	3	1	1	3	1	2	3	1	0	0	0	2	1
18. Impact of industrial development on agriculture	2	3	3	2	-	1	1	1	4	3	2	4	3	0	2	1	0	2
19. Changes in the world market under sustainable agriculture	0	2	4	4	-	4	2	3	4	2	1	4	2	0	3	0	2	2
20. Environmental and social effects of extremely new technologies	4	4	4	4	-	2	3	2	4	1	2	2	0	0	1	4	3	3

Note: (-) means that an expert did not estimate an option on this criteria find more additional specifications of combined tasks in order to make the final selection of a future research project at IIASA.

However, with our current understanding and knowledge in this field we think that a "technological" study is likely to be the most appropriate one. This "technological" combination is based on the ideas described in options 1,2,3,4,6,7,8,11,12,13,14,16,17 and 20.

D. More About "Technological" Combinations

Accordingly we started out with an attempt to specify which agricultural technologies will be used over the long term. Since that is an impossible forecast to make, an alternative is to specify a range of possible technological scenarios. The scenarios should span the full range of what is ever remotely possible, not because the real world will likely follow the extreme edges of such a range, but because investigating the extremes clarifies the choices and usually points up the advantages of the middle ground.

The group in Sopron, in discussing the technical options available in agriculture known now and visible on the horizon, kept coming back to three distinct paths, or mindsets, or "technical bundles", which seemed to span the visible future choices and to capture the current schools of thought. They can be loosely labeled the "conventional", the "organic", and the "high-tech" paths. For purposes of clarity they will be described here as much more distinct and mutually exclusive than they really are. Elements of all three paths can in fact be found in practice on some present-day farms, and in the future they might be mixed together in intriguing combinations, as their costs and benefits become better understood.

It is not at all clear whether in a IIASA project on agricultural sustainability these paths should be explored as separate and pure options. But it is worth laying them out here as distinct, to help organize the large array of present and future technologies now under discussion. And there is some validity to distinguishing these "bundles" of technologies, because underlying each set there *is* an identifiable mindset or philosophy or set of assumptions. The technologies will probably be intermixed in the future to the extent that human beings can mix different guiding philosophies in their minds, or to the extent that they can choose technologies by purely pragmatic criteria, rather than by the congruence of a technology with a comfortable mindset.

The following specification of the three technical bundles is preliminary and incomplete. It would need to be developed and made more comprehensive by many discussions and much research before it would be sufficient as a guide to precise scenarios of future agricultural technical paths.

In introducing these "technological bundles" we should distinguish their guiding philosophy:

Organic – utilize and enhance cost-free natural processes; deal with living things differently from inanimate things; respect natural systems and existing rural social structures.

Conventional – maximize output, minimize cost, be guided by short-term economic rationality.

High-tech – bring biological systems under more control, increase predictability and uniformity, be guided by the logic of current industrial methods.

"Technical Bundle"			
CROP PRODUCTION	**Organic**	**Conventional**	**High-Tech**
Soil Preparation	disturb soil as little as possible to prevent erosion and to keep weed seeds from germination. Contour ploughing, no-till (without herbicide) ridge-till, build humus content to keep soil friable	moldboard plow; regular cultivation with disks and harrows, same no-till (with herbicides)	same as conventional, with tracks or overhead suspension to reduce compaction, increased robotization *or* no soil (see below)
Plant nutrient supply			
nitrogen	fixation with legumes, composting and manuring, recycling of residues, green manuring, slow release from humus	chemical fertilization combined with use of organic methods	genetic attachment of N-fixation ability to all plants, *or* chemical fertilizer in computerized hydroponic solution
other nutrients	same as above *plus* mineralization by soil microbes from parent soil material	same as above	chemical fertilizer in optimized amounts in hydroponic solution
Water Supply	high humus content to hold water, strip planting and contour ploughing to enhance infiltration and reduce runoff, some irrigation with careful attention to efficient water use and avoidance of salting or of groundwater drawdown	irrigation where necessary	controlled supply automatically delivered when requested by soil moisture probes, perhaps enclosed fields *for* recapture of evapotranspiration and total climate control
Plant protection			
insects	natural predators, natural resistance, companion planting, avoidance of monoculture, use of resistant varieties	insecticides, some breeding for resistant varieties	either complete enclosure from insects or genetically engineered resistance
pathogens	crop rotation, avoidance of monoculture, use of resistant varieties	fungicides breeding for resistance	genetically-engineered resistance

weeds	ridge-till or conventional tillage, mulching crop rotation, relay cropping allelopathy	conventional tillage and herbicides	either complete enclosure or herbicides combined with crops genetically-engineered for herbicide resistance
Machinery			
type	usually lightweight and small-scale to avoid compaction, flexible to handle many crops in a rotation	high-powered specialized and large to pass quickly over large fields of monoculture	highly robotized and computerized, self-adjusting
energy source (other than solar)	ultimately biogas and some non-renewable fossil fuel	non-renewable fossil fuel and solar	fossil fuel and renewable?

