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H.A.J. van Lanen
J. Bouma
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Phone: +318370-19100; fax: +318370-24812; telex VISI-NL

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MIXED QUALITATIVE/QUANTITATIVE LAND EVALUATION METHODOLOGY APPLIED TO THE EC SOIL MAP. STEP I: SELECTION OF POTENTIALLY FAVOURABLE AREAS

H.A.J. van Lanen*, J.Bouma**, Y. van Randen*

*Soil Survey Institute, P.O. Box 98, 6700 AB Wageningen the Netherlands

**Agricultural University, Department of Soil Science and Geology, P.O. Box 37, 6700 AA Wageningen, the Netherlands

ABSTRACT

Mixed qualitative/quantitative land evaluation methodology has been proposed because the general and descriptive results of qualitative methods are not always adequate. The mixed evaluation approach comprises the screening of land, based on severe climatic and site limitations for a defined crop, using qualitative methods. The more detailed, quantitative methods can then focus on the remaining, potentially favourable land. The mixed evaluation is explained and illustrated for mechanized winter wheat growing in the Dutch part of the EC. Evaluation results, which can easily be obtained from a Geographical Information System (GIS), are presented as maps and tables with the acreage of potentially favourable land, or excluded land, specifying the limitations.

INTRODUCTION

Production surpluses of several major crops in the European Communities (EC) are forcing policy makers to stimulate the introduction of new crops (e.g. oil seed, protein and fibre crops) or short rotation forestry. Futhermore, nature and landscape conservation, and environmental matters also impose restrictions on land use. These developments are likely to affect land use in vast areas within the EC. Adverse socio-economic effects in rural areas could occur if the land use policy is not properly thought out. Land evaluation can help policy makers to define standards. There are different levels of detail in the technical approach of land evalution (Bouma, 1988). These levels vary due to the different questions being asked or to the lack of appropriate data needed to make detailed analyses. Qualitative land evaluation methods, which represent less detailed technical approaches (from farmers' experience to expert judgement) often produce quick but general answers. More quantitative information is usually needed, which can be provided by applying quantitative land evalution methods. The essential difference between qualitative and quantitative procedures is that the latter applies more detailed technical approaches, i.e. the use of simple or complex dynamic simulation models (e.g. Van Lanen and Bouma, 1988). Many crops, and a wide range of site conditions, both actual and potential, can be evaluated using the quantitative procedures. The quantitative evaluation methods require more input data and more sophisticated tools (e.g. computers) than the qualitative ones, so application is generally more expensive. Because of these costs, the most efficient use of quantitative methods would be to combine them with the qualitative ones. This mixed approach involves the broad screening of all land for moderate or severe restrictions for a particular land utilization type, using qualitative evaluation methods, and then applying quantitative methods for the remaining areas which are potentially suitable.

The aim of this paper is: (1) to explain the methodology of the mixed approach within the context of available data bases on an EC scale and (2) to illustrate the methodology used in the Dutch part of the EC for one specific crop.

METHODOLOGY OF THE MIXED APPROACH

When defining the possibilities of new crops within (parts of) the EC, mixed qualitative/quantitative land evaluation methodology starts by characterizing the crop or the crop rotation (Fig. 1). This should include farm management information, such as the degree of mechanization, irrigation and, if relevant, whether the land is drained or not.

Minimum climatic requirements needed to grow various crops (e.g. thermal regime, length of growing period) have been described (e.g. Sys, 1985; Van Keulen and Wolf, 1986; Lee, 1986). The minimum climatic requirements of the selected crop(s) are compared with the agro-climatic data of the considered area in order to exclude those areas which have unfavourable climatic conditions. Therefore, the minimum requirements are compared with the agro-climatic data of the considered area. Areas are excluded if the climatic conditions of a particular area do not meet the minimum requirements of that particular crop. It is to be expected that the climatic data (mean monthly figures) can be obtained fairly quickly from EC agro-climatic data bases. These are being compiled within the context of the CORINE programme and by Verheye et al. (1986).

