Environmental Quality Criteria for Agricultural Landscapes

SWEDISH ENVIRONMENTAL
PROTECTION AGENCY

Preface

The following assessment criteria are intended to facilitate the interpretation of data on: the distribution and characteristics of agricultural landscapes; the chemical and physical characteristics of cropland; and levels of unhealthy substances contained in crops.

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Summary

The Swedish agricultural landscape is a natural resource of great quality. Its ability to produce crops has increased dramatically in recent decades, as the result of technological developments and more intensive farming methods. Land that is farmed with traditional methods can provide habitat for a rich diversity of plant and animal species, most of which are dependent on the continued use of traditional methods.

The most serious threats to the biological diversity of agricultural landscapes are the removal of farmland from production in marginal areas, and the overgrowth that follows reduced utilisation of land which is still being farmed. Deposition of airborne pollutants containing nitrogen also contributes to increasing overgrowth.

The long-term threats to the quality and production capacity of cropland are related to farming methods, which can have both positive and negative consequences for crop quality and the soil's chemical and physical characteristics. Excessive applications of nutrients may also result in their leaching to surrounding bodies of water.

The assessment criteria for agricultural landscapes are intended to facilitate the interpretation of data relating to such problems and their consequences.

Distribution and Characteristics of Agricultural Landscapes

Presented here are three different measures of the distribution and characteristics of agricultural landscapes. Through repeated observations, it is possible to monitor changes over time which can be described and classified according to uniform criteria.

Background

In many respects, agricultural landscapes are created or at least transformed by humans. This makes it difficult to specify original or ideal conditions which could provide a basis of comparison for evaluating a landscape's current characteristics. Therefore, assessment criteria for agricultural landscapes include neither reference values nor a classification of deviations.

Nevertheless, changes to agricultural landscapes can be of the utmost importance for biological diversity, production capacity, aesthetic values, etc. Considerable change has taken place since World War II. Large areas of farmland have been taken out of production, and farming methods in the remaining areas have become increasingly intensive. While the total area of agricultural landscape has declined, it has also become more homogeneous.

Such a development can be interpreted in a variety of ways. The following discussion deals with farmland as a proportion of the total, the distribution of various types of land, and the presence of point and linear features in the landscape. Any changes to such features can be interpreted and classified according to the same criteria, which are presented in the following table:

Changes in the proportion of farmland, areas with different types of land, and presence of point and linear features

Class	Increase/Decrease	Change (annual %)
1	Large increase	> +1.0
2	Slight to moderate increase	+0.3 – +1.0
3	No or little change	-0.2 – +0.2
4	No to moderate decrease	-1.0 – -0.3
5	Large decrease	< -1.0

Proportion of farmland

Active farming is a basic requirement for the preservation of the biological diversity of agricultural landscapes. If farmland's proportion of the total decreases, conditions for biological diversity usually deteriorate. Removing farmland from production in areas dominated by agriculture may, however, lead to greater landscape variation, and thereby to higher species diversity.

Farmland is here defined as including meadows, grazing land and all components of the landscape that are associated with such uses. Farmsteads and roads are also included.

Data on farmland's proportion of the total land area can be derived either from the interpretation of infrared aerial photographs or from agricultural statistics.

Note that the foregoing table states any changes in the proportion of farmland as percentage changes (not area percentages). Thus, if the proportion of farmland in a given area decreases from 50 to 49 percent during the year, the annual change is given as -2 percent.

Areas with different types of land

Many species and communities of plants and animals are associated with specific types of land in the agricultural landscape, such as meadows or pastures. The presence of different types of land therefore constitutes a more specific index of preconditions for biological diversity than does farmland's proportion of the total area.

Decreases in the area of agricultural landscape usually leads to less biological diversity. But in areas dominated by agriculture, the conversion of cropland to other types of land can have positive consequences for diversity.

The types of land that best lend themselves to evaluation are:

- cropland
- cultivated grazing land
- natural grazing land
- meadows

It is also possible to make other kinds of distinctions, for example between different types of ecosystem. The proportion of various types of land or ecosystem within a given area can be calculated through the use of infrared aerial photos in combination with observations on the ground.

Point and linear features of the landscape

Features that differ markedly from an otherwise fairly uniform agricultural landscape can be important as refuges and migration routes for many species. Such features can usually be sorted into two general categories – linear and point.

