# S1. Executive summary

## S1.1. Background and definition of ICM

Integrated Crop Management can be thought of as a concept defining ideals and goals which then have to be 'translated' into definitions which can be implemented by producers. Simply put, the concept is to integrate the management of individual crops in order to benefit from the interactions between them. In many respects integrating crop production strategies to provide benefits such as pest control, maintain soil fertility, etc. is an ancient technique. However, ICM also takes advantage of modern technology to improve on the system.

The International Organisation for Biological and Integrated Control of Noxious Animals and Plants (IOBC) redefined and published a conceptual framework for Integrated Production, within which ICM fits. In addition to this, a common codex for integrated farming was developed in January 2001 by the members of the European Initiative for Sustainable Development in Agriculture (EISA). Practicable ICM schemes translate the concept of ICM into more specific, 'working definitions' which define a management protocol for crop production.

A wide range of fairly similar 'working definitions' are used by various institutions throughout the EU. Eight of these definitions were examined and 'environmental sensitivity' emerged as the key component of ICM systems. This is closely followed by 'economic viability', reflecting the fact that food production is a business and hence must be profitable to exist. 'Modern techniques' is an important component and this reflects a key point of difference in comparison to organic farming which can be thought of, at least in principle if not always in practice, as rejecting modern techniques such as artificial inputs.

Although the concept of 'whole farm approach' is fairly prominent, two of the definitions that include this component are actually IFS or Integrated Production definitions. It is considered that it is possible to have an ICM approach within a single crop, although clearly some definitions suggest that multiple crops are often grown together in an integrated manner. In terms of two of the three least prevalent concepts, 'long term strategy', may be considered inherent in the use of 'integrated', but its inclusion is felt to be important as a reflection of the importance of the use of rotations in minimising weed and pest problems. 'Efficiency of input use' is not implied in the same manner, although it could be argued that rational producers would seek efficient input use in any case.

Finally, comments on food quality and consumer requirements in the definitions are not widespread. Whilst it is probably taken for granted that food produced through ICM techniques is of high quality, its inclusion in definitions might be a useful marketing aid.

Based on the above, one might summarise the main aspects of current ICM definitions by saying that it is an environmentally sensitive and economically viable production system or process which uses the latest available techniques to produce high quality food in an efficient manner.

Placing ICM on the scale between conventional production (as defined by the Codes of Good Agricultural Practice) and organic production is not straightforward. Although initial impressions would suggest that ICM is fairly closely aligned to organic production, their origins are very different and this has implications for their relationships with conventional production. Organic production represents a system distinct from conventional production and marketing, whilst ICM is clearly placed within the conventional framework. In terms of philosophy at least, ICM should therefore be placed closer to conventional farming than to organic production, representing as it does, modification of the existing system rather than abandonment of it.

### S1.2. EU review of ICM systems

There are two broad categories of ICM system: those established for research purposes and those set up and run commercially. The purpose of this project was not to provide a comprehensive listing of all current ICM systems, but rather to illustrate the range and diversity of current systems.

On the basis of this review there are at least 10 research-type systems and 32 commercial systems (although this latter figure is in reality expected to be significantly higher). Of these systems, 19 apply to arable crops, 17 to fruit, 20 to vegetables, 4 to grapes/wine and 3 to 'other crops', which include hops, medicinal plants, herbs, spice, ornamental plants and olives[1]. However, if the crop coverage is analysed according to whether the system is research or commercially driven, then a different picture emerges in that the majority of research protocols (10 from 13) relate to the arable sector whereas the majority of commercial protocols (34 from 50) relate to the fruit (16) and vegetable (18) sectors[2]. All the wine systems are commercial.

An examination of the protocols for these systems shows that fertilisation and plant protection restrictions/guidelines are virtually universal (appearing in 95% and 93% of schemes respectively), while protocol elements referring to soil husbandry and tillage practices and crop rotation and varietal choice appear in more than half the examples. More than a third of the system protocols refer to harvest and post-harvest and irrigation restrictions.

