Integrated Farming Systems and Sustainable Agriculture in Europe

Dr. John M. Holland
The Game Conservancy Trust, Fordingbridge, Hampshire, England, UK

Background

This paper is a summary of the progress being made in western Europe in developing integrated or ecological farming systems with particular emphasis on climate and cropping patterns. Research is underway at a number of locations to address the needs of farmers who wish to lower their production costs. Many farmers have already adopted some practices of integrated or ecological farming (e.g., reduced pesticide usage), but without the knowledge of long-term agronomic, economic and environmental implications of changing their practices. Such changes are occurring because of increasing economic pressure from:

- reduced monetary support;
- reduced subsidies on agricultural exports because of lower world market prices (resulting from recent GATT negotiations); and
- increased costs of inputs.

Interest in integrated and ecological farming systems began in the late 1970’s because of increased costs of conventional farming, and increased public pressure to reduce food surpluses. At that time there were growing concerns about environmental pollution from chemical fertilizers and pesticides, and their effects on human health and wildlife. Questions had also arisen on the long-term sustainability of high-input farming systems that were largely dependent on fossil fuels and synthetic chemicals. Moreover, crop production was being adversely affected by the development of herbicide resistance in weeds and insecticide resistance in insect pests. Thus, we need to know whether integrated farming can help to resolve these problems by using agricultural and ecological knowledge, combined with non-chemical husbandry techniques, to reduce the farmer’s dependence on agrichemicals (Vereijken, 1989a). However, if integrated farming is to be widely adopted, this must be achieved while maintaining profitability and food quality.

To achieve these goals the entire crop production process must be examined because the agroecosystem is highly interactive; thus, changing one practice may influence other aspects of the system. An example of this is the relationship between nitrogen and its effect on crop growth rates, yield, susceptibility to pests and diseases, and the competitive-ness with weeds. With this in mind, the International Organization of Biological Control (IOBC) appointed a working group on Integrated and Ecological Farming Systems. The group is comprised of very knowledgeable participants from each of the EU-member countries and five non-member countries, and its objectives are to a) coordinate research methodology and extension services, b) exchange results, and c) provide information on integrated and ecological farming systems to scientists and farmers in their respective countries (EI Titi et al., 1993). The success of this group so far has been largely due to the efforts of Dr. P. Vereijken in the Netherlands; Dr. A. El Titi in Germany; and Dr. V. Jordan in the United Kingdom (UK).

Research on Integrated and Ecological Farming Systems

The first long-term, large-scale research projects on integrated farming systems began in the late 1970’s with the Development of Farming Systems Project at Nagele, the Netherlands (Vereijken, 1989b) and the Lautenbach Project in Germany (EI Titi, 1991). Since then some 16 additional research projects on integrated farming systems have been initiated in other European countries (Vereijken, 1993). The locations, major thrusts, and experimental designs of these projects are reported in Table 1. While the objectives and designs of these projects differ somewhat, all of them focus on the development of integrated or ecological farming systems for producing a range of crops adapted to local climatic and agroecological conditions. The exceptions are the UK’s TALISMAN (Towards A Low Input System Minimising Agrochemicals and Nitrogen) and RISC (Reduced Input System of Cropping) projects which are more concerned with a comparison of input levels; and the SCARAB (Seeking Confirmation About Results at Boxworth) project in which the environmental effects of different pesticide regimes are the priority.

In most of these projects reviewed by Holland et al. (1994), one or more crop rotations ate compared either at a single site, or by using additional sites across a geographical area. The rotations studied, however, can provide only a part of the information that is needed. Thus, it is the role of the pilot farms established at a later date to extend the diversity of crop rotations. Nevertheless, for each project, the conventional farming system for each location is being compared with one or more integrated farming systems. The scale of the projects ranges from the 18 x 20 m plots in TALISMAN to whole farm comparisons in the Netherlands.

In his review, Holland et al. (1994) describes many of these projects in greater detail. Each project examined the economic viability of the farming systems that were studied because ultimately their acceptance by farmers will depend on maintaining profitability. Most of the projects assessed the agronomic aspects of integrated or ecological farming systems using such indicators as weed populations, pest and disease incidence, and soil minerals. Environmental assessments were usually limited to studies of non-target invertebrates and earthworms. These have the advantage of being easy to sample, often large populations, and are adversely affected by intensive soil tillage and pesticide applications.

The review (Holland et al., 1 994) also identified other environmental factors that might be useful indicators of soil quality and plant health such as beneficial microorganisms, which have received little attention thus far. In some studies, e.g., LINK IFS (Integrated Farming Systems) in the UK and INTEX in Germany, small scale validation trials are carried out in conjunction with the main experiment to verify individual findings. Such trials can contribute greatly to the interpretation of results and provide useful modifications to the system.