ANIMAL PRODUCTION	**organic**	**conventional**	**high-tech**
breeding	natural methods on artificial insemination	artificial insemination	genetic engineering, cloning, test-tube insemination and implantation
feeding	grazing on highly-mixed pastures, self-selection of feeds, organic grains, greens. No additives	high-density feedlots, grains mixed to minimize cost and deliver basic (known) nutrients. Hormonal and antibiotic additives	computerized individualized automatic feed delivery. Hormones genetically manipulated for maximum yield
shelter	normal barns with access to fresh air, sunlight	tight confinement to minimize motion and maximize yield and to minimize building cost	complete confinement in climate controlled buildings
disease prevention	low density, natural health of animal, some vaccination	antibiotics in feed, regular medication for parasites, vaccination	enclosure to minimize exposure to pathogens genetically-engineered resistance
manure handling	regularly returned to fields, which are nearly, or made into biogas	sold to cash-crop farmers for return to fields, or regarded as a troublesome waste product	biogas?

Summary — Use of Input Factors

	organic	conventional	high-tech
knowledge and information	high	moderate	very high
capital	moderate	high	very high (much off-farm)
labor	moderate (moderately skilled)	low (moderately skilled)	moderate (highly skilled, off-farm)
land	high	low	very low
natural ecosystem services	high	moderate	very low
chemicals	low	high	moderate
energy (other than solar)	low	moderate	high?

E. Conclusion: Next Steps

As it has been said these technical paths should be explored further and only afterwards will it be possible to decide whether we should investigate their dynamics and structural consequences in their above defined pure form or should we rather create those mixed technical bundles which seem to be the most realistic from the point of view of the present and expected resource scarcity.

Looking at the possible combinations of the topics listed above, as a first tentative approach we can define the following research tasks for our feasibility study:

1. Define three technical bundles (sustainable, conventional and high tech.) or their appropriate combinations and

- using their production-environment feedback loops (option 3.)
- look at their future development (option 8.)
- calculate their environmental (option 4.)
- social, (option 16.) and
- economic consequences (option 14 and 9)

and by evaluating the results assess the trade offs between their short run economic efficiency and long run sustainability.

This research would not deal with all the factors influencing the technical choices in the real world. If required, these could be embodied in the predetermined technical bundles. The investigation would rather be oriented towards the consequences of development, the question being not so much how the technologies originate but rather where do they lead to? In the real world there would not be any guarantee that the particular bundles chosen for the analysis will be realized. Their future existence and development will only be assumed. Yet by comparing these assumed technical bundles and evaluating them in their largest possible context, the research will show

- the different consequences of three technical development paths (a market driven, an ecological and an autonomous one) in the economic, social and environmental fields,
- the complexity and interdependence of the extended system,
- the different dynamics of the three development patterns originating from the different environmental feedback systems involved in them,

- the economic, social and ecological vulnerability and possible break down points of these development paths and
- the extent of the necessary structural changes resulting from them.

2. Analyze economic factors (markets, prices, subsidies, taxes, tariffs, quotas etc.) to assess how they are related to the producers' choices concerning technical development. Find out what kind of long term considerations are involved in the present investment and technological decisions. Analyze the long run consequences of these decisions and the possible conflicts between long run and short run aspects (option 11). Describe the interaction and the dynamics of the involved short run and long run processes. Identify the underlying principles in the technical choices (option 13). Identify important externalities and effects beyond the generally used time horizon to assess how much are the present decisions distorted by using a myopic, narrow microeconomic view (options 3 and 4). Develop small illustrative models to reflect the dynamics of short run vs.long run decisions (option 6).

The starting point of this research would be an empirical investigation of the real world factors influencing investment and technological decisions. Accordingly the genesis of these decisions would be in the focus of the analysis. However a critical point of view would be used concentrating also on the missing elements and neglected aspects and showing how can short run decisions lead to unexpected and adverse long term consequences.

It is expected that as the result of this research

- it will be better understood what kind of aspects are dominating in the present decisions affecting the technical development in agriculture,
- in addition to the present criteria, social and environmental aspects will also be introduced in the evaluations in these decisions,
- foreclosed options in the present technical paths can be detected,
- it can be demonstrated how can the maximum flexibility of the system be preserved by avoiding some harmful consequences of the decisions made in the short run,
- it will be shown what are the most important externalities and future impacts neglected in the present decision systems.