Although the proportion of ICM in the EU is small, under 3% of Utilisable Agricultural Area (UAA), there is considerable variation between Member States. The UK has by far the largest area under ICM at around 1.5 million hectares whilst this figure is only 268 hectares in Greece. ICM accounts for around 20% of UAA in Austria and Denmark, although accounts for less than 1% of UAA in Belgium, Finland, France, Greece, Ireland and Spain. However, these figures should be interpreted with a degree of caution because ICM systems differ from scheme to scheme.

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[1] There is clearly double counting in that many of the schemes apply to more than one of these cropping sectors.

[2] Including double counting where research is involved in more than one cropping sector.

## S1.3. Impact of ICM systems in the EU

### S1.3.1. Methodology

The research undertaken has sought to quantify the environmental effects of ICM at the individual system level for 10 different systems with an emphasis on plant protection (including choice of plant varieties and effects on biodiversity) as a priority. Where applicable, the research has also sought to evaluate the effects on nitrogen; erosion/soil protection; irrigation; waste management; and, crop rotation.

The scope and timescale of this project precluded primary research on the environmental impact of ICM. This aspect of the project therefore had to be conducted using research and data on existing systems. It was thus primarily based on an extensive review of available research and field trials, although where feasible the review was supplemented by limited field research.

The ten case studies selected represent a balance between the desire to examine commercial systems and the need for the environmental impact to have been assessed. It was also important to examine systems concerned with a range of crops including arable systems, fruit and vegetable production and viticulture. In order to meet these criteria, ten systems were selected for examination in five Member States as follows:

- **France:** Boigneville project and Champagne production
- **Germany:** the Lautenbach project and the AKIL project
- **Italy:** the CAMAR project and Chianti production
- **Spain:** citrus production in Valencia and pome fruit production in Cataluña
- **UK:** Less Intensive Farming and the Environment (LIFE) and Focus on Farming Practice (FOFP)

The case studies therefore provide five research and five commercial systems and six arable, two fruit and two viticulture systems.

### S1.3.2. How protocols address environmental impact

**Water**

- Pesticide leaching: pesticide minimisation strategies coupled with the selection of pesticide products with minimal non-target impacts and varieties selected for resistance provide the main protection against pesticide leaching. Crop rotations are used in some cases to reduce the need for herbicide application. Rational fertilisation strategies will also help by reducing competition from non-crop plants and therefore reducing the requirement for pesticide application. Irrigation management strategies are also sometimes used.
- Nitrate leaching: fertiliser management strategies rely on either mandated reductions in use or on observation/soil sampling to determine requirements under the assumption that this will lead to reduced application. Crop rotations are also used to build up natural fertility and irrigation control programmes provide a better matching of water to crop needs which reduces leaching. Cover crops are also sometimes used to ‘lock in’ nutrients over winter.

**Soil**

- Pesticide residues: the main strategies for reducing pesticide residues are the pesticide minimisation strategies (including use of lowest effective rate and band or partial application) used in conjunction with the selection of resistant varieties to reduce pesticide requirement and rotational control. Rational fertilisation strategies will also help in that they will reduce the demand for pesticide.
- Soil nutrient balances/soil nitrogen: the main tactic for achieving a better soil nutrient balance is fertiliser reduction strategies. These more frequently refer to nitrogen, but in many cases are extended to cover other nutrients ($P_2O_2$, $K_2O$). This approach is augmented in some cases by row application and the use of slow release nitrogen. Rotational management to reduce demand for artificial nitrogen is also used, as are cover crops to 'lock in' nutrients.
- Soil erosion: where this is considered an issue, soil erosion is addressed through the replacement of ploughing with non-inversion tillage. Cover crops and/or green cover are used to anchor the soil. There are also restrictions on the times of year when soil tillage activities can take place and contour planting of trees is mentioned in the Spanish pome fruit production case study.
- Soil quality: soil fauna are protected through pesticide minimisation strategies and the use of low toxicity compounds. Non-inversion tillage also helps maintain good soil quality, as does the use of organic manure. The use of fertiliser containing heavy metals is sometimes banned in order to reduce soil contamination.