Linear features	**Point features**
Tree rows and avenues	Field "islets"
Verges	Fieldstone heaps
Stone walls	Isolated trees or groves
Open ditches	Water accumulations
Rivers, streams and dry riverbeds	
Vegetation margins	

As a result of increased efficiency and mechanisation of agriculture since World War II, such landscape features have often been regarded as obstacles to rational farming, and removed accordingly. It is only in recent years that they have become protected by legislation. But an even greater number of point and linear features have been eliminated due to cessation of farming and its replacement by other land uses, and this trend continues today. As far as biological diversity is concerned, this development has only negative consequences.

The extent of point and linear features within a given area is calculated and stated as their combined length and number per square kilometre. Individual linear features should be at least 30 metres in length in order to qualify, and one-quarter of a hectare (2500 square metres) is an appropriate maximum size for individual point features.

Quality of Agricultural Landscapes

Declining utilisation of farmland for such purposes as hay-making and grazing results in overgrowth and a general reduction of biological diversity. Three methods for monitoring and assessing such a development are presented below.

Background

Regular utilisation of meadows, grazing land and other farmland is essential to the biological diversity of such land. Many species of the agricultural landscape are dependent on continuous utilisation. Otherwise, the species that are dependent on such open land are displaced by tall grasses, herbs, and eventually by shrubs and trees. That overgrowth leads to reductions in biological diversity. Farmland which is entirely abandoned is soon transformed into forest land.

Degree of utilisation – ground level

The degree of utilisation can be assessed by observation of ground-level vegetation at the end of the growing season. Among ground-level vegetation are usually included all vascular plants, including shrubs and trees, that are less than one metre in height.

Degree of utilisation at ground level

Class	Degree	"Use coefficient"	Description
1	High	1	Adequate grazing or cutting at ground level
3	Low – moderate	0.5	Inadequate grazing/cutting; some overgrowth
5	Null	0	Overgrowth

Any change in the utilisation of larger areas can be evaluated by means of the repeated classification of individual sub-areas (meadows, pastures, etc.). Every sub-area is assigned a “use coefficient” based on the foregoing table. Changes in the average use coefficient for the entire area, adjusted for the square dimensions of the individual sub-areas, are classified according to the following table.

Changes in ground-level utilisation

Class	Extent of change	Change in use coefficient (annual %)
1	Great improvement	> +1.0
2	Little–moderate improvement	+0.3 – +1.0
3	No or little change	-0.2 – +0.2
4	Little–moderate deterioration	-1.0 – -0.3
5	Great deterioration	< -1.0

Degree of utilisation – shrubs and trees (overgrowth)

Farmland which partially or entirely ceases to be utilised eventually acquires an increasingly dense growth of shrubs and trees. The proportion of land area covered by the crowns of shrubs and trees can be used as a measure of the extent of such vegetation.

However, certain types of land in agricultural landscapes have for centuries included an element of shrubs and bushes. This “traditional” vegetation cannot be regarded as overgrowth, and can therefore not be included in the following classification.

Overgrowth of shrubs and trees

Class	Extent of overgrowth	Crown cover
1	None	0 %
2	Slight	1-10 %
3	Moderate	11-25 %
4	Large	26-50 %
5	Very large	> 50 %

Any change in the amount of shrub and tree overgrowth can, after repeated observations of crown cover, be classified as follows:

Changes in extent of overgrowth

Class	Extent of change	Changes in crown cover (annual %)
1	Large decrease	< -1.0
2	Moderate decrease	-1.0 – -0.3
3	No or little change	-0.2 – +0.2
4	Moderate increase	+0.2 – +1.0
5	Large increase	> +1.0

Note that, in the foregoing table, changes in crown cover refer to percentage changes, not changes in area covered. Thus, if crown cover increases from 50 percent to 55 percent in ten years, the percentage change is 1% per year.

Species and communities of organisms

The presence of certain representative species or communities of plants and animals can often be used to describe the characteristics of an agricultural landscape. Such species and communities may be selected from a variety of different categories. Among the best-documented and easiest to observe are birds, moths and butterflies, wood beetles, dung insects, vascular plants, lichens and large mushrooms. The extent of such species and communities can be measured in terms of the number of species or individuals, their distribution, etc.

With repeated observations over a number of years, it is possible to develop some idea of changes in the population of a species or community within a given area. Such changes can be classified according to the following table.

Changes in species or community population

Class	Extent & direction of change	Annual % change
1	Large increase	> +1.0
2	Slight – moderate increase	+0.3 – +1.0
3	No or little change	-0.2 – +0.2
4	Slight – moderate decrease	-1.0 – -0.3
5	Large decrease	< -1.0

Cropland Quality

Chemical and physical analyses of cropland have been carried out for a long time, primarily in order to gauge the earth's productivity and its suitability for growing crops. In addition to such analyses, this section also deals with the evaluation of the potential impact of farming on bodies of water in the vicinity of cropland.

