THE FUTURE OF THE LAND

MOBILISING AND INTEGRATING KNOWLEDGE FOR LAND USE OPTIONS

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Chapter 3 Tension between Aggregation Levels
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CHAPTER 3

Tension between Aggregation Levels

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INTRODUCTION

Land use studies comprise contributions of various disciplines and take place at several levels of aggregation. Tension between aggregation levels and also between disciplines occurs frequently and is partly due to misunderstanding, improper definitions and the absence of well-defined aims of a study. In this contribution definitions of concepts are given and different objectives of land use studies are discussed in an analysis of real and apparent conflicts between disciplines and aggregation levels.

All land use studies consider systems, at a high aggregation level. Crops, or cropping systems, are building blocks in land use studies for farming systems or systems at regional level. Systems are limited parts of reality with well-defined boundaries. The boundaries are selected on the basis of the objectives of the study.

In land use studies, agricultural and other land use systems have to be well-defined. The definition comprises three sets of classification criteria: time, space and the influence of man. The last criterium requires an appropriate description of objectives of a study. Roughly three types of land use studies with different objectives may be distinguished: (i) descriptive and comparative studies, (ii) explorative studies, and (iii) planning studies.

In descriptive, comparative land use studies, the functioning of the system (e.g. the farm household or a region) is investigated. By analysing the various descriptions of the system it is possible to explain the current situation and to gain insight in its limitations. By means of descriptive, comparative system analysis it may be possible to tell something about the near future. In this type of study the influence of man is a very important driving variable in the system analysis.

Another group of land use studies aims at exploring possibilities and potentials for a particular farm or area in the long run. This can be done from a biophysical and technical point of view or in such a way that socio-economic factors are also involved. In studies meant to investigate the biophysical potentials of a particular area, the way

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man manages the system at present is excluded. The potentials in land use of the area are dictated by the soil, the climate and the characteristics of a crop. In explorative studies, concepts like best technical means and best ecological means are used rather than best practical means. In such studies the potentials cannot be translated into consequences for the farming system, or in the day-to-day management of a cropping system or crop. In explorative studies in which socio-economic factors are also taken into account, assumptions on farm management have to be introduced. These studies explore which land use changes can take place, taking into account socio-economic factors also. Management decisions are very often determined by socio-economic objectives and constraints rather than production–ecological possibilities. Land use studies that are meant to identify and explore technical possibilities and limitations are usually relatively narrow and need mainly biophysical knowledge and insight, whereas explorative land use studies in which socio-economic objectives and constraints are included need a much wider interdisciplinary approach.

After certain land use options for the future have been chosen, studies for planning and management become important. The question of how the land use options that have been chosen can actually be achieved is crucial. Policy instruments play an important role in it. Predictive models at various aggregation levels may be very useful. They may help in strategic and tactical planning. At various levels of aggregation other models are needed.

It is vital for any study to identify the appropriate level of aggregation, i.e. the level that corresponds with the objectives of the evaluation. Studies on possibilities at farm level have a different character to those at a regional level. It is important to choose the appropriate aggregation level in relation to the objective of the study and to be explicit about the aggregation level of the study.

In this chapter, production-ecological and socio-economic aggregation levels are discussed, and possible reasons for tension and conflicts between aggregation levels and disciplines are mentioned. An interface between the farm and regional level and various disciplines is given. Finally, possible rules and recommendations to prevent tensions and conflicts are suggested. It may be useful to screen the various case studies on land use against these guidelines.

AGGREGATION LEVELS IN PRODUCTION-ECOLOGICAL TERMS

The basis of all primary and secondary production in agro-ecosystems is the photosynthesis of plants. Individual leaves intercept the radiation of the sun and use its energy for the production of sugars by means of a reaction between carbon dioxide and water. The underlying diffusion of CO_2 and photochemical and biochemical processes can be quantified, thus enabling us to compute the sugar yield from the number of CO_2 and H_2O molecules involved. The sugars are used for the construction of all types of structural components. This construction requires energy that is obtained through combustion of sugar—the so-called 'growth respiration'. Together with the photosynthesis and the growth respiration, the maintenance respiration closes the C-balance at leaf level. Insight in the physical, chemical and physiological processes