After screening areas for climatic constraints, other minimum site requirements must be defined. Both crop and management requirements are taken into account. When defining minimum site requirements, the relatively limited availability of data on a small-scale map, such as the

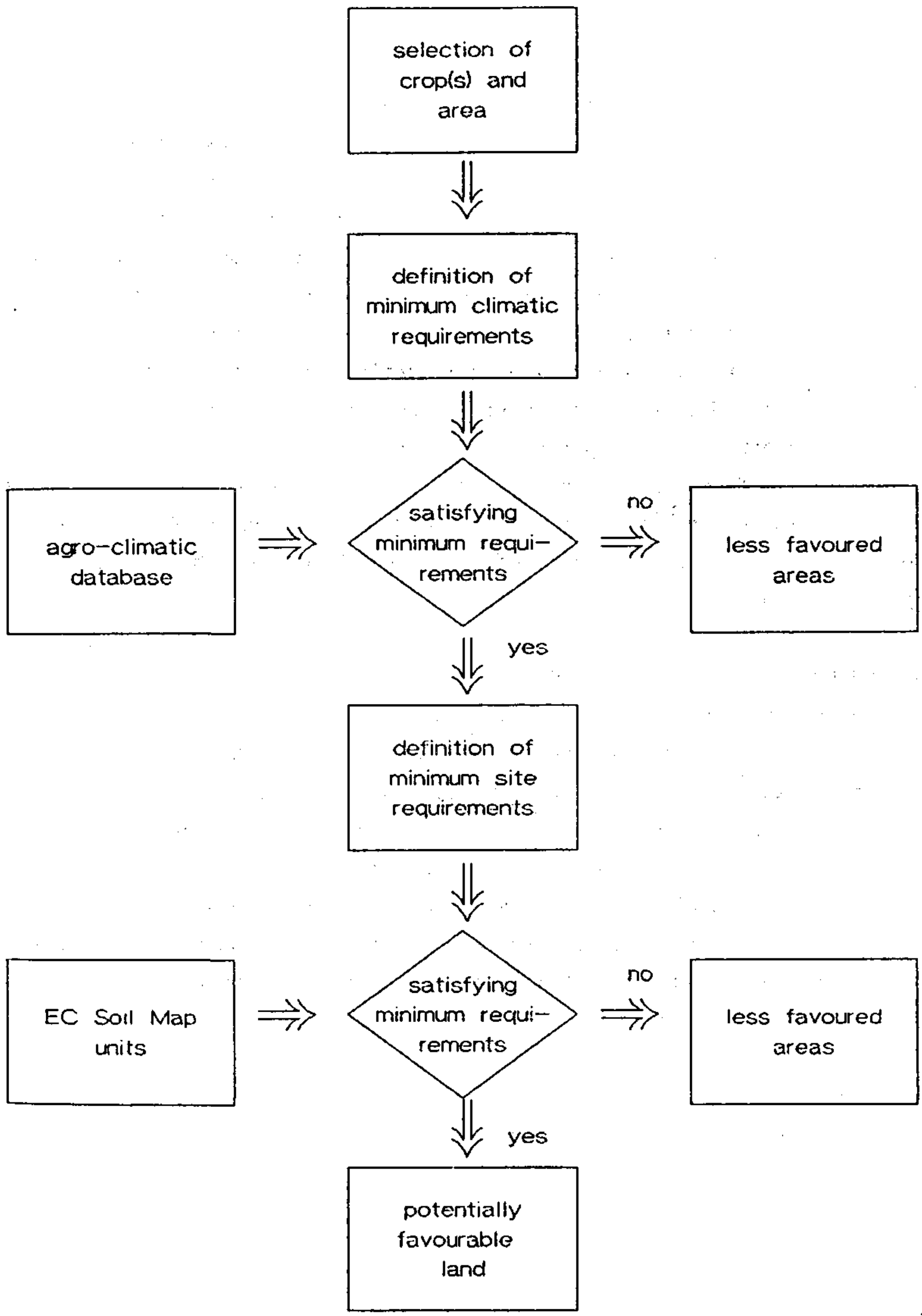

Fig. 1 Relational diagram of the mixed qualitative/quantitative land evaluation method.