Acid/alkaline conditions in cropland

Soil acidity has great significance for the production capacity of cropland, which declines if pH values become too low.

Acidification of Swedish cropland is caused primarily by biological processes, but deposition of acidic pollutants and the use of acidifying fertilisers also contribute. The regular application of lime to cropland is necessary in order to counteract acidification.

Soil acidification leads to lower levels of base cations such as those of calcium and magnesium; put differently, it lowers the base saturation.

Base cations are important plant nutrients, which means that plant growth is often more sensitive to a reduction of base saturation than to the underlying acidification. For that reason, the assessment criteria for acid/base conditions of cropland presented here are based on both pH value and base saturation.

The values cited in the table below refer to topsoil at depths of 0–20 centimetres and sub-soil at depths of 40–60 centimetres. The pH values are distributed between mineral-rich and humus-rich soils. Soils of the latter type are in most cases relatively acidic, but they can have lower pH values than mineral-rich soils without any negative effects on the size of harvests. The pH tables also include data on the classification of Swedish topsoil resulting from a nation-wide survey in 1995.

pH values in mineral-rich soils

Class	pH level	pH_{H2O}	Description	% of total
1	Very high	> 7.0	Rich in carbon	11
2	High	6.5-7.0		22
3	Moderate	6.0-6.5	Good calcium supply	33
4	Low	5.5-6.0	Liming recommended	27
5	Very low	< 5.5	Poor root growth	7

pH conditions in humus-rich soils

Class	pH level	pH_{H2O}	Description	% of total
1	Very high	> 7.0		11
2	High	6.5-7.0		2
3	Moderate	5.5-6.5	Good calcium supply	44
4	Low	4.5-5.5	Liming recommended	42
5	Very low	< 4.5	Non-arable	1

Base saturation in mineral-rich soils

Class	Saturation level	% soils with pH 7	Description
1	High	> 70	Optimal conditions
3	Moderate	50-70	Liming required
5	Low	< 50	Risk of plant nutrient deficiencies

Accessible phosphorus and potassium in cropland

In addition to nitrogen, phosphorus and potassium are among the most important plant nutrients, and deficiencies of them result in lowered production. Due to heavy applications of phosphate fertilisers since World War II, however, phosphorus deficiency is fairly unusual in Swedish cropland. Very high levels of phosphorus and calcium (class 1 in the table below) do not result in higher production than the levels of class 2.

Plants are only able to take up that phosphorus and potassium which is available to them in readily accessible forms. With a special chemical, ammonium lactate-acetate, the substance in question can be extracted for the purpose of determining its concentration. The results are expressed as P-AL (phosphorus) and K-AL (potassium).

Measurements of this type are used in the development of Sweden's agricultural soil charts. The scale used with those charts has been applied to the classification of soil conditions in the tables below (Roman numerals).

The levels of phosphorus and potassium cited in the tables below refer to topsoil at depths of 0–20 centimetres and sub-soil at depths of 40–60 centimetres. The tables also include data on the current distribution of Swedish cropland among the various classes. (Distribution of phosphorus levels refers only to topsoil.)

Levels of readily accessible phosphorus (P-AL) in top- and sub-soils

Class	Level	P-AL class	P-AL (mg P/ 100 g soil)	Description	% of total
1	Very high	V	> 16	Surplus of phosphorus	12
2	High	IV	8-16	Very good supply of plant nutrients	34
3	Moderate	III	4-8	Good supply of plant nutrients	36
4	Low	II	2-4	Deficiency of plant nutrients	12
5	Very low	I	< 2	Serious deficiency	1

Levels of readily accessible potassium (K-AL) in top- and sub-soils

Class	Level	K-AL class	K-AL (mg P/ 100 g soil)	Description	% of total
1	Very high	V	> 32	Surplus of potassium	2
2	High	IV	16-32	Very good supply of plant nutrients	18
3	Very high	III	8-16	Good supply of plant nutrients	45
4	Low	II	4-8	Deficiency of plant nutrients	30
5	Very low	I	< 4	Serious deficiency	5

Risk of nitrogen and phosphorus leaching from cropland

If the supply of nitrogen or phosphorus in cropland is greater than the capacity of crops to make use of it, there is a risk that those nutrients will leach out into surrounding bodies of water. This usually leads to eutrophication (over-fertilisation) of the affected waters.

