iSQAPER
Interactive Soil Quality Assessment

Classification of farming systems across Europe and China

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Classification of farming systems across Europe and China

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1. Introduction

1.1 What is farming system?

There is a large diversity in defining farming systems (FSs). The most frequently used terminology is included hereinafter.

> FS is a decision making unit comprising the farm household, cropping and livestock system that transform land and labor into useful products, which can be consumed or sold (Fresco and Westphal, 1988).
>
> FS is a resource management strategy to achieve economic and sustained production to meet diverse requirement to farm household while presenting resources base and maintaining a high level environmental quality (Lal and Miller, 1990).
>
> FS is a set of agro-economic activities that are interrelated and interact with themselves in a particular agrarian setting. It is a mix of farm enterprises to which farm families allocate its resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of the farm. These farm enterprises are crop, livestock, aquaculture, agroforestry and agri-horticulture (Sharma et al., 1991).
>
> FS is a mix of farm enterprises such as crop, livestock, aquaculture, agroforestry and fruit crops to which farm family allocates its resources in order to efficiently manage the existing environment for the attainment of the family goal (Lal and Miller, 1990).
>
> FS is a unique and reasonable stable arrangement of farming enterprises that a household manages according to well defined practices in response to the physical, biological and socio-economic environment and accordance with the household goals preferences and resources (Shaner et.al., 1981).
>
> FS is defined as a complex interrelated matrix of soil, plants ,animals, implements, power, labor, capital and other inputs controlled in part by farming families and influenced to varying degrees by political, economic, institutional and social forces that operate at many levels (Dixon et al., 2001).
>
> A FS is defined as a population of individual farm systems that have broadly similar resource basis, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (FAO, univ.fao.org/farming systems).

There are significant differences among FSs depending largely on agro-ecological conditions and pedo-climatic zones. This agro-ecological diversity, plus the heterogeneity of economic, political and social conditions has resulted in the development of a wide variety of farming systems.

1.2 General requirements towards FS classifications

The aim of this report is to do a dynamic agricultural production system classification that can be mapped and refined through time (Robinson and Thornton, 2006).

Farming System should be able;

- to summarize existing global agricultural production classifications

- to develop a common classification framework that:
    a) can be mapped using existing global or at least EU/China data sets,
    b) meet various operational requirements e.g. stratification for data sets, livestock and crop production modelling,
    c) be of operational level use at EU and China level,
- to develop a detailed plan of work for completing a global system classification;
    a) the definition of the category of mixed farming is challenging,
    b) to define a generally applicable production system classification,
    c) a particular cropping system may be associated with a number of different livestock system and a particular livestock system may be associated with a number of different cropping systems,
    d) the classification scheme should be interpretable and repeatable, given updates of information, additional data layers and adjustments to classification criteria,
    e) the classification should be dynamic to allow investigation of the likely developments of FS in the future, and how they might evolve in response to global drivers such as population pressure, changes in demand for livestock and crop product and climate change.

1.3 Proposed working definition of FS

In the iSQAPER project the farming systems represent the combination of cropping and livestock activities and the resources available (pedoclimatic conditions) to the farmers to raise them for their production purposes. The philosophy behind this approach is to secure a judicious mix of cropping system with associated enterprises like animal husbandry suited to the given pedo/agro climatic conditions in accord with the socio-economic status of farmers in order to bring prosperity to the farm.

2. Existing classification of farming systems

The classification of the farming systems traditionally has been based on the available natural resource base and the dominant pattern of farm activities and household livelihoods taking into account the kind of soil management and land use and the main technologies used. These in turn determine the intensity of production and integration of crops, livestock and other activities.

The farm as a unit transfers input into agricultural output, which undergoes changes over time. In the process of adapting cropping patterns and farming techniques to the natural, economic and socio-political conditions of each location and the aims of the farmers, distinct farming systems are developed. For the purpose of agricultural development it is advisable to group farms with similar structures into classes (Elemo, 2015).

The classification of agricultural systems has a long history but there is no generic system that is truly comprehensive and can serve all purposes (Spedding, 1975).

