European Journal of Plant Pathology **103:** 197–201, 1997.

Scenario studies for future agriculture and crop protection

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Accepted 26 November 1996

Key words: decision making, methodology, production ecology, technology evaluation

Abstract

The history of crop protection has shown two shifts of focus. In the second half of this century, attention shifted from the pathogen to the pathosystem, and at present we are witnessing a further shift to a focus on the whole production system. So, crop protection is now seen as just one activity among many in agricultural production systems and improvement of crop protection is no longer seen as separate from goals such as maximizing yield and minimizing inputs, as for example nitrate use per unit of product and use of pesticides per unit of land. To explore options for future crop protection in conjunction with other production goals, scenario studies can be useful tools. Scenario studies may be used for the evaluation of technologies or may comprise feasibility analyses of land use at various aggregation levels. The methodology of scenario studies is explained in this paper and some examples are described. It is demonstrated how useful organised thinking about the future can be.

Introduction

The need for developing new approaches to crop protection can be made clear by examining the changes in crop protection during the last centuries. We can distinguish four periods in crop protection history so far (Zadoks, 1991).

The first period, before the eighteenth century, was characterized by passive acceptance of pests and diseases in crops. We can consider this as the *pre*history of crop protection, because active protection was not carried out. Pests and diseases were deemed inevitable and were sometimes considered as punishment by God.

In the second period, mainly the eighteenth and nineteenth century, preventive measures were considered possible, but when diseases did appear they were still considered uncontrollable.

The third period, the greater part of the twentieth century, saw the increased reliance on chemical means to control pests and diseases.

In the fourth era of crop protection, up to the present, it was recognized that the chemical fight against pathogens has unwanted environmental side effects. This led to a threefold change in crop protection: (1) the aim was no longer eradication of pathogens but keeping their populations at acceptable levels; (2) non-chemical means of crop protection such as biological control and rotation schemes were developed or improved; (3) crop protection became a matter of searching for the optimal combination of different control measures rather than reliance on one – chemical – measure alone. This period saw the development of integrated pest management (IPM) and improvements in resistance breeding. The fourth era of crop protection thus recognized that one should manage pathosystems rather than control pathogens. However, as in the periods before, crop protection was still considered a management activity that could be considered independent of other agricultural management measures such as improvement of quantity and quality of the produce, or improvement of the efficiency of fertilizer use.

Now, at the turn of the century, we are entering a new era of crop protection. Crop protection is increasingly seen as an integral part of production systems. The effectivity of pathogen control measures may change with measures taken to improve yield or decrease losses of inputs, so it is now recognized that all have to be optimized in conjunction. On the basis of understanding of the whole agroecosystem in which pathosystems function, actions are considered such that the maximum of the biological production and control is achieved, while the efficiency of external inputs is maximised and negative side effects are minimised. This new, multi-faceted problem, requires solutions that address all facets simultaneously. New agrotechnologies must be developed and patterns of land use may have to be re-arranged, for better adaptation of agricultural systems to local production possibilities and overall needs. This may resolve many negative side effects of agriculture, which are due to application of wrong (or suboptimal) agrotechnologies at the wrong place. Heterogeneity in the past considered as a liability may be developed into an asset. So, this new era of crop protection is characterized by a threefold upscaling: (1) from pathosystem to production system (upscaling of the problem); (2) from presently available agrotechnology and food demands to new technologies and future demands (temporal upscaling); (3) from local issues to regional land use allocation and strategic land use policies (spatial upscaling).

The scientific discipline that analyses biological production systems, and assesses the sensitivity of such systems to disturbance by biotic and abiotic factors, is called production ecology (Rabbinge et al., 1990). Production ecological studies can provide the basic information on the effects of human interference with one specific production system. However, when dealing with land use options, i.e. a problem of selecting and combining multiple production systems, we need a methodology that combines the manifold production ecological information. In that way the threefold upscaling problems should be tackled by exploring options and explicitizing various trade-offs. In this paper, we want to show how scenario studies can perform that role, and organise our thinking about the future, showing unexpected perspectives and rejecting unjustified claims of particular technologies. We describe the methodology and mention three examples of completed scenario studies with strong emphasis on crop protection problems. These examples are described in other papers in this journal or at other places. The present paper is based on a contribution to the IPPC (International Plant Pathology Congress) in The Hague in 1995. A session on scenario studies was organised and some of the contributions are published in this issue of the European Journal of Plant Pathology. The title of that session, and of this paper, indicates the awareness that crop protection can no longer be viewed separately from agriculture as a whole.

