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Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture

Proceedings of the JRC Summer University
Ranco, 2-5 July 2007

Editors:
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Foreword

The concept of sustainability applied to agriculture developed mainly as a result of growing awareness of negative impacts of intensive farming systems on the environment and the quality of life of rural and neighbouring communities. Intensive farming systems are based on genetically uniform crops and livestock breeds, vulnerable to pests and diseases. High yields are obtained through dependency on external inputs (especially fossil energy, fertilizers and pesticides) which can cause decreased air, water, soil and food quality. Intensification and specialisation also bring about landscape changes, resulting in its homogenisation and destruction of traditional landscape elements and, consequently, loss of habitats. Marginal areas, on the other hand, are threatened with cessation of agricultural practices and land abandonment. All these factors also lead, directly or indirectly, to the loss of biodiversity.

Lewandowski et al. defined in 1999 sustainable agriculture as *'the management and utilization of the agricultural ecosystem in a way that maintains its biological diversity, productivity, regeneration capacity, vitality, and ability to function, so that it can fulfill – today and in the future – significant ecological, economic and social functions at the local, national and global levels and does not harm other ecosystems'*.

The search for sustainability of agriculture inevitably leads to the exploration of the potential of Low Input Farming Systems (LIFS) to achieve this goal.

Within this context, the European Commission Joint Research Centre, Institute for Environment and Sustainability and SOLAGRO organized a Summer University '**Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture'** which took place on 2-5 July 2007 in Ranco (Italy). The programme of the Summer University has been drawn to reflect the diversity of Low Input Farming Systems in Europe and the complexity of factors currently impacting on European agriculture.

This report contains the papers which were presented at the meeting as well as final conclusions, summarizing the main points of the discussions which suggested possible lines of future research and policy options which might support LIFS in Europe

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The organisers would like to express their sincere gratitude to all the speakers and participants who contributed to the success of the meeting

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Cover photograph: © Krzysztof Kujawa

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Low input farming systems in Europe: What is at stake?

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Keywords: farming systems, environment, economy, EU policies, low-input farming

Abstract Low input farming systems (LIFS) can be defined as those which maximize the use of on-farm inputs. Compared to farming systems heavily relying on off-farm bought inputs (thus high input farming systems or HIFS), LIFS will have a physical productivity limited by the maximum on-farm resources that can be mobilized. LIFS can then be associated with lower output.
The paper addresses the issue why LIFS should be considered as a core option for Europe. Indeed, at the farm level, LIFS might have a higher efficiency than HIFS. In addition, from an environmental point of view, not only are LIFS able to reduce pollutions risks but allow producing positive amenities in terms of landscape and biodiversity as well.
Despite these assets, the paper shows how, in the long term, the technical and economic competition between farming systems entails the advantage of HIFS upon LIFS. More precisely, the inter-regional competition can be analysed through a 'cerealization' process of the whole EU agriculture: more cereals produced upstream, with more incorporation into the livestock sector downstream. On-farm resources and closed nutrient cycles (LIFS) are progressively replaced by off-farm resources and opened cycles (HIFS).
Developing LIFS at European scale needs radical changes in the EU policy. Notably, while decoupling has been thought as a way to promote LIFS, the analysis proposed shows that the competition mechanisms are likely to achieve the opposite results. A CAP reform targeted on LIFS evenly distributed on the European territory is what is at stake in order to reach a sustainable European agriculture.

Introduction: The characteristics of Low input farming systems There is no official definition of Low input farming systems (LIFS later in the paper). The main definition explicitly addressing the concept has been proposed by J.F. Parr et al. (1990): low input farming systems are those who "*seek to optimize the management and use of internal production inputs (i.e. on-farm resources)... and to minimize the use of production inputs (i.e. off-farm resources), such as purchased fertilizers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long-term farm profitability.*"

While the general idea underlying LIFS makes sense in general terms, this definition can be considered as common for different agricultural labels which practically stand on quite different, if not opposing, patterns. This definition of LIFS can, for example, encompass organic farming, "*agriculture raisonnée*" or efficient agriculture, integrated farming mobilising biological control under IOBC definition, just to mention some of the numerous labels and attributes of agriculture.

The idea of 'optimizing' and 'minimizing' the inputs is, nevertheless quite general. Indeed, Norman et al. (1997) note that the term is "*somewhat misleading and indeed unfortunate. For some it implied that farmers should starve their crops, let the weeds choke them out, and let insects clean up what was left. In fact, the term low-input referred to purchasing few off-farm inputs (usually fertilizers and pesticides), while increasing on-farm inputs (i.e. manures, cover crops, and especially management). Thus, a more accurate term would be different input or low external input rather than low-input*." But this discussion still leaves open the level of what is considered "*few off-farm inputs*" for example. Low input or lower input: what is the limit?