EC Soil Map (EC, 1985), should be considered. The minimum site requirements might be defined in terms of slope, soil texture, soil wetness, stoniness, soil depth and salinity. Then, the soil units which occur on the EC Soil Map in areas without climatic limitations, are compared with the minimum site requirements. If the soil unit does not meet the minimum requirements, it should be excluded as less favoured land for that particular crop. So, the remaining land has no severe climatic or site limitations. This potentially favourable land could, if relevant, be analysed in more detail.

The knowledge incorporated in qualitative land evaluation methods (e.g. Haans and Heide, 1984; Sys, 1985; Verheye, 1986) can be efficiently used in the screening process. The principle of matching crop requirements to land characteristics or land qualities using these methods, provides a useful tool for distinguishing land with severe limitations (unsuitable land) for a particular use. If necessary, poorly or moderately suitable land can also be excluded by applying such qualitative evaluation methods. The Dutch part of the EC Soil Map is stored in a Geographic Information System (GIS). This information is readily accessible (Van Lanen et al., 1988). Maps showing delineations of excluded land and tables with acreage, derived from qualitative evaluation methods, can be rapidly (re)produced.

Summarizing the procedure: two sieves are used; an agro-climatological sieve and, subsequently, a physiography soil sieve leading to a Boolean result (suitable or unsuitable) in relation to crop and management requirements.

RESULTS

The application of the mixed qualitative/quantitative land evaluation approach is illustrated for mechanized winter wheat growing in the Dutch part of the EC (Fig. 2). The cropping of winter wheat is part of a high input agricultural production system (e.g. optimal application rates of fertilizers, optimal weed and disease control). Land is conventionally tilled, including ploughing before seedbed preparation. It is assumed that there is no supplementary irrigation. The soils are drained if necessary.

To screen the land for severe limitations for growing winter wheat, the following land characteristics and land qualities (FAO, 1976) are used: temperature regime, slope, stoniness, salinity, alkalinity, germinating conditions, workability of the land, resistance to erosion,