Below we provide an overview on the farming system classifications (models) developed and used in the last few years in Europe and China

2.1 The FS system of the FAO

The classification of farming systems according to the FAO (2015) can be specified based on one or more of the following criteria:

- size of farm,
- proportion of land, labor and capital investment,
- value of products or income or on the bases of comparative advantages,
- water supply,
- type and intensity of rotation,
- degree of commercialization,
- degree of nomadic,
- cropping and animal activities,
- implements used for cultivation.

In iSQAPER project to fulfill the aims of the SQ App, we consider classification of farming systems based on the cropping and animal activities.

2.2 CORINE Land Cover classification

In 1985 the CORINE Land cover program was initiated by the EU. CORINE stands for COoRdination of INformation on the Environment and it was a prototype project working on many different environmental issues (CEC-EEA, 1993). The results were published in 1995. According to that the agricultural areas of Europe are divided as follows (CEC-EEA, 2012):

ARABLE AREAS:

- arable land
- non-irrigated arable land
- permanently irrigated land
- rice field
- permanent crops
- vineyards
- fruit trees and berry plantations
- olive groves

PASTURES

HETEROGENEOUS AGRICULTURAL AREAS

- annual crops associated with permanent crops
- complex cultivation
- land principally occupied by agriculture, with areas of natural vegetation
- agro-forestry areas

2.3 The system of Dixon

To develop the farming system knowledge base Dixon et al. (2015) blended information from global Geographic Information Systems (GIS) with existing local farming system studies. They identified the characteristics and extent of each farming system zone. For this purpose the teams used the FAO Agri-Ecological Zone (AEZ) maps as a basis and added other GIS layers as relevant, including environmental constraints, cultivated extent, livestock etc.

2.4 The FS developed in the SEAMLESS project

In the SEAMLESS integrated project (Andersen, 2010) the regions are typified based on cluster analysis for each of the three dimension of a farm typology based on farm size, intensity and specialization/land use. The three dimensions are combined into one typology of agricultural regions including all combinations of the three dimensions. The results of the different clusters and the final typology are described and the regional distribution is presented on maps (Tables 1 and 2).

Table 1. Types in the specialisation dimension with definitions and reference to codes in Community typology (SEAMLESS).

Specialisation type	**EU-code**	**Definition**
Arable systems	1 + 6	> 2/3 of SGM* from arable or (> 1/3 of SGM from arable and/or permanent crops and/or horticulture)
Dairy cattle	4.1	> 2/3 of SGM from dairy cattle
Beef and Mixed cattle	4.2 and 4.3	> 2/3 of SGM from cattle and < 2/3 of SGM from dairy cattle
Sheep, Goats and mixed grazing Livestock	4.4	> 2/3 of SGM from grazing livestock and < 2/3 of SGM from cattle
Pigs	5.1	> 2/3 of SGM from pigs
Poultry and mixed Pigs/poultry	5.2	> 2/3 of SGM from pigs & poultry and < 2/3 of SGM from pigs
Mixed farms	7	All other farms
Mixed livestock	8	> 1/3 and < 2/3 of SGM from pigs & poultry and/or > 1/3 and < 2/3 of SGM from cattle
Permanent crops	3	> 2/3 of SGM from permanent crops
Horticulture	2	> 2/3 of SGM from horticultural crops

*SGM: Standard Gross Margin.

Table 2. Land use types and definitions (SEAMLESS).

Land use type	**Definition**
Land independent	Utilised agricultural area (UUA) = 0 or LU (Livestock units)/ha (hectare) => 5
Horticultural	(> 0 UAA or LU/ha<5) and >= 50% of UAA in horticultural crops
Permanent crop	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and >= 50% of UAA in permanent crops
Temporary grassland	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and >= 50% of UAA in grass and >= 50% Temporary grass)

Permanent grassland	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and >= 50% of UAA in grass and < 50% Temporary grass)
Fallow land	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and < 50% of UAA in grass and >= 12.5% Fallow)
Cereal	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and < 50% of UAA in grass and < 12.5% Fallow) and >= 50% Cereals
Mixed crop	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and < 50% of UAA in grass and < 12.5% Fallow) and < 50% Cereals and < 25% of arable land in specialised crops.
Specialised crop (Grain Maize, potatoes, sugar beet, hops, soya, tobacco, medicinal plants, sugar cane, cotton, fibre lax, hemp, mushrooms, vegetables in open, flowers in open, grass seeds, other seeds)	(> 0 UAA or LU/ha<5) and < 50% of UAA in horticultural crops and < 50% of UAA in permanent crops and < 50% of UAA in grass and < 12.5% Fallow) and < 50% Cereals and >=25% of arable land in specialised crops.