Project Results and Observations: Economic, Agronomic and Environmental Aspects

Economic Aspects

It is encouraging that many similar conclusions were drawn from the studies which have been completed or are well underway. With respect to economics, in most cases only the gross margin data have been published. However, this was usually equal to or greater for the integrated and ecological system, despite the yield reductions which often occurred for these non-conventional systems. The results varied between crops, although cereals and oilseed rape were better suited to the integrated farming regimes. Nevertheless, in comparing the performance of these farming systems, it is important that the results over the entire crop rotation be considered.

Agronomic Aspects

In reviewing these projects (Table 1) it was noted that the inputs of fertilizer nitrogen, herbicides, fungicides, insecticides and plant growth regulators were substantially reduced for the integrated-ecological regimes compared with conventional farming systems. Nitrogen inputs were often reduced by utilizing animal manures, but this is practical only when they are available locally. For specialized crop production farms, to include an animal unit for the sake of manure would be prohibitively expensive and may contribute to a surplus of animal products.

Herbicide inputs were reduced by switching to mechanical weeding combined with an appropriate crop rotation. However, weeds presented the greatest problem integrated-ecological systems where minimum tillage was adopted, mainly because it encourages the growth of grass and other weeds. This may, however, be resolved by occasional plowing.

Fungicide and insecticide use was reduced primarily by selecting lower rates of application adjusted to the level of infestation. Fungicide use was further reduced by using disease-resistant cultivars. Because of the sporadic nature of pest and disease infestations, no firm conclusions could be drawn on their incidence in the integrated system. This may be better investigated using small-scale, manipulative trials.

Table 1: Summary of Experimental Designs for Integrated and Ecological Farming System Research Projects in Western Europe.

Project	Duration	Number of Sites	Regimes	Experimental Designs
Denmark				
Foulum	1987-	1	ecological	6/blocks/systems
Finland				
Nummela Project	1992-	1	conventional/HP,LP,NP; integrated/HP,LP,NP	randomized blocks
Suita	1994-99	1	integrated	2 rotations of 5 blocks
France	1990-99	4	conventional integrated	6-10 paired blocks per site with rotations in deep and shallow soils
Germany				
Lautenbach	1978-89	1	current farming system; integrated farming system	7-9 paired blocks
INTEX	1989-97	3	I. conventional high input II. integrated III. reduced IV. extensive/ecological V. fallow	3-4 contiguous fields per site 3-4 contiguous fields per site 3-4 contiguous fields per site 1-4 contiguous fields per site 1 field per site
Ireland				
Johnstown	1993-96	1	ecological	8 blocks
Italy				
Montepaldi	1991-97	1	conventional integrated ecological	2-4 blocks/systems
The Netherlands				
Nagele	1979-	1	conventional/arable integrated/arable organic/mixed	3 whole farm comparisons
Borgeswold	1986-	1	conventional integrated conventional/LR integrated/LR	3 whole farm comparisons
Vredepeel	1989-	1	conventional integrated integrated/LR integrated/MR	4 whole farm comparisons
Sweden				
Logarden	1991-99	1	conventional integrated ecological	4-8 blocks/systems
Alnarp	1992-04	1	conventional integrated	6 split fields
Switzerland				
Third Way	1981-	3	conventional integrated no pesticide	whole farm comparison with no pesticide within fields
UK				
Boxworth	1981-88	1	full insurance supervised integrated	4 continuous fields 4 continuous fields 3 continuous fields
SCARAB	1989-96	3	current farm practice; reduce input approach	7 paired half-fields

(Continued)

Project	Duration	Number of Sites	Regimes	Experimental Designs
UK				
TALISMAN	1989-96	3	current farm practice; low input, integrated integrated, low input	6-12 randomized blocks per site
RISC	1991-00	2	as for TALISMAN minimum input	12 randomized blocks per site
LIFE	1989-99	1	current farm practice/CR current farm practice/IR integrated farming system/CR integrated farming system/IR	5 paired blocks
LINK IFS	1992-97	6	conventional farming practice integrated farming system	7-9 paired blocks

HP= high pesticide pressure, LP= low pesticide pressure, NP= no pesticide, CR= conventional rotation, IR= integrated rotation, LR= less root crops, MR= more root crops

Overall, the reduction in pesticide inputs for the integrated-ecological systems varied depending on the cropping system and agroclimatic factors. However, for some projects, herbicide use was reduced by 15 to 75 percent, fungicides by 50 to 90 percent, insecticides by up to 90 percent, and plant growth regulators by as much as 100 percent. The incidence of soil-borne diseases was also variable but tended to increase with minimum tillage.