The risk of leaching depends to a large extent on the type of crop, fertilisation, methods of cultivation and other agricultural factors, but also on climatic factors. All of these factors can vary widely from year to year. But particularly in the case of humus-rich soils, the risk of nitrogen leaching is also related to soil characteristics that are less subject to change, and not very easy to influence through choice of farming methods. For humus-rich mineral and organic soils, it is therefore possible to evaluate the risk of nitrogen leaching on the basis of the soil's total nitrogen level.

Risk of nitrogen leaching from humus-rich mineral soils

Class	Humus depth (m)	Total nitrogen (%)	Estimated nitrogen mineralisation (kg/ha/yr)	Risk of nitrogen leaching
1	1.0	< 0.25	< 250	Moderate
1	0.5	< 0.5	< 250	Moderate
3	1.0	0.25-0.4	250-400	Great
5	1.0	> 0.4	> 400	Very great

Risk of nitrogen leaching from organic soils

Class	Humus depth (m)	Total nitrogen (%)	Estimated nitrogen mineralisation (kg/ha/yr)	Risk of nitrogen leaching
1	1.0	< 0.85	< 250	Moderate
1	0.5	< 1.7	< 250	Moderate
3	1.0	0.85-1.35	250-400	Great
3	0.5	1.7-2.7	250-400	Great
5	1.0	> 1.35	> 400	Very great
5	0.5	> 2.7	> 400	Very great

Prior to the introduction of commercial fertilisers, phosphorus levels in Swedish cropland were low. But since imported feed and phosphate additives have come into common use, levels of both slow- and fast-dissolving phosphorus have increased generally, thus increasing the risk of phosphorus leaching.

As with many soil processes, phosphorus leaching is complex. In addition to the quantity of fertiliser applied, leaching is affected by several factors concerning which detailed knowledge is still lacking. Evaluating the risk of leaching therefore implies a degree of uncertainty, but is nonetheless urgent.

Here, evaluations of the risk of leaching from cropland are based on the level of readily accessible phosphorus (P-AL) in the soil; the evaluation process applies only to mineral-rich soils. (In sloping terrain, phosphorus can also be transported via draining water; but that is not dealt with here.)

In most cases, data on phosphorus are available only for topsoil; and in such cases, evaluation of leaching risk is based on that data. If data on P-AL are available for sub-soil, they are also used for purposes of classification – with the exception of clay soils (>15 percent clay), for which evaluations are always based on phosphorus levels in topsoil. The table below indicates, as well, the current distribution of Swedish soils among the various risk classes.

Risk of phosphorus leaching

Class	P-AL class	P-AL (mg P/100 g soil)	Risk of extensive leaching	% of total
1	I - III	< 8	Low	49
3	IV	8-16	Slight	34
5	V	> 16	Significant	12

Organic carbon in cropland

The amount of organic carbon in the soil is an index of its humus content, i.e. the proportion of decaying organic matter and living organisms. Organic matter consists of roughly 58 percent carbon. Inadequate levels of organic carbon (or humus) indicate impaired productive capacity – because the soil becomes more difficult to work, for example.

The table below provides a classification of carbon and humus levels in topsoil, as well as data on the current distribution of Swedish cropland among the various classes.

Organic carbon in topsoil

Class	Level	% carbon	% organic material	Description	% of total
1	Very high	> 7.0	> 12	Naturally rich in humus	7
2	High	3.6-7.0	6-12	Good soil structure	11
3	Moderate	1.8-3.5	3-6		57
4	Low	1.2-1.7	2-3		25
5	Very low	< 1.2	< 2	Low production capacity	< 1

Cropland’s soil structure

The use of heavy equipment on cropland compacts the soil. Tractors and other equipment with an axle load over eight metric tons compact not only the topsoil, but also the sub-soil to a depth of ca. fifty centimetres. Surface layers can be restored by ploughing, but beneath ploughing depth the compaction is permanent.

Soil compaction reduces the growth potential of plant roots and thereby lowers productivity. Very dense compaction of sub-soils in class 5 (see table below) can reduce the production capacity of higher layers by as much as one-third.
The following assessment criteria are based on penetrometer measurements of sub-soil compaction.