**Air**

- Air quality: this is usually not addressed in protocols, but where it is, the banning of volatile fertilisers such as ammonia is the main approach to addressing the issue.
- Spray drift: only addressed in half of the case studies and none of the non-case study systems, the risk of drift is reduced through more stringent machinery maintenance and calibration. The use of low pressure nozzles also helps.
- $CO_2$ emissions: this is addressed only in the Lautenbach case study where the use of non-inversion tillage is thought to reduce $CO_2$ emissions.

**Biodiversity**

- Soil fauna: the two main approaches that enhance soil fauna are the use of low toxicity pesticide compounds with minimal side effects on non-target organisms and reductions in the total application of pesticide. Non-inversion tillage also promotes soil fauna.
- Plant species: again, the use of low toxicity pesticide compounds with minimal side effects on non-target organisms and reductions in the total application of pesticide are the main protocol elements with a positive impact in this area. These are augmented by rational fertilisation strategies which both reduce the need to apply pesticides and reduce the risk of nutrient-rich soil which is not conducive to many endangered plant species. Finally, the promotion of ecological infrastructure provides a habitat reservoir in which plant species can thrive.
- Macro fauna: this was only investigated in one of the case studies (FOFP) and improvements in bird populations result from the use of low toxicity pesticide compounds with minimal non-target species impact which maintains a source of food for bird life. Ecological infrastructure provide habitat for larger fauna and

the protection of smaller fauna through pesticide reduction strategies will also have a positive knock on effect.

**Landscape**

- Ecological infrastructure: there are no particular production protocols which will have an influence on landscape, and in many ways, ICM is concerned with micro rather than macro impacts. However, the monotony of monocropped landscapes is broken up in half of the case studies by mandated areas of hedgerows, shrubs and woodland, field margins, flowering strips and headlands.

### S1.3.3. Environmental impact of ICM systems

**Water**

- Pesticide leaching:
- *case study evidence:* two of the 5 research systems showed quantitative reductions in pesticide leaching. The other 3 all showed reductions in application which is likely to have reduced the risk of leaching. The commercial case studies all have protocols which will lead to reductions in pesticide use.
- *non-case study evidence:* Six of the 8 non-case study systems showed a quantitative reduction in pesticide use, whilst the remaining 2 suggested qualitative reductions in application.
- Nitrate leaching:
- *case study evidence:* two research systems showed quantitative reductions in leaching; the other 2 showed reductions in application which is likely to have reduced the risk of leaching. One research system showed higher leaching from the integrated system. Three of the commercial systems showed quantitative reductions in N application and 1 suggested a qualitative reduction in N leaching.
- *non-case study evidence:* two of the non-case study systems had quantified reductions in N application and 2 reported a qualitative reduction. One system showed a quantitative reduction in N in run-off water and 2 others suggested qualitative reductions in N leaching
- Soluble phosphate:
- *Case study evidence:* one research system showed a reduction in soluble phosphate in drain water.
- Summary: on balance it seems highly likely that ICM systems reduce the incidence of pesticide leaching, although more direct quantitative evidence linking reductions in application to reductions in leaching needs to be collected. The above evidence also suggests that ICM systems generally result in a reduction in the risk of nitrate leaching. Again, as with pesticide leaching, more quantitative evidence should be sought to investigate the link between reduced N application and reductions in N leaching. Although there is not enough evidence on soluble phosphate to make a firm statement, it is likely that ICM does generally contribute to reductions in application through fertiliser rationalisation/reduction strategies.

**Soil**

- Pesticide residues:
- *case study evidence:* one research system showed quantitative reductions in residues compared to conventional systems and the implication from all another research systems is that pesticide use reduced as a result of protocol restrictions and this should reduce the risk of soil residues. Two commercial systems suggested a reduction in soil pesticide residues, 1 through reduced application and

the other through the use of pesticides with reduced residual activity and low toxicity.