The methodology of scenario studies

What are scenario studies?

Scenario studies are completely transparent descriptions of possible futures. They consist of a list of conditions and assumptions, pertaining to future agriculture, and a list of rules. The rules, which are used to derive the consequences of known and assumed future conditions, are formalized. Therefore the only subjective aspect of scenario studies is the *choice* of rules and conditions. One may disagree with such choices but not with the validity of the deductive process. Scenario studies can thus be characterized as a systematic way to organize our thinking about the future.

Contrary to what their name may suggest, scenario studies do not always picture possible time courses of changes in agriculture. The method is not necessarily dynamic, but may describe various alternatives for agriculture statically as a function of expected constraints reigning at some selected point in the future.

Studies that aim at different objectives should use different types of scenario approaches (Schoonenboom, 1995). Basically three types of scenario studies may be distinguished (Table 1): predictive studies, analytic studies and explorative studies.

Predictive studies predict future developments, they are in many cases based on an extrapolation of trends and presume continuity in trends and developments. These studies are of limited value for long term studies as discontinuities that occur or are desired are not considered and behaviour of actors is considered to be very conservative. The value of these studies is in short term evaluation of changes.

Analytic studies analyse developments and changes in the recent past and elaborate on the possible and impossible for the near future.

Explorative studies aim at the derivation of options for future developments. They show the possible and make clear what trade offs there are between various objectives and constraints.

Delineation of scenario studies: objectives and constraints

Any study that uses scenarios should be very clear in the description of its objectives and the boundaries

Table 1. Classification of scenario studies

Characteristics	Time/spatial scale	Criteria for usefulness
Predictive studies	Limited	Good prediction
Analytic studies	Limited	Good understanding of process
Explorative studies	Unlimited, various possibilities depending on objective	Good delineation of options

of the systems which are considered and should use explicit and clear definitions of the various variables that are distinguished (Van Ittersum and Rabbinge, 1996). Neglecting this may lead to unjustified predictions with predictive scenarios or to unacceptable claims on future possibilities in explorative scenarios.

Both the spatial scale and the time span of the study have to be defined. A precise definition of spatial and temporal boundaries limits claims outside the field for which the study is done. When a study on regional development is performed a time horizon of 20–40 years is feasible and the socio-economic or physical-geographical boundaries dictate the size of the system. When an analysis at the farm level is done, farm size and structure are often accepted as unchanging boundaries and the time horizon is much smaller.

When spatial scale and time frame have been set, one must make explicit what additional boundary conditions are supposed to apply. Scenario studies typically differ in their assumptions concerning human population growth and global climate change. Human population growth may be neglected if the time span of the study is short or if the region of study has low birth rates. Climate change may be neglected if its effects on agriculture are expected to be low or to cancel out.

Finally, the rules according to which the consequences of the assumptions are calculated, must be stated. For example, a predictive scenario study may adopt the rule that agricultural yields will continue to increase with the same relative growth rate as seen in the past. Another study may make other choices, e.g. that absolute rather than relative growth rates are conserved.

Applications of scenario studies

Scenario studies are widely used to help strategic policy making, to set priorities and to gain insight in the possible and to reject unjustified claims for the future. Policy making and strategic decisions may be based on such future studies and pave the way for a structured decision making process. The need for more sight on the future increases as the rate at which agriculture changes increases, as more explicit aims are formulated by farmers, politicians and environmental groups, and as technologies to organise our thinking about the future become available. The need for more understanding and insight in the ecological, physiological, chemical and physical processes that govern agroecosystems is demonstrated when options for agrotechnologies and land use are developed and that need is also felt in such notions as sustainable agriculture. That notion accounts for awareness of the consequences of present activities for future populations, awareness of environmental side effects, and on a global scale relations between North and South. At all aggregation levels the need for better perspective on the future is present and ecological literacy at all levels, global, regional, local and farmers field scale is required. Expressing a notion or using slogans is not sufficient to get sustainable development, better judgement is only possible when information is organised in an appropriate way.