2.5 The system used in the SMART SOIL project

The SMART SOIL project (Sustainable farm Management Aimed at Reducing Threats to Soils under climate change) (2011-2013), in its Deliverable 2.2. presented the indicators in the database regarding the typical farming systems and soil management practices. The FS have been derived from the SEAMLESS project (Andersen, 2010). In that project a classification was developed which distinguished 21 farm types into the following six main farm systems (Table 3).

Table 3. SEAMLESS farm types and grouping to main farming system (SMART SOIL)

Code	SEAMLESS farm type	Main farming system
1	Arable/Cereal	Field crops
2	Arable/Fallow	Field crops
3	Arable/Specialised crops	Industrial crops
4	Arable/Others	Field crops
5	Dairy cattle/Permanent grass	Pasture and grasslands
6	Dairy cattle/Temporary grass	Pasture and grasslands
7	Dairy cattle/Land independent	Mixed farms
8	Dairy cattle/Others	Mixed farms
9	Beef and mixed cattle/Permanent grass	Pasture and grasslands
10	Beef and mixed cattle/Temporary grass	Pasture and grasslands
11	Beef and mixed cattle/Land independent	Mixed farms
12	Beef and mixed cattle/Others	Mixed farms

13	Sheep and goats/Land independent	Mixed farms
14	Sheep and goats/Others	Mixed farms
15	Pigs/Land independent	Mixed farms
16	Pigs/Others	Mixed farms
17	Poultry and mixed pigs/poultry	Mixed farms
18	Mixed farms	Mixed farms
19	Mixed livestock	Mixed farms
20	Horticulture	Horticulture
21	Permanent crops	Permanent crops

According to the SMARTSOIL classification (?), the predominant farming systems in the EU-27 are field crops, mixed farming, and pasture and grasslands.

2.6 The system used in the CATCH-C project

In the CATCH-C project (twin project to Smart Soil 2012-2014) farm types were calculated to AEZs (agri-environmental zones) over Europe according to the procedure developed by Kempen et al. (2011). This allocation procedure uses farm accountancy data network (FADN) farm data at NUTS-2 level to estimate the presence of certain farm types within AEZs. The AEZ is based on three variables: climate (environmental zones), soil texture and slope. Overlaying the three datasets results in spatial zones with similar biophysical characteristic (Tables 4 and 5).

Table 4. Classes and definitions of farm specialisation according to FADN (CATCH-C).

Specialisation	**EU-code of FADN**	**Definition**
Arable systems (specialised field crops and mixed cropping)	1+6	- >1/3 of standard gross margin from general cropping (arable farming) - Or > 1/3 but ≤ 2/3 of standard gross margin from horticulture - Or > 1/3 but ≤ 2/3 of standard gross margin from permanent crops Combined with ≤ 1/3 of standard gross margin from meadows and grazing livestock and ≤ 1/3 from granivores
Permanent crops	3	> 2/3 of standard gross margin from permanent Crops
Horticulture	2	> 2/3 of standard gross margin from horticultural crops
Dairy cattle	4.1	> 2/3 of standard gross margin from dairy Cattle
Beef and mixed cattle	4.2 and 4.3	> 2/3 of standard gross margin from cattle and < 2/3 from dairy cattle
Sheep, goats and mixed grazing livestock	4.4	> 2/3 of standard gross margin from grazing livestock and < 2/3 from cattle

Pigs	5.1	>2/3 of standard gross margin from pigs
Poultry and mixed pigs/poultry	5.2	> 2/3 of standard gross margin from pigs and poultry and < 2/3 from pigs
Mixed livestock	7	> 1/3 and < 2/3 of standard gross margin from pigs and poultry and/or >1/3 and < 2/3 from cattle
Mixed farms	8	All other farms

Table 5. Classes and definitions of the land use of a farm (CATCH-C).