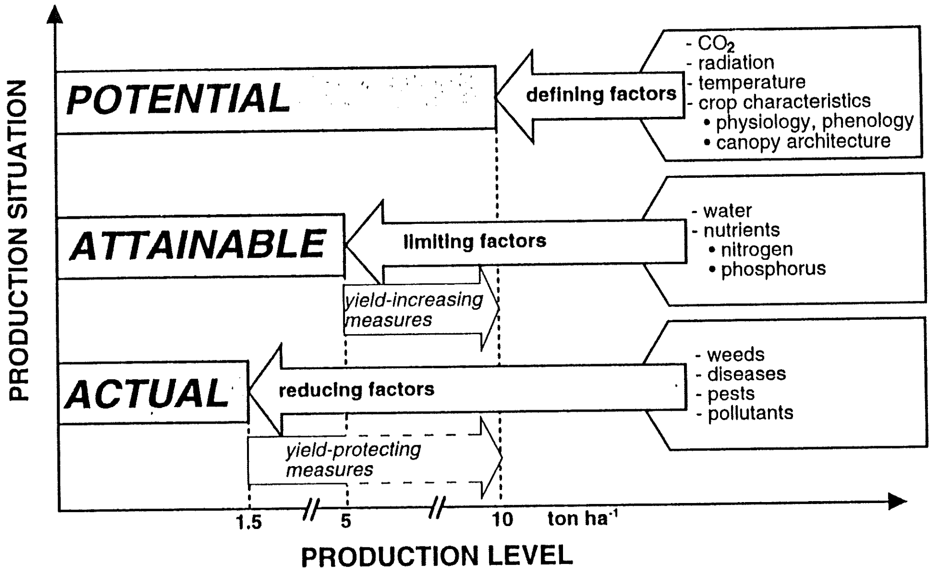

Figure 3.1 Schematic overview of different types of production factors and their corresponding production levels (Reproduced from Rabbinge, 1993, by permission of the Ciba Foundation)

involved in photosynthesis of leaves and respiration forms the basis of production-ecology.

Integration of leaf photosynthesis to crop level (De Wit, 1965) enables the quantification of crop performance under various circumstances. Dynamic simulation models are used for that purpose. At the crop level, various growth factors can be distinguished; the growth-defining, limiting and reducing factors (Figure 3.1). From a plant's point of view, the potential production is dictated by the growth-defining factors climate and characteristics of the crop. The attainable and actual production are determined by production-limiting and production-reducing factors.

A crop is part of a cropping system, and a cropping system is part of land use on the farm and in the region. In land use studies at the farm or regional level, production-ecological concepts and insights may be used to *explore* the system. The biophysical potentials of land units within a system can be investigated using crop growth simulation models. The production-ecological concepts and insights are used in this case only for the exploration of land use potentials and not for prediction, explanation and management support. The latter objectives would require completely different approaches and models.

In a system analysis, the level of detail of each of the underlying levels is dictated by the questions posed at the higher level. The more accuracy or the more quantitative aspects needed at the higher level, the more detail at the underlying level is necessary. In dynamic simulation studies, e.g. crop-growth simulation studies, this is made explicit by using the concept of aggregation level and the spatio-temporal characteristics, scale and time coefficients. Many production-ecological studies, e.g. leaf photosynthesis or