Environmental Aspects

Beneficial arthropods usually increased in the integrated systems probably due to the lower pesticide inputs, adoption of minimum tillage, greater weed coverage within the crop and incorporation and better management of non-crop areas. Earthworms also benefited from the change in soil tillage practices. No precise conclusions could be made for the other environmental aspects. The mobility of birds and mammals prevented their assessment in many of these studies. In the Boxwortil project molluscide pellets were found to reduce wood mice (Apodemus sylvaticus L.) but no long-term effects of pesticides were detected on the breeding performance of birds (Greig-Smith et al., 1992). It has been shown that the encouragement of invertebrates is beneficial to farmland birds, e.g., the grey partridge (Perdix perdix L.), which rely on an adequate supply of insects for chick food (Potts, 1986). Only some short-term adverse effects of pesticides on soil biota were detected in the UK’s SCARAB and RISC projects, but complete results will not be available until these projects are completed.

Soil and Crop Management

The integrated farming systems evolving from the earlier projects have a number of similarities that have been used as guidelines by the more recent projects. The most important component of any integrated farming system is the cropping mix or crop rotation because it will have a profound influence on:

- soil fertility,
- nitrate leaching,
- soil minerals,
- disease and pest incidence, and
- weed populations and diversity.

Crop rotations must be selected with careful attention to the soil type, agroclimatic factors, husbandry requirements, and market economics for each crop.

Soil Tillage

The selected method of soil tillage is also a key component of an integrated farming system and is considerably influenced by the soil type and crop rotation. Reduced tillage systems are often beneficial because they require less power, preserve the soil structure, and enhance the soil biota. This practice also helps to prevent soil erosion and encourages predation of weed seeds on the surface (Jordan et al., 1993). However, this practice may facilitate disease carry-over, increase grass weed problems, facilitate greater nitrate leaching and encourage slugs. In such cases, plowing or a combination of reduced tillage and conventional tillage methods may be appropriate; but this decision will depend on the agronomic requirements and environmental considerations for each farm.

Crop Cultivars

The use of disease-resistant cultivars is essential in an integrated system. When combined with appropriate sowing dates this can help to reduce the incidence and infestation of diseases and pests, thus, reducing the need for pesticides. Further reductions in pesticide inputs may also be achieved by diversifying cultivars between fields. Using mixtures of cultivars is not advisable because of marketing difficulties, although they would be appropriate for animal feed grains.

Integrated Nutrient Management

Many of the projects were able to reduce the fertilizer nitrogen requirement for the integrated farming systems by using animal manures; however, this may not be possible in the intensive cropping areas, e.g., the eastern counties of the UK where animal husbandry is not a predominant enterprise. Animal manures also require careful management to avoid nitrate leaching. The greater use of legumes and cover crops as green manures can reduce the need for "bagged" nitrogen and, if feasible, would be best incorporated into the rotation as set-aside. Choice of sowing date can also affect the nitrogen requirement. In some cases, a greater proportion of spring crops in the rotation would require less nitrogen, but may need to be combined with a cover crop over winter to prevent nitrate leaching.

For all of these options, the crop's nutrient requirement must be met to optimize crop yield and quality, and at the same time must minimize the risk of nutrient leaching and environmental pollution. Soil sampling can help to identify residual nutrient levels, and when such data are combined with the previous cropping history, the crop yield potential, and the crop nutrient requirements in a computer model, accurate predictions are possible. However, there is still insufficient knowledge on the relationship between nitrogen fertilization, the incidence of insect pests and diseases and crop competitiveness with weeds, so that nitrogen applications can be adjusted to the most appropriate level for an integrated system.

Integrated Pest Management

While pesticides may still be required in an integrated farming system, their use can be markedly reduced through a combination of non-chemical practices, and judicious use of spray thresholds linked to the cost-benefit relationship. The farmer can readily apply these strategies for insect pest control; however, easily-implemented, reliable methods are still needed for disease and weed control. Mechanical weeding can help reduce the need for herbicides and is most successful when combined with low herbicide application rates; however, the machinery is not suitable for all soil and crop types. In many in-stances the integrated systems may rely on a wait-and-see approach for disease, weed and insect control and are, therefore, a more risky strategy for the farmer compared with a more cautious prophylactic approach. Furthermore, such a strategy is difficult to implement on a farm-scale when machinery availability and climatic conditions are limiting.

We need to recognize the role of natural regulatory mechanisms within an integrated farming system. Insects and spiders that prey upon or parasitize crop pests have been extensively studied, and much is known about their contribution to pest control. Such insects include aphid parasitoids, aphid-specific predators, and the polyphagous ground beetles, In addition invertebrates also consume plant pathogens and weed seeds although this has not been thoroughly quantified. New techniques and strategies are also being evaluated which may enhance the populations of these beneficial insects.