1	Land independent	UAA[1] = 0 or LU[2]/ha≥ 5
2	Horticultural	Not 1 and ≥ 50% of UAA in horticultural crops
3	Permanent crops (not grassland)	Not 1 and 2 and ≥ 50% of UAA in permanent crops
4	Temporary grass	Not 1,2 or 3 and ≥ 50% of UAA in grassland and ≥ 50% of grassland in temporary grass
5	Permanent grass	Not 1,2,3 and ≥ 50% of UAA in grassland and < 50% of grassland in temporary grass
6	Fallow land	Not 1,2,3,4 or 5 and ≥ 50% of UAA in fallow
7	Cereal	Not 1,2,3,4,5 or 6 and ≥ 50% of UAA in cereals
8	Specialised crops	Not 1,2,3,4,5,6,7 and ≥ 25% in specialised crops[3]
9	Mixed crops (others)	Not 1,2,3,4,5,6,7 or 8

2.7 Farming systems in China according to FAO

FAO classifies farming systems according to the following land uses/cropping systems (FAO, 2015)

Lowland rice
Tree crop mixed
Root –tuber
Upland intensive mixed
Highland extensive mixed
Temperate mixed
Pastoral
Sparse (forest)
Sparse (arid)
Costal artisanal fishing (not mapped)
Urban based (not mapped)

2.8 Global land cover (30 m resolution)

Chen et al. (2015) mapped the following land cover types:

1) Cultivated Land. Lands used for agriculture, horticulture and gardens, including paddy fields, irrigated and dry farmland, vegetation and fruit gardens, etc.

2) Forest. Lands covered with trees, with vegetation cover over 30%, including deciduous and coniferous forests, and sparse woodland with cover 10 - 30%, etc.

3) Grassland. Lands covered by natural grass with cover over 10%, etc.

4) Shrubland. Lands covered with shrubs with cover over 30%, including deciduous and evergreen shrubs, and desert steppe with cover over 10%, etc.

5) Water bodies. Water bodies in the land area, including river, lake, reservoir, fish pond, etc.

6) Wetland. Lands covered with wetland plants and water bodies, including inland marsh, lake marsh, river floodplain wetland, forest/shrub wetland, peat bogs, mangrove and salt marsh, etc.

7) Tundra. Lands covered by lichen, moss, hardy perennial herb and shrubs in the polar regions, including shrub tundra, herbaceous tundra, wet tundra and barren tundra, etc.

8) Artificial surfaces. Lands modified by human activities, including all kinds of habitation, industrial and mining area, transportation facilities, and interior urban green zones and water bodies, etc.

9) Bare land. Lands with vegetation cover lower than 10%, including desert, sandy fields, Gobi, bare rocks, saline and alkaline lands, etc.

10) Permanent snow and ice. Lands covered by permanent snow, glacier and ice caps.

3. Farming system classification in the iSQAPER project

3.1 Aim of farming system classification in the iSQAPER project

The classification of FS's has been traditionally based on the available natural resource base and the dominant pattern of farm activities and household livelihoods, taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities. Different approaches to farming system classification were analysed and the best-for-the purpose classification was integrated with the pedo-climatic zones concept. Apart from traditional farming system classifications, which are based on combined land cover and land use descriptions, the feasibility of management-based classification was assessed. Hierarchical classification is provided to enable multi-scale analysis as well as to facilitate the implementation of the Soil Quality App in diverse environmental conditions in a clear, hence comprehensive structure.

Preconditions for developing FS in the iSQAPER:

- FS should be applicable within the pedo-climatic zones,
- proper data should be available,
- FS should be suitable to the Soil Quality App.

Primary functions of the iSQAPER FS classification:

- best for-purpose classification within a comprehensive structure,
- possibilities to enhance and/or combine land use description (classes),
- hierarchical classification to enable multiscale analysis,
- thematic competency with the pedo-climatic zones concept,
- data interoperability with expected outputs of the pedo-climatic zonation,
- feasibility for enhancement with management based classification,
- available IT support facilities with regular updating to the implementation of the Soil Quality App.