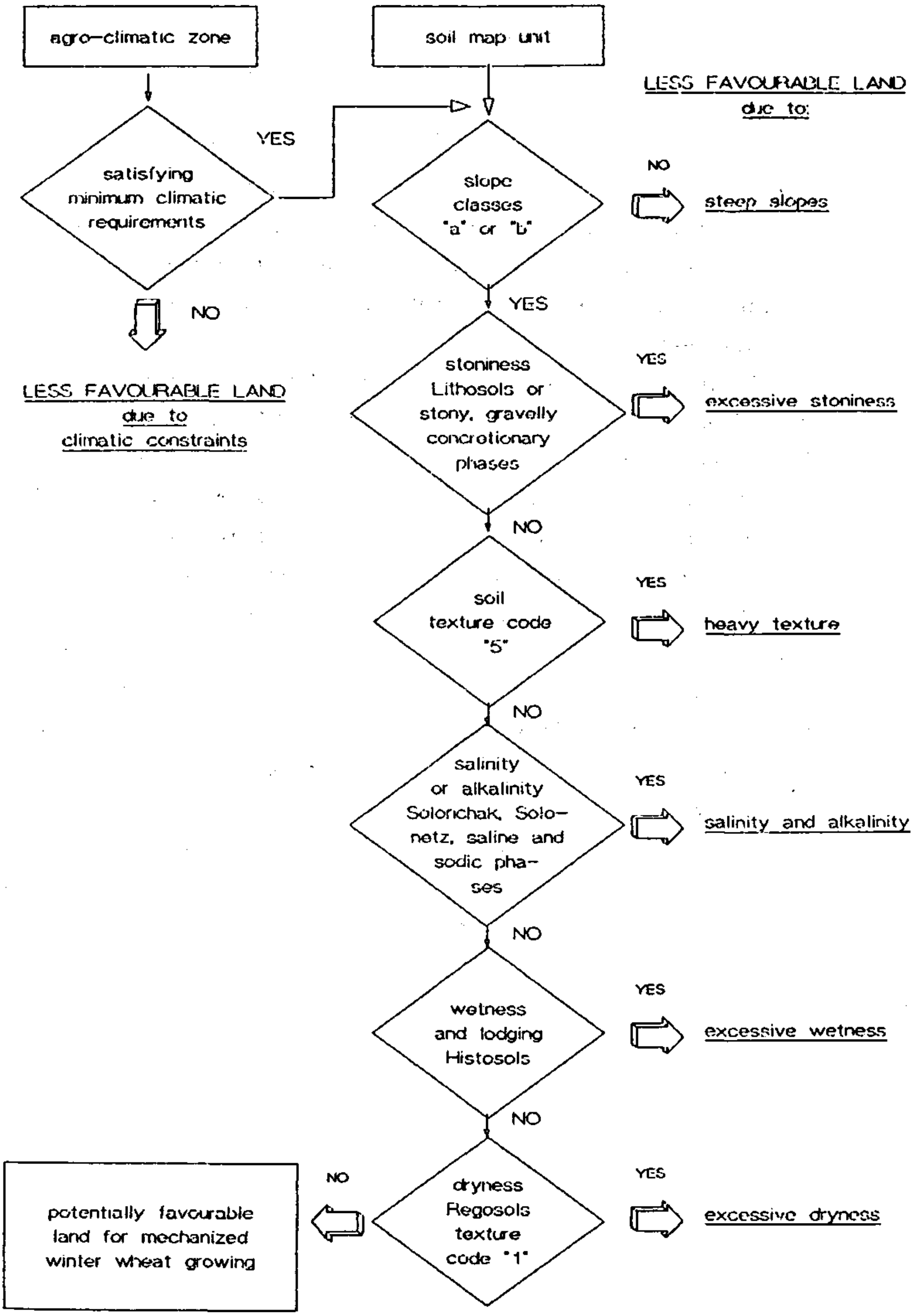

Fig. 2 Relational diagram to exclude less favourable areas for mechanized winter wheat growing.

and moisture availability.

Screening for climatic restrictions

The optimal period for sowing winter wheat is from mid-October to mid-November. Usually, winter wheat is harvested in July or August. The most important requirement of the crop is the need for a cold period in which to vernalize. In the early development stage, winter wheat is strongly resistant to frost (down to temperatures of -20 °C). When analysing the agro-climatic conditions of the EC, areas without cold winters (central and southern parts of the EC) must be excluded. During spring and summer, the winter wheat crop, with many varieties, can grow in a wide range of temperature regimes. Thus, the thermal conditions (e.g. minimum spring temperatures or maximum summer temperatures) of the remaining areas, including the Netherlands, do not result in the discrimination of other unfavourable areas. If, however, other crops, such as grain maize, olives or vine were selected to evaluate the potentials of the EC, the geographic delineation of the potentially favourable areas within the EC would be completely different. The thermal conditions of the northern member states would not allow a further detailed land evaluation analysis.