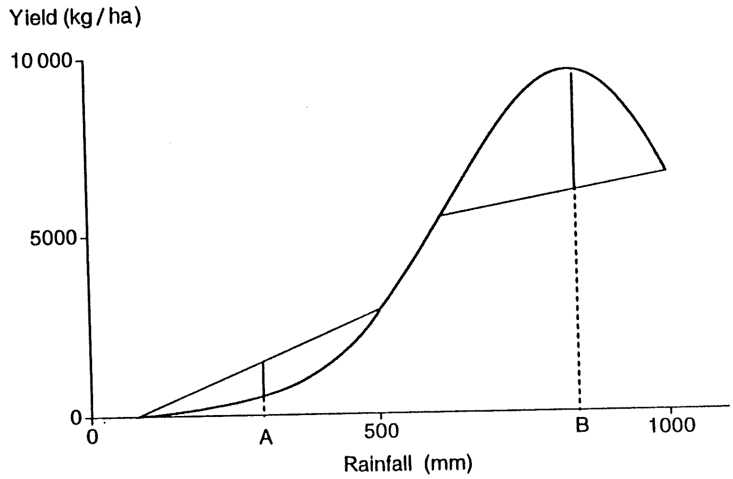

Figure 3.2 The influence of averaging rainfall on its calculated yield response. The yield is underestimated by averaging in the lower rainfall region (A) and overestimated in the higher rainfall region (B). Source: De Wit and Van Keulen (1987) (Reproduced by permission of Elsevier Science Publishers BV)

crop growth analysis, aim at understanding and explanation, and in these studies a detailed crop-growth simulation model is required. However, it does not make much sense to work with a detailed crop-growth simulator in explorative land use studies. The results of detailed crop-growth simulators are very plot-specific and cannot be used for the objective of quantifying (quesstimate) various yield levels in different land evaluation units. Land use studies need crop-growth simulators of a low level of complexity. They should be adequate for the determination of a first estimate of potential and attainable yield for homogeneous units on the soil and climate map. Time coefficients are then normally big and the land units for which yield is estimated are of a considerable size.

Aggregating information from a lower to a higher aggregating level is dangerous when homogeneity at the lower level is absent. Two examples of possible consequences of aggregation in land use studies are given in Figures 3.2 and 3.3. The first concerns heterogeneity in rainfall, which affects the results of a quantitative land evaluation (Figure 3.2). Because of the curvilinear relation between rainfall and yield, the yields are underestimated in the lower rainfall region and overestimated in the higher rainfall region by using average rainfall figures. The second example shows a possible consequence of aggregating land units or sub-regions in a land use study using linear programming (Figure 3.3). By aggregating heterogeneous land evaluation units or sub-regions and averaging the corresponding input–output data of the different units or sub-regions, the extremes in the original input–output data level off. When these aggregated data are used in an LP model the results of an optimisation may be less extreme than when non-aggregated data are used. Suppose a particular region consists of four land evaluation units of 1000 ha each. The wheat yields with a certain production technique in these regions are supposed to be 8, 6, 4 and 2 ton/ha for units 1, 2, 3 and 4, respectively. The objective of the optimisation in this example is to minimise the area in the region

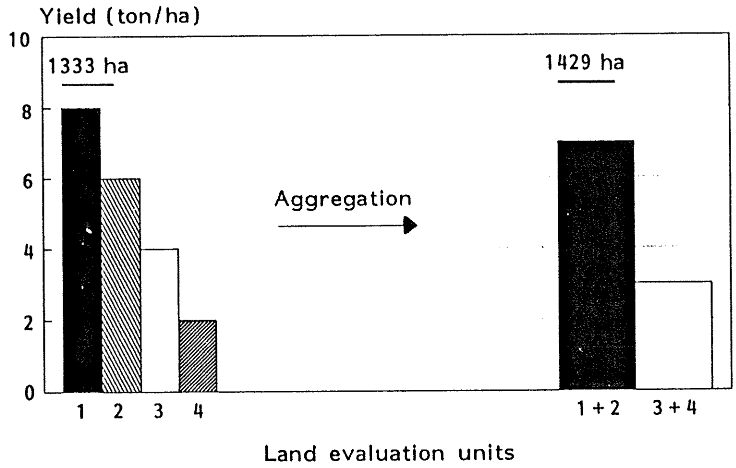

Figure 3.3 The effect of aggregation of four land evaluation units of 1000 ha each to two units of 2000 ha each on the minimum agricultural area required to produce 10 000 ton wheat in the region (4000 ha total). The average wheat yields in units 1, 2, 3 and 4 are 8, 6, 4 and 2 ton/ha, respectively. The average yields in the aggregated units 1+2 and 3+4 are 7 and 3 ton/ha, respectively. The minimum area in the non-aggregated problem is 1333 ha, wheras after aggregation the minimum area is 1429 ha. Source: unpublished data of R. J. Hijmans and M. K. van Ittersum

required to produce 10 000 ton wheat. In Figure 3.3 the effect of aggregating units 1 and 2 and units 3 and 4 is shown. Without aggregation, the minimum area is 1333 ha (1000 ha in unit 1 with 8 ton/ha and 333 ha in unit 2 with 6 ton/ha), whereas after aggregation the minimum area is 1429 ha (1429 ha in unit 1+2 with an average yield of 7 ton/ha). In the aggregated model the minimum agricultural area is larger than in the non-aggregated model.