One such strategy is that of Conservation Headlands developed by The Game Conservancy Trust in the UK where the outer 6 meters of the crop is only selectively sprayed, thus, retaining the rich

weed flora in this area on which many invertebrates feed (Sotherton, 1991). Beetle "banks" established on raised grassy areas provide an overwintering site for many invertebrates (Thomas et al., 1991). Flower strips sown either along field margins or within fields, provide an additional source of pollen, nectar and ground cover, and serve as an easily-managed, non-crop habitat (Marshall et al., 1994).
Maintaining a healthy soil environment, as we will hear at this conference, is essential to integrated farming systems because it helps to suppress soil-borne plant pathogens. The proper and regular addition of organic amendments is one of the easiest and most effective means of maintaining and enhancing beneficial soil microorganisms, earthworms and invertebrates, in addition to improving soil quality and productivity. Biocontrol may also be improved by minimizing the disturbance of the environment through reduced tillage and lower rates of agrichemicals. However, farmers, scientists, and farm specialists need additional information to select the most environmentally -friendly production system to minimize disturbance of the farmland ecosystem.

Future Prospects

Integrated arable farming is still in its infancy in many parts of Europe although interest is expanding rapidly with the initiation of many pilot farms. Examples of these can be found in the Netherlands where 40 farms converted to integrated farming during 1990-94 using the methodology developed at the experimental farms (Wijnands and Vereijken, 1992). The concept and training programs are being extended to the farming community and to other production systems, including the flower, fruit, vegetable and bulb industries. In the UK, LEAF (Linking Environment and Farming) was launched in 1991 to promote the principles of Integrated Crop Management (ICM). This combines environmentally-friendly with economically-viable production systems. To date 17 demonstration farms have been established throughout the UK which have already adopted these systems.
Complete results from many of the projects in western Europe will not be available until the mid to late 1990's. By this time, with the predicted decline in subsidies, economics will have driven most farmers to a minimum level of pesticide inputs. At this stage, farmers will require additional guidance if they are to further reduce their pesticide inputs while maintaining an acceptable level of productivity and profitability. Hopefully, the results from these projects will help to provide this knowledge and thereby contribute to the long-term sustainability of agriculture.

References

El Titi, A. 1991. The Lautenbach Project 1978-89: Integrated wheat production on a commercial arable farm, south-west Germany. p. 399-411. In L. G. Firbank, N. Carter, J. F. Darbyshire and G. R. Potts (ed.). The Ecology of Temperate Cereal Fields. Blackwell Scientific Publications, Oxford, England.

El Titi, A., E. F. Boller, and J. P. Gendrier. 1993. Integrated Production-Principles and Technical Guidelines. IOBC/VPRS Bulletin 16(1). 96 p.

Greig-Smith, P.W., G.K. Frampton and A.R. Hardy. 1992. Pesticides, Cereal Farming and the Environment. HMSO, London, England. 281 p.

Holland, J. M., G. K. Frampton, T. Cilgi and S. D. Wratten. 1994. Arable acronyms analyzed: A review of integrated arable farming systems in western Europe. Ann. Applied Biology 125:399-438.

Jordan, V. W. L., J. A. Hutcheon and D. M. Glen. 1993. Studies in Technology Transfer of Integrated Farming Systems: Considerations and Principles for Development. Booklet, AFRC Institute of Arable Crops Research, Long Ashton, Bristol, England.

Marshall, E. J. P., C. F. G. Thomas, W. Joenje, D. Kleijn, F. Burel and L. De Coeur. 1994. Establishing vegetation strips in contrasted European farm situations. p. 335-340. In N.D. Boatman (ed.). Field Margins: Integrating Agriculture and Conservation. BCPC Monograph No. 58. Farnham, England.

Potts, G. R. 1986. The Partridge: Pesticides, Predation and Conservation. Collins Publ., London, England.

Sotherton, N. W. 1991. Conservation headlands: A practical combination of intensive cereal farming and conservation. p. 373-398. In L. G. Firbank, N. Carter, J. F. Darbyshire and G. R. Potts (ed.). The Ecology of Temperate Cereal Fields. Blackwell Scientific Publications, Oxford, England.

Thomas, M. B., S. D. Wratten and N. W. Sotherton. 1991. The creation of 'island' habitats in farmland to manipulate populations of beneficial arthropods: Predator densities and emigration. J. Applied Ecology 28:906-917.

Vereijken, P. 1989a. Experimental systems of integrated and organic wheat production. Agricultural Systems 30: 187-197.

Vereijken P. 1989b. From integrated control to integrated fanning, an experimental approach. Agriculture, Ecosystems and Environment 26:37-63.

Vereijken, P. 1993. Integrated and ecological arable farming systems. Progress Report 1. Designing Prototypes. Concerted Action AIR 3-CT920755.

Wijnands F. G. and P. Vereijken. 1992. Region-wise development of prototypes of integrated arable farming and outdoor horticulture. Netherlands J. Agric. Science 40:225-238.