Screening for site conditions

After screening for severe climatic limitations, the remaining land is evaluated for severe site restrictions. Mechanized farming requires slopes of less than 15 %. Anything more than that hampers traffic and tillage operations. The negative consequences of water erosion on annual arable land should be minimized, including adverse off-site effects. Therefore, land having slope classes "c" or "d", which refer to slopes of more than 15 % (EC, 1985), should be excluded. Remaining land is then screened for stoniness. Excessive stoniness could inhibit cultivation practices, such as ploughing, seedbed preparation, and straw incorporation. Furthermore, stony soils often have limited available water or a shallow soil depth, which means high susceptibility to water stress, even under the relatively favourable Dutch climatic conditions (Hack-ten Broeke and Kabat, 1988). Land classified as Lithosols, or land having a stony, gravelly or concretionary phase, must be excluded. Heavy clay soils (texture code "5") are also characterized as unsuitable, because of serious problems with ploughing and straw incorporation. Salinity and alkalinity might also impose restrictions on land used to grow wheat. Although winter wheat is moderately tolerant to salinity and alkalinity, land classified as Solonchaks, Solonetz, or land having a saline or sodic phase, will show severe yield reductions. Hence, these salt-affected soils are classified as unsuitable. Remaining land should be appraised on both excessive wetness and dryness. Usually, (reclaimed) peat soils, classified as Histosols, are too wet for winter wheat. There is no point in having a deep and intensive drainage system, because the peat would shrink and waste away too quickly. Although peat soils can be characterized as wet soils, low moisture contents in the upper few centimetres of the topsoil usually prevent optimal emergence in autumn. Furthermore, peat soils are excluded from detailed analysis, because of the high lodging risk to the wheat crop. Finally, soil units classified as Regosols, which have a coarse soil texture, are characterized as unsuitable. These soils are very susceptible to drought even under Dutch climatic conditions. The excessive dryness characterization is derived from the pedogenic name and the soil texture. A more general estimate of the drought susceptibility of a particular area can be made if soil and climatic conditions were to be combined. The soil droughtiness, which considers plant available water, growing season rainfall and potential transpiration (e.g. McKeague et al., 1984) would be a better standard by which to exclude land due to excessive dryness.

Areas with particular limitations and potentially favourable regions for growing winter wheat are presented in Figure 3 for the Dutch part of the EC. The acreage of excluded land and potentially favourable land is summarized in Table 1. About 15 % of Dutch agricultural land has severe limitations for the growing of winter wheat. This estimate is five times higher than the assessment made by Lee (1987). He concluded that 9 % of Dutch arable land, which means about 3 % of all agricultural land, is unsuitable for arable farming.

If the well-drained sandy soils, which are moderately susceptible to drought, were also excluded, the potentially favourable area for growing winter wheat would drop from 85 % to 60 %. The remaining potentially favourable land could be analysed in more detail by using quantitative land evaluation procedures (e.g. Hack-ten Broeke and Kabat, 1988; Van Lanen and Bouma, 1988).

TABLE 1 Acreage of excluded land and potentially favourable land for growing winter wheat.

Limitation	Excluded (km^2)	Potentially favourable (km^2)
climatic	0	28 410
slope	0	
stoniness	630	
heavy texture	0	
salinity and alkalinity	0	
wetness and lodging	3220	
dryness	930	

DISCUSSION

When the results of a qualitative land evaluation system are inadequate, a mixed qualitative/quantitative land evaluation approach can be applied. The approach efficiently combines expert judgement incorporated into the qualitative methods, and current process-oriented agroecological knowledge into quantitative procedures. Expert judgement is used to define areas of land that have severe climatic and site limitations, while the application of the more expensive quantitative methods, including data collection, is focused on potentially favourable land. The quantitative methods can be applied in different ways. Essential to the quantitative methods are process-oriented dynamic simulation models. Different types of models, from simple to comprehensive, are available within the context of land evaluation. Input data can be measured (e.g. Carter, 1988), or estimated (e.g. Bouma and Van Lanen, 1987; Kabat and Hack-ten Broeke, 1988).

Currently, quantitative methods can cope with only part of all land qualities, distinguished by FAO (1986). When land qualities which cannot be dealt with by the quantitative procedures are important, the mixed qualitative/quantitative approach is a prerequisite.

The mixed evaluation methodology, as explained in this paper, is physical by nature. Other constraints on land use, such as environmental restrictions (e.g. nitrate leaching risk) as illustrated by Proctor et al. (1988) can be incorporated.