The theoretical well-known figure of the production function showing the relationship between the nitrogen (N) input and the physical output (yield) can help organising a bit the ideas on this issue. We insist on the fact that the discussion proposed here is albeit simplified for the needs of the length of the paper.

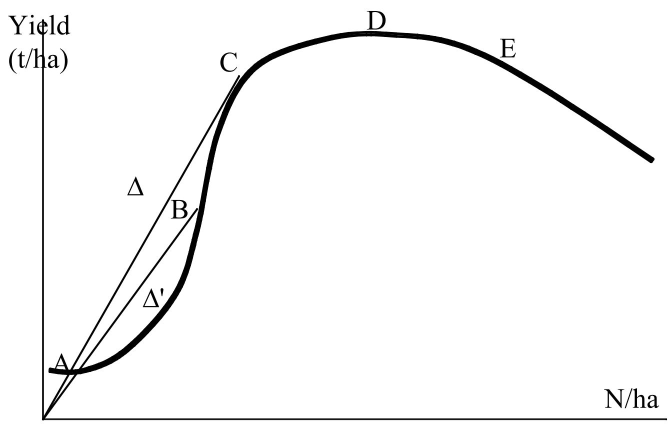

Figure 1: Where are the different types of LIFS on the theoretical yield = f(N) curve?

Both A, B, C and D can be qualified as "low-input" compared to the situation in E (of a farmer who, by lack of knowledge or simplification of cropping patterns applies N at a higher level than required). For the purpose of our reasoning, we shall name this F situation of conventional farming, assimilated to high input farming system (HIFS).

However, the strategies are different between A, B, C and D (Shortel et al. 2001) and the meaning of "low-input" is not the same between the points:

- D is minimising the waste of N in trying to achieve the maximum yield. This can typically be the strategy of a farmer engaged in "*agriculture raisonnée*". In this meaning, we are in a situation of "lower input" in a still HIFS, under a conventional production pattern. It is simply a "better F" (Blouet et al. 2003).
- C is maximising the efficiency of the overall use of nitrogen (Δ > Δ'), and this could be an alternative and best strategy in "*agriculture raisonnée*"
- B is maximising the efficiency in the use of N in the sense that any extra kg of N will entail less yield that on B
- A is the situation of lowest input, where N can be a limiting factor for example.

We are aware that this discussion stands on several assumptions. The first one is the shape of the curve, which is commonly accepted but can be significantly different with other inputs (such as pesticides), for example. The second issue is that the production patterns can fundamentally vary between A, B, C and D as developed by Viaux (1999). For example, a farmer with no input availability (A) will not have the same varieties, crop rotations and tillage practices than E or F; such systems cannot really be placed on the same curve and we should not compare the efficiency of the same amount of N between a conventional wheat farmer in the Bassin Parisien using seeds provided by a large seed company and a mixed farmer in Romania, for whom the production of straw is as important as the one of grain and who selects his seeds on his own farm.

This being said and even with the specification we have made (i.e. LIFS vs. conventional systems), it is clear that the level of use in inputs can be different across different types of LIFS and shall deliver different types of environmental goods. For example, high nature value farming systems (HNV) are recognised of being low input: "*High Nature Value (HNV) farming systems are predominantly low-intensity systems which often involve a relatively complex interrelationship with the natural environment"* (Beaufoy et al. 1994) and this natural attribute is frequently associated to a rather low use of fertilisers and pesticides (Baldock et al. 2002), close to none at the field level (thus close to the "A" situation in figure 1). Other LIFS might be designed and managed with regards to water quality issues, with the idea of the best use of a limited amount of fertilisers (B or C situations), for example (CEDAPA in France) which nevertheless might be over the optimum for biodiversity at the stand level.

However, despite all these simplifications, we shall defend the idea that it makes sense for our discussion to cluster those systems which stand on production patterns which significantly reduce the use of inputs compared to conventional agriculture, assimilated to HIFS for the purpose of our discussion. C, B and A situations are not simply adjustments in conventional production patterns (that could be D compared to E) but require more fundamental changes in the management of the cropping system.