Heterogeneity in time and space should be handled with care. In land use studies the credo 'first calculate, then average' is valid. Heterogeneity and curvilinearity in input relations should be retained as long as possible and their consequences should be included in the evaluation studies.

AGGREGATION LEVELS IN SOCIO-ECONOMIC TERMS

Many land use studies in socio-economic terms describe the functioning of farm households at micro-level. By analysing the various descriptions at this level it is possible to explore options for change and to get a better insight into limitations. These limitations may be biophysical but are often institutional. They comprise limitations due to shortage of labour, capital, knowledge, infrastructure or policy. Solutions to eliminate such limitations may be described when the functioning of the farm systems is better understood. Lower levels of aggregation than the farm are usually not considered in socio-economic terms. The farm is the basic unit.

Studies on a regional level may be based on the aggregation of studies on a farm level. However, that creates many difficulties as there is variation between individual farms, and limitations at regional level may differ from those at farm level. The 'bottom-up' approach has, therefore, its limitations; aggregating farm level to regional level will lead to ambiguous results. On the other hand, it is very hard to draw conclusions from regional studies about decisions to be made at the farm level. An iterative approach between the regional and the farm level seems a more apt approach, but before substantiating that for explorative studies, we will deal with the tension between the different types of land use studies and disciplines.

TENSION AND CONFLICTS BETWEEN AGGREGATION LEVELS AND DISCIPLINES

The presence of various aggregation levels and many disciplines in land use studies may easily lead to misunderstanding, polarisation and finally absence of any communication. The conflicts and tension often arise from differences in objectives or unclear objectives of a study.

Many studies are concerned with a static description of the present situation and do not take into account the dynamics of systems. On the basis of static observations of present land use, conclusions on the possibilities in the future are possible only up to a certain extent. In the short term, insight into possibilities for change can be given but it is virtually impossible to explore long-term options. In those cases, the future is an extrapolation of past and present, and discontinuities in trends are absent. The future is regarded as restricted by the past and shows no unexpected possibilities. In many socio-economic studies for the short term this type of extrapolation makes sense. Deterministic, descriptive studies are then sufficient.

New results are possible when the past is not used as a measure for the future but when political or societal desires are combined with technical possibilities. This means explorative instead of predictive studies, which use plausibility and predictive value as the criteria for measuring the quality. In explorative technical studies plausibility is not important but consistency, completeness and scientific soundness of the technical possibilities are the most important criteria for measuring the quality of long-term studies. In explorative studies for land use the relations are not described but based on insight into the input–output relations. In studies that describe the present situation, correlations between various variables and characteristics are used. Causal relations based on an understanding of basic processes are then absent. For explorative studies, a good understanding of the input–output relations is necessary. This may lead to the definition of techniques that are not yet widely used in practice. The feasibility of various options is not based on their relation to the present status, but on the biophysical and technical limitations and possibilities that determine the potential.

Often, in land use studies the behaviour of actors is incorporated and seen as an integral part of land use. In descriptive analytic studies this approach is necessary as actors form part of the way the present situation may be explained from developments in the past. However, in explorative land use studies behaviour of actors should be explicit and choices should be transparent. This may help in the judgement of *a priori* assumptions, expectations and objectives.

Production-ecological studies are in most cases explorative and deterministic, using explanatory models that are integrated in multiple goal explorative models.

Socio-economic studies are in most cases predictive, using descriptive input–output relations based on the past.

POSSIBLE INTERFACE BETWEEN VARIOUS AGGREGATION LEVELS AND DISCIPLINES

In explorative land use studies at the regional level, technical information about land use is confronted with different objective functions in an interactive multiple-goal linear programming model. The technical information can be derived from crop-growth simulation models, literature and expert knowledge, and the objective functions can be distilled from the different policy views in the region. The time horizon (e.g. 25 years) of these studies is far enough away to limit its effect. In this way, different land use options can be generated which represent the different policy views in the system; they demonstrate the extremes in land use from a technical point of view for the long run.