3.2 List of the crops and livestock types for EU and China

The following information can be used to derive farming system classification.

1. ARABLE Land

1.1. Non irrigated
- 1.1.1. Cereals: Wheat, Barley, Sorghum, Millets, Oats
- 1.1.2. Rice
- 1.1.3. Maize
- 1.1.4. Pulses: Soybean, Peas, Been, Lentil, Other (Groundnut, Pigeonpea, Cowpea)
- 1.1.5. Oil crops: Sunflower, Oilseed rape, Oilcrops, Other
- 1.1.6. Fodder crops: Alfalfa, Red clover, Other
- 1.1.7. Roots and tubers: Potato, Sugarbeet, Sweet potato, Yam
- 1.1.8. Fiber crops: Cotton, Fiber, Other
- 1.1.9. Tobacco
- 1.1.10. Cassava (manioka)
- 1.1.11. Vegetable
- 1.1.12. Fallow

1.2. Arable irrigated
the same subdivision as described above

2. PERMANENT CROPS

2.1. Vineyards
2.2. Fruit trees and berry plantation
2.3. Olive groves
2.4. Banana
2.5. Oil Palm
2.6. Tea
2.7. Sugarcane

3. PASTURES

3.1. Extensive

3.2. Intensive

4. LIVESTOCK specialisation

4.1. Cattle
4.2. Sheep
4.3. Goats
4.4. Pigs
4.5. Chickens
4.6. Ducks

3.3 The proposed farming system classification for the purpose of the ISQAPER project

Proper classification of farming systems tailored for the need of the iSQAPER project is created based on the assessment of the different kind of farming systems reported above.

For classification based on crop production and land use the CORINE database provides the best option for Europe. Its applicability for the analysis of pedo-climatic zones and FS divisions is supposed to be the most successful among all above described options, because of the comprehensive spatial coverage and 100 m resolution of the CORINE data for Europe. For China land cover information is available from Global Land Cover (GLC30) (Chen et al., 2015; Han et al., 2015).

Information about croplands is available from the MapSpam Cropland dataset (You et al., 2014). It provides information about crop area, yield and production for 20 most important crops. The maps are globally available in 5 arc minute grid resolution.

Farming system classes can be further amended by information on animal breeding using the Global Distribution of Livestock dataset (Robinson et al., 2014).

The recommended farming system classification thus includes a crop production system component, which might be refined by crop types, and an additional livestock component for possible extension with animal husbandry aspects.

The following farming system classification is based on CORINE and it can be analysed for arable land and heterogeneous agricultural area categories in combination with data from the MapSpam Cropland dataset (You et al., 2014) and Global Distribution of Livestock data (Robinson et al., 2011, 2014).

The livestock component for potential amendment to the iSQAPER FS system

The livestock component of the FS classification and analysis is based on the Global Distribution of Livestock dataset (Robinson et al., 2014). This dataset includes information on livestock density with 1×1 km or 5×5 km resolution by major groups of animal species.

Proposed categories of the FS:

1. **ARABLE:** Farming systems according to the crop rotations highlighting the most important crops in the crop rotation.

1.1. Cereals
1.1.1. non-irrigated

1.1.2. permanently irrigated
1.2. Rice
1.2.1. non-irrigated
1.2.2. permanently irrigated
1.3. Maize
1.3.1. non-irrigated
1.3.2. permanently irrigated
1.4. Legumes
1.4.1. non-irrigated
1.4.2. permanently irrigated
1.5. Oil crops
1.5.1. non-irrigated
1.5.2. permanently irrigated
1.6. Fodder crops
1.6.1. non-irrigated
1.6.2. permanently irrigated
1.7. Root crops
1.7.1. non-irrigated
1.7.2. permanently irrigated
1.8. Fallow

2. PERMANENT CROPS

2.1. Vineyards
2.2. Fruit trees and berry plantation
2.3. Olive groves
2.4. Banana
2.5. Oil Palm
2.6. Tea
2.7. Sugarcane

3. PASTURES

3.1. Extensive
3.2. Intensive

4. LIVESTOCK SYSTEMS

Main farming systems:

- pasture
- mixed farms (with arable)

Farm types:

4.1. Dairy cattle

4. Discussion

A number of different classification system exists to classify farming systems in Europe and globally. Some approaches built on the structure of economic enterprises, while others on the physical basis (land, crops, livestock) of the production. From the viewpoint of the iSQAPER project, which aims to deliver spatially explicit solution for sustainable land management, only those classifications could be realistically considered, which is supported by spatial data of continuous coverage.