Three examples of scenario studies related to crop protection

Several typical examples of scenario studies were presented in the IPPC-symposium. Two of the studies are elaborated in separate papers in this journal: an analytic study on the application of various pest and disease control strategies by Oerke and Dehne (1997), and an explorative study at the farm level on land use for bulb production in the Netherlands (Rossing et al., 1997).

In the first study various technologies of pest and disease control are investigated and their impact for crop protection is explored. This is an example of an analytic study which presents a good overview of how things may develop. The scope of the study is limited to crop protection s.s.

In the second example various techniques, including crop rotations are evaluated with a multiple goal

Table 2. Land and pesticide use for agriculture in the European Union: situation at present and according to four different scenarios from the ‘Ground for Choices’-scenario study (Rabbinge et al., 1994). The four scenarios are characterized by different policy philosophies, i.e. cohesive sets of preferences with regard to policy goals

Policy philosophy	Land use for agriculture (ha)	Total pesticide use (kg active ingredient)	Pesticide use per ha (kg active ingredient)
Present	127×10^6	400×10^6	3.2
‘Free market and free trade’	42×10^6	60×10^6	1.7
‘Regional development’	77×10^6	89×10^6	1.3
‘Nature and landscape’	26×10^6	21×10^6	0.8
‘Environmental protection’	61×10^6	33×10^6	0.5

technique. The approach enables quantification of trade offs between various objectives and constraints. How such a scenario study supports the interaction between various groups of stake holders environmentalists, farmers, administrators etc. is demonstrated in this example. It has bridged the gap between polarised groups and enabled the development of common strategies.

As a third example we mention the ‘Ground for Choices’-study (Rabbinge and Van Latesteijn, 1992). In this study on the possibilities of renovation of European common agricultural policy towards policy for rural areas, the production ecological approach is fully used in land evaluation studies, in the description and design of agricultural technologies and in the development of technical coefficients. This study uses a crop growth simulation model to estimate potential local yields as a function of local weather conditions. This is an example of a ‘yield-rule’ embodied in a computer program. The rule may be considered complex (because one has to run a simulation program for each set of conditions), but it still obeys the requirement of scenario studies that all rules must be stated unambiguously and transparently. Full details of the study have been published elsewhere (Rabbinge and Van Latesteijn, 1992; Rabbinge et al., 1994), here we just give the outcomes of the study with respect to pesticide use. In four different scenarios, characterized by different choices of constraints, future pesticide use was shown to differ widely (Table 2). This explorative scenario study for agriculture in general thus indicated likely consequences of different policy philosophies for crop protection.

Discussion

The examples given above have shown some of the possibilities of scenario studies. The value of the studies depends to a large extent on the quality of the available information. Especially when dealing with global or large-scale regional issues, much quantitative information is lacking and the studies thus should be updated when better information becomes available.

However, all three examples do show the advantage of making one’s assumptions explicit, and of calculating the consequences of those assumptions in a transparent manner. Readers can check the analyses, which ensures maximum objectivity.

The field of scenario studies in agriculture is still young. We may expect it to develop further with respect to methodology, technology and applications.

Methodology

At present the rules used in scenario studies are generally deterministic so the outcome of scenario studies is not accompanied by any measure of reliability. In future, scenario studies may become probabilistic when there is an urgent need for it. That will allow estimation of confidence intervals, but in general the probabilistic approach may be unneeded.

Technology

Scenario studies will benefit from advances in information technology. When data are collected and retrieved faster (sensor networks, satellites), or combined more easily (improved computer hardware, GIS-software), studies aiming at large spatial scales may start to incorporate more fine-grained small-scale information.

Applications

The range of subjects to which scenario studies will be applied, is likely to increase. We especially expect increased application of explorative scenario studies for evaluation of land use options in regions that are agriculturally less developed (i.e. where the technology of agriculture is changing rapidly), and in regions where reduced land availability forces re-arrangement of land use (i.e. where the options for agriculture are decreasing).

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