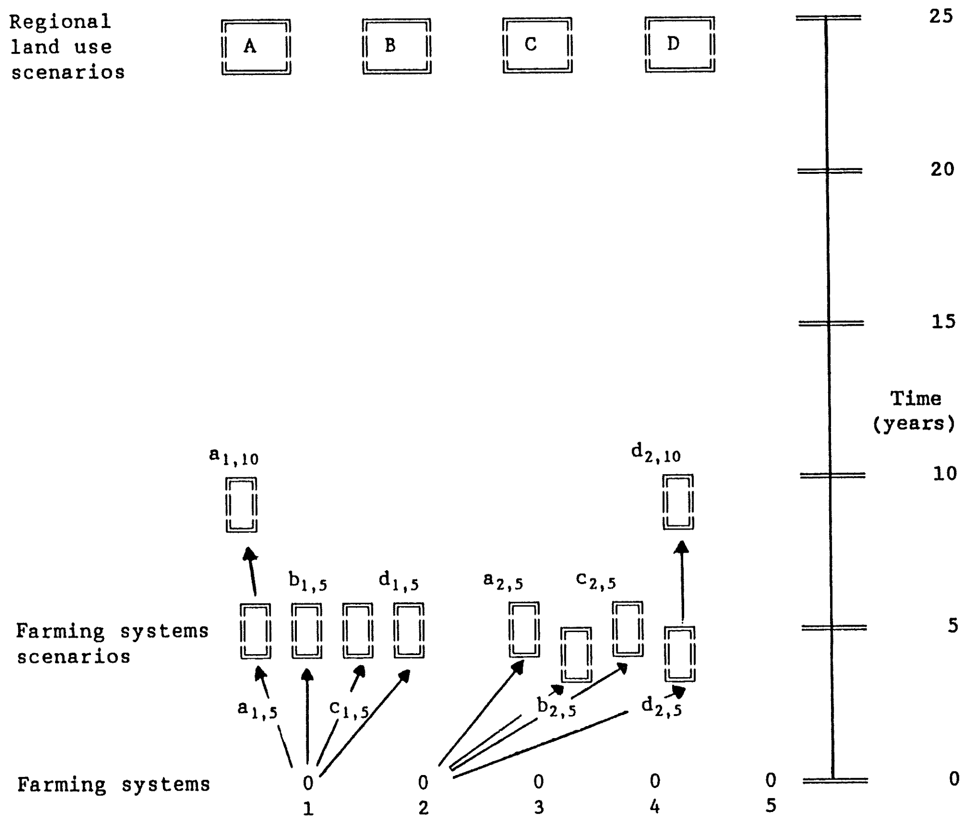

Figure 3.4 Interface between an explorative land use study at the regional level and explorative land use studies at the farming system level within the region. A, B, C and D are regional scenarios representing different policy views. $a_{1,5}$: Scenario a (priority of different objectives similar to those in Scenario A for the region) for farming system 1 in year 5; $d_{2,10}$: Scenario d (priority of different objectives similar to those in Scenario D for the region) for farming system 2 in year 10

However, these studies do not show the consequences for the individual farms within the region. The relation with the actual situation and short-term options is absent but may be achieved with a procedure explained in Figure 3.4.

The regional land use options set the scene for more detailed studies at farm level. This can be done in an iterative way. Different farming systems in the region can be distinguished. For each of these farming systems explorative studies can be carried out with much shorter time steps (e.g. 5 years) by confronting technical information about land use on the farm with the objectives of the farmer and those of the region in LP models. Different scenarios for each of the farming systems can be generated by putting different weights to the objectives of the region. For the first time interval, the land use activities that are offered to the linear programming model are more closely related to the current land use activities, whereas for later intervals they are more closely related to possible future land use activities. From these explorative farm studies an answer to the question of whether individual farms (farming systems) may be capable of reaching the land use patterns found in the regional study might be obtained. Often structural changes in size and structure are necessary. Exploration with studies at farm level may help to gain insight into the way transfer can take place. These studies should demonstrate whether institutional, socio-economical or cultural factors limit the attainable changes in the near future. Such studies require detailed economic and social analysis of the present situation. The connection with explorative studies for the long term may take place from both sides, from the present and from the potential future. When necessary the regional studies may be made more dynamic by the introduction of various time horizons (Spharim et al., 1992).