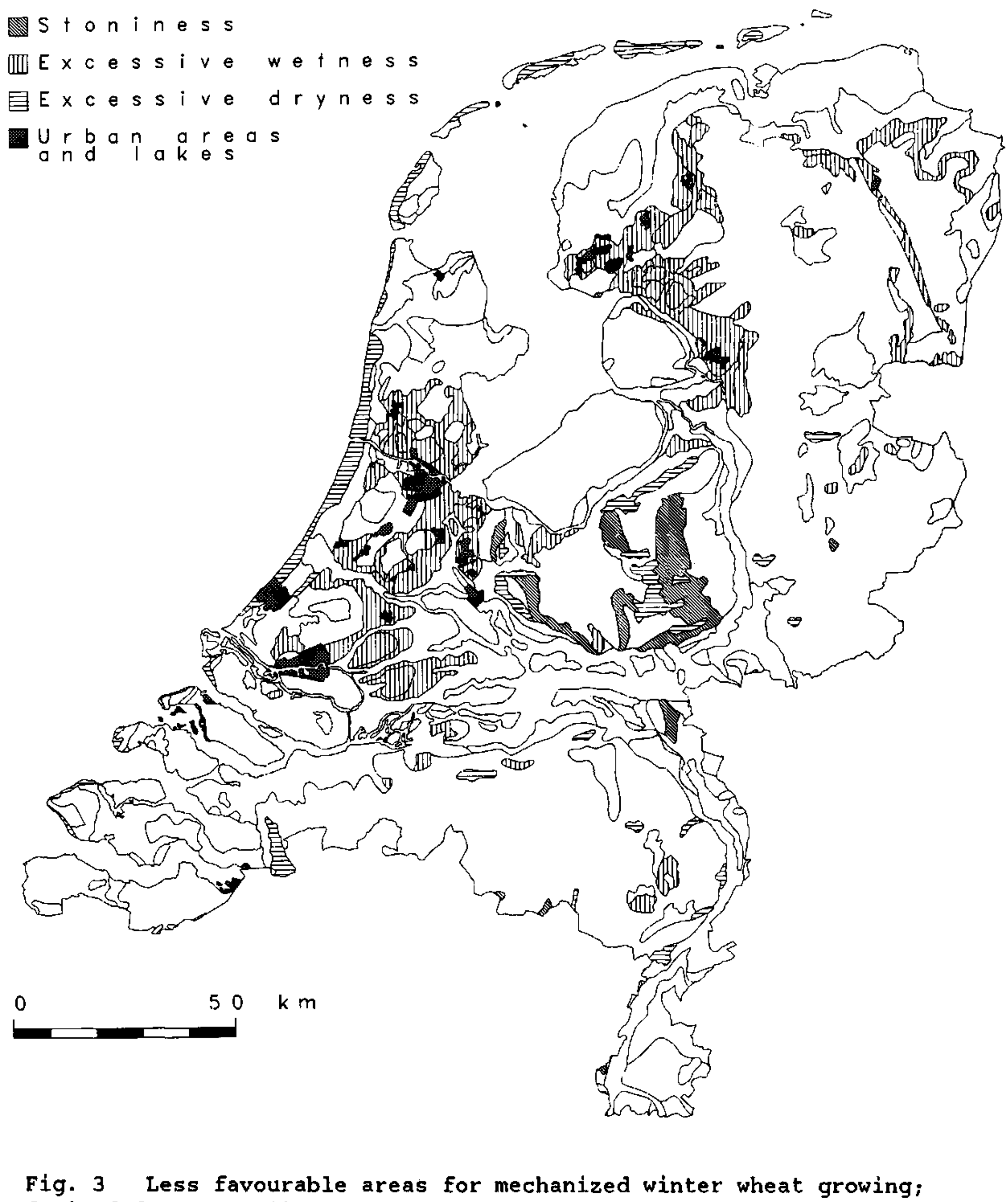

Fig. 3 Less favourable areas for mechanized winter wheat growing; derived from EC Soil Map scale 1 : 1 000 000.

The results of the mixed evaluation approach may be validated using remote sensing techniques, as far as predictions for the actual situation are concerned.

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