- *non-case study evidence:* six of the non-case study systems reported quantified reductions in pesticide application. The other 2 reported qualitative reductions.

- Soil nutrient balances:
- *case study evidence:* although there is no quantitative evidence that soil N has been reduced, N application was reduced in 1 research system and another found that N uptake was better under integrated management. One research system showed a decrease in soil P. One commercial system reported quantitative reductions in the level of nutrients in the soil.
- *non-case study evidence:* one of the non-case study systems reported a reduction in N reserves, although this was coupled with an inferior N use balance. Other non-case study systems showed quantitative and qualitative reductions in fertiliser use.

- Soil erosion:
- *case study evidence:* 1 research system showed a quantitative reduction in soil erosion resulting from the use of non-inversion tillage, another system showed a greater degree of soil cover which should help reduce the risk of erosion. One commercial system provided quantitative evidence of a reduction in soil erosion and another suggested qualitatively that soil erosion had reduced. Two other commercial systems suggested that the risk of soil erosion was reduced through the use of green covers; this was also the case in one non-case study system.

- Summary: it seems clear that ICM systems, through a reduction in the application of pesticide, lead to a reduction in the risk of pesticide residues building up in the soil, although it is not possible to ascertain for definite on the weight of this evidence that they result in actual reductions in residues; more research is needed to establish the nature of any link. Where systems have restrictions on fertiliser use within the protocols (i.e. in the vast majority of cases), it is likely that nutrient application is better matched to crop demand. ICM systems generally appear to reduce the risk of excessive nutrients in the soil through lower or more rational fertiliser application strategies, although, as with pesticide residues, more research into the link between reduction in application and more appropriate soil nutrient balances should be conducted. Soil erosion is not considered an important issue in most systems, although where it is a consideration (in some cases a central one), the evidence suggests that the risk can be reduced.

**Air**

- Air quality:
- *case study evidence:* two research systems suggested improvements in air quality as a result of protocol restrictions. One quantified the environmental exposure to pesticides. Another research system assumed improvements to $CO_2$ emissions through the use of non-inversion tillage. One commercial system suggested a qualitative improvement in air quality.

- Spray drift:
- *case study evidence:* none of the research or non-case study systems commented on this issue. However, 4 of the commercial systems suggested a qualitative reduction in spray drift through better machinery maintenance and sprayer calibration.

- Summary: there is little evidence of the impact of ICM on air quality, although this does not mean that there is no impact in practice. However, ICM systems are likely to have a positive impact on spray drift.

**Biodiversity**

- Flora:
- *case study evidence:* the density of native non-cropped plants was found to be higher under integrated management in 1 research system. Another found greater species richness in integrated systems. Two commercial systems concluded that there is qualitative evidence that ICM systems provide a benefit to flora.
- Micro-fauna:
- *case study evidence:* 1 research system found that population density was higher, although this was not quantified. Three research systems demonstrated quantitative improvements in populations in terms of number of individuals and biomass. One commercial system also provided quantitative evidence of increased population density and 3 suggested qualitative improvements based on pesticide reduction strategies and the use of less toxic chemicals.
- *non-case study evidence:* 1 study provided quantitative evidence of increased population density.
- Macro-fauna:
- *case study evidence:* 1 research system quantified increases in bird populations.
- Summary: all systems that reduce the use of pesticide and fertiliser are likely to have a positive impact on non-cropped species. Although only 1 system examined this area, it is likely that there will be an increase in macro-fauna populations which depend on the habitats and food sources of both flora and soil fauna which are enhanced under ICM.

**Landscape**

- Ecological infrastructure:
- *case study evidence:* 3 research systems showed a positive impact on landscape through the addition and/or maintenance of landscape features. Two commercial systems cited improvements in landscape through management of ecological infrastructures.
- Summary: landscape is not an element that is directly addressed in ICM protocols and the closest proxy for it refers to ecological infrastructure. In many cases landscape elements such as boundary features are encouraged under ICM.