Compaction of sub-soil (depths of 30–50 cm)

Class	Extent of compaction	Penetrometer resistance (MPa at field capacity)		Effect on root growth
		Light soils (<20% clay)	Clay soils (>25% clay)	
1	Very little	< 1.1	< 1.1	
2	Slight	1.2-1.5	1.2-1.8	
3	Moderate	1.6-1.9	1.9-2.6	Reduced
4	Dense	2.0-2.4	2.7-3.4	> 50% impairment
5	Very dense	> 2.4	> 3.4	No growth in light soils

Soils with 20–25 percent clay are counted as clay soils if they clearly demonstrate a capacity to contract and expand; otherwise, they are counted as light soils. Humus-rich soils are not affected by compaction.

Heavy metals in cropland

Concentrations of heavy metals in Swedish cropland have risen steadily during the 1900s. For copper and zinc, the increase is limited to roughly one percent. But concentrations of lead have increased by ca. 15 percent as a result of airborne pollution; and cadmium has risen by 30 percent due to its presence in commercial fertilisers.

At high concentrations, all the heavy metals mentioned below have toxic effects on plants and/or soil micro-organisms. Even at fairly low concentrations, cadmium may pose a health risk to humans when it is taken up by crops from the soil.

Very low levels of copper and zinc in the soil can lead to harmful deficiencies of those substances in plants.

The heavy metals referred to in the table below are total concentrations (measured after extraction with nitric acid) in topsoil at depths of 0–20 centimetres, and in sub-soil at depths of 40–60 centimetres. The tables also include data on the current distribution of Swedish cropland among the different classes, based on topsoil analysis.

Lead in topsoil and sub-soil

Class	Level	Lead (mg/kg soil)	Effects	% of total top-soil
1	Very low	< 8		3.9
2	Low	8-15		46.7
3	Moderate	15-30		46.6
4	High	30-50		2.4
5	Very high	> 50	Toxic for plants and micro-organisms	0.4

Cadmium in topsoil and sub-soil

Class	Level	Cadmium (mg/kg soil)	Effects	% of total topsoil
1	Very low	< 0.1		7
2	Low	0.1-0.2		47
3	Moderate	0.2-0.3		29
4	High	0.3-0.4		9
5	Very high	> 0.4	Risk of unhealthy levels in crops	8

Copper in topsoil and sub-soil

Class	Level	Copper (mg/kg soil)	Effects	% of total topsoil
1	Very low	< 7	Risk of deficiency in plants	21
2	Low	7-20		57
3	Moderate	20-35		17
4	High	35-50		4
5	Very high	> 50	Toxic to plants	1

Nickel in topsoil and sub-soil

Class	Level	Nickel (mg/kg soil)	Effects	% of total topsoil
1	Very low	< 5		20
2	Low	5-10		33
3	Moderate	10-20		31
4	High	20-30		12
5	Very high	> 30	Toxic to plants	4

Zinc in topsoil and sub-soil

Class	Level	Zinc (mg/kg soil)	Effects	% of total topsoil
1	Very low	< 7	Risk of deficiency in crops	< 1
2	Low	7-50		45
3	Moderate	50-100		46
4	High	100-150		8
5	Very high	> 150	Toxic to plants	< 1

Heavy metals in cropland – deviations from reference values

At deeper layers of cropland sub-soil, it may be assumed that heavy metals are relatively unaffected by pollution and other consequences of human activity. Concentrations at those depths can therefore be used as reference values, i.e. estimates of the concentrations that apply under pristine conditions. The quotient between concentrations of heavy metals in topsoil and those in sub-soil reflects the extent to which the former differ from the latter, and thus provides a measure of the accumulation of heavy metals in topsoil.

Accumulation of heavy metals in topsoil

Class	Level of accumulation	Deviation quotient (topsoil concentration/sub-soil conc.)
1	None	< 1
3	Moderate	1-2
5	High	> 2

Crop Quality

The presence of the toxic heavy metal cadmium in farm crops is on the way to becoming a serious public health problem. Grains account for one-half, and potatoes for one-fifth, of the Swedish population's ingestion of cadmium, which is now very near the level at which health effects may begin to appear. The cadmium levels of crops have gradually increased in recent decades, primarily due to its presence as a contaminant in phosphate fertilisers.

Cadmium levels in crops are directly related to those in topsoil, but the variations are so great that it is not possible to predict a crop's cadmium content on the basis of soil analyses. In addition, different crops have different propensities to take up cadmium; levels are often exceptionally high in wheat, for example. It is therefore necessary to directly analyse crops in order to assess their cadmium content; the results can be interpreted with the help of the following table.

Cadmium in crops

Class	Level	Cadmium (µg/kg dry weight)	Comments
1	Low	< 50	
3	Moderate	50-100	
5	High	> 100	WHO's recommended limit for human consumption