The aim of WP2 is to integrate existing soil quality related information with characterisation of crop and livestock farming systems in various pedo-climatic zones across Europe and China. The selected classification of FSs is based on the traditional approach to classify available natural base and the dominant pattern of farm activities and households, taking account the main technologies used, which determine the intensity of production of crops, livestock and other activities. Different other approaches to FS classifications were also tested and to best-for-the purpose classification had been selected. This classification can be integrated with the pedo-climatic zones concept. Apart from traditional FS classifications, which are based on combined land cover and land use descriptions (SEAMLESS, CATCH-C, Dixon, SMART-SOIL), in case of iSQAPER a classification supported by continuous map data is used which will be provided to enable multi-scale analysis as well to facilitate the implementation of the Soil Quality App in diverse environmental conditions. In case of ISQAPER project it is an essential aspect that FS should be applicable within the pedo-climatic zones, proper data should be available and the FS has to be suitable for the Soil Quality App. The recommended farming system classification (Table 6.) thus relies on available spatial datasets such as CORINE for Europe, GLC30 for China; MapSpam Cropland dataset; Global Distribution of Livestock and includes a crop production system component for possible extension with animal husbandry aspects.

Although classification may have been based on the approach of the SEAMLESS project (Andersen et.al. 2006 and Andersen et al. 2007), but its data support is not enough detailed for the purpose of the iSQAPER project. It is based on the FADN data which has a level of aggregation on the NUTS2 scale which is not the best solution for the purpose of the iSQAPER analysis. It is also not suitable in every respect for harmonization with the pedo-climatic zones.

Analysis of farming systems will be based on the harmonized dataset prepared in Task 2 of WP2 of iSQAPER project (Report on Milestone M2.1. of iSQAPER project). Therefore the aim of Task 4 was to derive a classification of farming systems including categories on which spatial datasets have information, which provides the possibility for spatial analysis of farming systems in Task 5. Categories on which there is no available information or resolution is not appropriate might be avoided.

Table 6. Farming system classification of iSQAPER

Farming systems		
Cropping systems		
1. ARABLE LAND*	1.1. Cereals: wheat, barley, sorghum, others (millets, oats, etc.)	1.1.1. Cereals, non irrigated 1.1.2. Cereals, irrigated
	1.2. Rice	1.2.1. Rice, non irrigated 1.2.2. Rice, irrigated
	1.3. Maize	1.3.1. Maize, non irrigated 1.3.2. Maize, irrigated
	1.4. Legumes: soybean, peas, been, lentil, pulses other: groundnut, pigeon pea, cowpea	1.4.1. Legumes, non irrigated 1.4.2. Legumes, irrigated
	1.5. Oil crops: sunflower, oilseed rape, others	1.5.1. Oil crops, non irrigated 1.5.2. Oil crops, irrigated
	1.6. Fodder crops: alfalfa, red clover, other fodder crops	1.6.1. Fodder crops, non irrigated 1.6.2. Fodder crops, irrigated
	1.7. Root crops and tubers: potato, sugar beet, other; sweet potato, yam	1.7.1. Root crops, non irrigated 1.7.2. Root crops, irrigated
	1.8. Fallow	
2. PERMANENT CROPS	2.1. Vineyards 2.2. Fruit trees and berry plantation 2.3. Olive groves 2.4. Banana 2.5. Oil Palm 2.6. Tea 2.7. Sugarcane	
3. PASTURES	3.1. Extensive 3.2. Intensive	
Livestock systems		
4. LIVESTOCK specialisation	4.1. Dairy cattle 4.2. Beef and mixed cattle 4.3. Sheep and goats 4.4. Pigs 4.5. Poultry	

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