### S1.3.4. Economic impact of ICM systems

**Production costs**

- *Case study and non-case study evidence:* production costs refer to variable production costs and there may be other costs such as increased management time, education and changes in fixed costs which should be taken into account in a more detailed investigation of the economic impact of ICM. In only 1 commercial system (Chianti) were production costs higher under ICM, and then this is the result of further processing rather than ICM *per se*. In all other examples where data were available, variable production costs were lower. In some systems it was explicitly stated that the reduction in variable production costs was mitigated to some extent by increased costs elsewhere, namely management costs (for instance, the two Spanish case studies where these lower variable costs were outweighed by increases in management and analysis costs).

Summary: on balance, the evidence suggests that ICM results in lower variable production costs, mainly through savings relating to pesticide and fertiliser application.

**Premium**

- *Case study and non-case study evidence:* there were no premiums available for research systems (including non-case study systems which were also exclusively research driven), which is not unexpected given that these systems have been established to develop and investigate protocols and environmental impact rather than to produce commercial returns. Premiums are also the exception rather than the norm in commercial systems (only Chianti has a premium, although this results from bottling rather than ICM production). In 1 case (AKIL) the initial premium has now disappeared as supply of ICM produce has increased, in another (Champagne) labelling as ICM is not currently legal so it is impossible to attract a premium, and in both Spanish case studies (pome and citrus fruit production), ICM has provided a marketing advantage by become more of a right to supply multiple retailers rather than an identity preserved marketing niche.

Summary: premiums are generally not available for ICM production, although a marketing advantage is often conferred in that multiple retail outlets are more willing to source ICM rather than conventional production.

**Yield**

*Case study and non-case study evidence:* the impact of ICM systems on yields appears mixed. Of the 9 case study systems that compared yields to conventional systems, 2 showed lower yields and the LIFE project showed lower yields for the feed quality system, but higher yields for the milling quality system. Six case study systems showed yields approximately equal to conventional systems. Of the 8 non-case studies, 5 recorded lower yields and 1 suggested that yields were comparable (2 did not compare yields). This is quite a mixed signal, although the non-case study research was primarily designed to examine environmental impact and therefore did not generally pay close attention to yield.

Summary: the yield in ICM systems tends to be lower at this point in time, however, further research could reduce this difference. Greater commercial interest may also result in greater investigation of the yield impact of ICM techniques.

**Revenue**
*Case study and non-case study evidence:* revenue is a function of premium availability and yield. Of the 9 case studies for which there is revenue data, 3 had a lower revenue as a result of lower yields and no premium and 5 had revenues equating to conventional systems. One system (Chianti) had higher revenues reflecting the availability of premium. Because none of the non-case study systems attracted a premium, the impact on revenue follows the same pattern as for yield, i.e. of the 6 systems where there are data, 5 systems returned a lower revenue and 1 had a comparable revenue.
Summary: although revenue is generally lower for ICM systems (reflecting reduced yields and lack of premium, it certainly seems to be the case that the marketing advantage mentionhed above reduces revenue risk because it facilitates the sale of produce to multiple retailers. As with yield, further research and the possibility of attracting premiums in the future might result in increased revenues from ICM systems.

**Profitability**
*Case study and non-case study evidence:* this is crudely defined as the difference between revenue and variable production cost, although it is recognised that this will not take into account other cost items (see under production costs, above). Four of the case study systems showed a profitability equivalent to that obtained under conventional management, 2 systems provided higher profitability and 3 systems lower profitability (including the 2 Spanish case studies where technically profitability, defined as revenue less variable costs, was higher, but the inclusion of increased management and analysis costs made whole farm profitability lower). The LIFE system showed a slightly higher profitability for the milling quality system and slightly lower profitability for the feed quality system. The evidence from the non-case study systems suggested that ICM resulted in lower profitability.
Summary: it is difficult to draw firm conclusions on profitability from the balance of the evidence, but the case study evidence at least suggests that it is possible to achieve similar levels of profitability using ICM techniques as a result of lower yields and hence revenue being balanced out by reductions in production costs.