Both in the regional and farm studies the definition of the boundaries of a system, the elements of the system and the influences of the environment are very important. At the farm level the 'farm gate' is the appropriate boundary; however, it should be clear whether income generated outside the farm but used for investment in the farm is taken into account. At a regional level, for instance, it is important to be explicit about possible imports and exports of products; in other words, to distinguish between policies aiming at self-sufficiency for agricultural products or those aiming at free market and free trade.

GUIDELINES

To prevent misunderstanding and lack of communication between disciplines and aggregation levels, some guidelines have been formulated:

(1) Describe the objectives of land use studies explicitly. The objectives of the study determine the size of the system, its boundaries and the environment. The objectives may vary from an investigation of the short-term perspectives of an individual farm to an exploration of possible land use in a region.
(2) Define the system and its boundaries in time, space and influence of man. Systems as a limited part of reality are not a construct but are quantifiable and identifiable phenomena. Models are simplified representations of systems.
(3) Describe the next lower level and next higher level of aggregation. The definition

of the system and boundaries enables a clear description in general terms of the next lower and next higher levels of aggregation. The relation between aggregation levels can be identified in that case. It is impossible to consider at once (for example, in one model) more than three aggregation levels. It will lead to unreliable results or to unjustified conclusions.

(4) Identify the external influences and constraints. Their influence in terms of driving force (e.g. as an effect on the demand for agricultural products in the system) and constraints that dictate the ultimate limits (technical limits, e.g. maximum yields or water availability, and normative limits, e.g. a minimum employment rate) should be defined.

(5) Determine the internal variables (activities) related to land use, their interaction and their relation with the environment. The objectives and size of the system dictate these variables. A minimal number of variables is as a preferable strategy.

(6) Make explicit the necessary technical information and the various policy issues. In regional land use studies an indication of various techniques and their organisation is sufficient, whereas studies on a household level require much more detail in the way of labour organisation, income generation, etc. Depending on the objectives and limits of the system, other technical information (e.g. consumption level, imports and exports) is needed.

(7) If explanation is the aim, distinguish clearly between levels. Systems behaviour is explained from the underlying process level. Quantification of explicit relations at a process level form the backbone of the explanation and understanding of systems behaviour.

(8) If prediction is the aim, be sure of the reliability of the models. Models that are used for predictions should be validated and their sensitivity for changes in inputs and input relations should be tested. Their robustness or fragility should be quantified and considered in the predictions.

(9) If exploration is the aim, do not pretend to predict. Often explorative studies are interpreted as predictions. If plausibility and not consistency or technical possibility is considered as a criterion for the value of an explorative study, this may lead to the wrong type of discussion.

(10) If decision-making is the aim, determine exactly the appropriate decision variables. Decision-making, be it strategic, tactical or operational, requires proper identification of the decision variables. Description of the ultimate decision variables and consequences of change should be quantified. In this way, decision-making is supported by land use studies.

(11) Aggregate or average as late as possible. Aggregation or averaging input data may lead to the wrong results. 'First compute/calculate and then average' should be the credo. Another order leads to the wrong results in cases of curvilinear input relations or in cases of much variation due to stochasticity of input data.

(12) Never disaggregate in order to derive guidelines for management decisions at a lower aggregation level. The relation between micro, meso and macro level in socio-economic studies is a critical one. The same holds for aggregation levels in production-ecological studies. It is dangerous to draw conclusions from studies on the meso or macro level for individual situations at micro levels. The study at the

meso or macro level shows the ultimate consequences of the choices of policy-makers at that level. They do not indicate what decisions have to be made at the micro level.

The guidelines and suggestions described above may be used as a checklist in the evaluation of case studies on land use. Awareness of these guidelines may increase the quality of these studies and indicate what may be expected and for what purpose the studies may be used.

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