Without developing any further the discussion on the different types of LIFS, two issues can be stressed:

(1) LIFS should be analysed in a holistic vision: the idea of a farming *system* is thus paramount to capture the complex relationships at play at the cropping system and the landscape ecology levels which enable the farmer to rely on low off-farm inputs. Fundamentally, the numerous nutrient flows between the different boxes of the farming systems entail the necessity of nutrients of natural origin at the farm level. Two main sources are considered: the N-fixation through legumes in the crop rotation and, more generally, the existence of non cultivated (non ploughed) crops able to take the nutrients from the soil at a level which does not alter the sustainability of nutrients cycles. The set of such non cultivated crops (e.g. permanent grasslands, meadows, scrubs, hedges,…) sometimes labelled semi-natural vegetation in the field of HNV analysis (Beaufoy et al. 1994) is forming what rural geographers calls the *saltus* (Poux 2005). It is paramount to note that the *saltus* is generally valued by grazing livestock, which ensure a fertility transfer through an appropriate use of manure on cultivated land. Thus, historically, autonomous LIFS in Europe have been set on the basis of mixed livestock-crops-*saltus* systems.

(2) It must be recognised that the management of such complex flows at the farm level requires a set of appropriate knowledge and a large amount of work. Labour is then a frequent limiting factor in the development of LIFS. Except for large grazing livestock systems which stand on a "ranching" pattern (and which require adapted land tenure structures in order to minimize the herding time such as large common lands and/or large holdings), many LIFS cannot exceed a certain physical size, expressed in ha per labour unit, over which the management of flows becomes impossible.

The following figure summarizes the idea developed above:

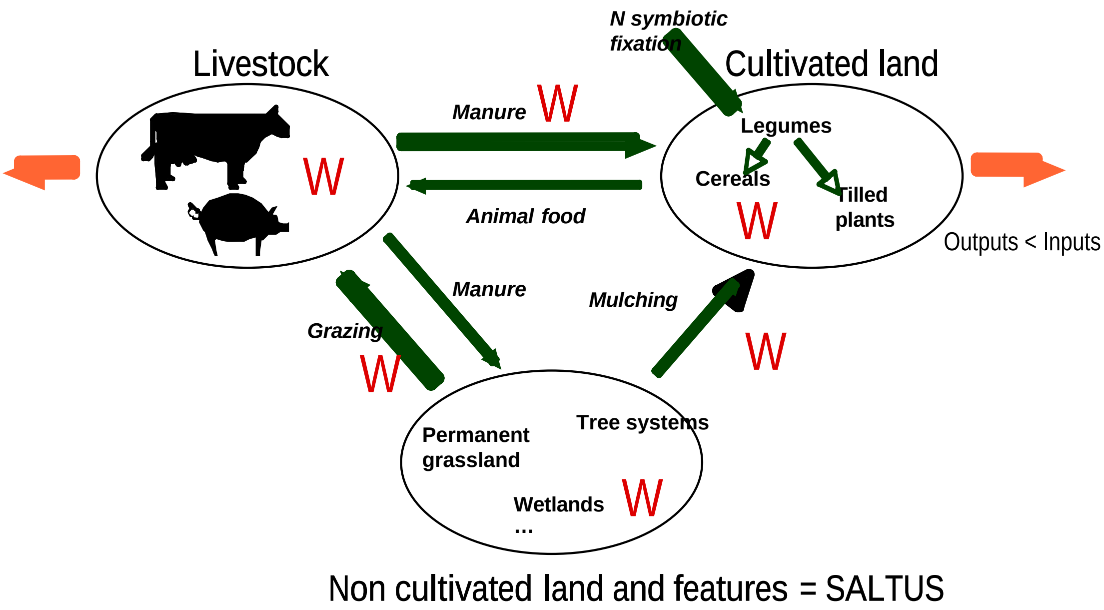

Figure 2: The components of an autonomous low input farming system (closed nutrient cycle) – the mixed livestock-crops farming model

The green arrows symbolise the nutrient flows available at the farm level (from saltus and N fixation)
The red arrows symbolise the output of the system: crops and livestock products (milk and meat)
The red "W" symbolise the labour required for the management of every component of the system
"Outputs<Inputs" reminds that the nutrients contained in the output can not exceed the natural inputs from N fixation and saltus natural mobilisation of the soil nutrients.

On this basis, the mobilisation of imported off-farm input can be interpreted as a way to go over the limit imposed by 100% autonomous farming system: bought fertiliser allows to cultivate more land without augmenting livestock and get rid of the demanding daily work required by animals; pesticides are a way to get rid of demanding crop rotation and keeping landscape features which on the one hand play a role in pest management, but on the other hand can be interpreted as a constraint for mechanisation. On the other hand, for a livestock farmer, buying off-farm animal feed is a way to increase the productivity. In a way, HIFS afford off-farm inputs to replace on-farm labour by an external auxiliary that allows the farmer to overpass a "natural" limit and maximise the physical productivity through land intensity and/or the size of the farming system. An important conclusion for our discussion is that LIFS will have a lower output, at the farm level, than the HIFS.

Why Europe needs more LIFS HIFS have been associated to the success of what can be called the European agri-food system. In the range of the this paper, we will mainly list, without developing them, the reasons why LIFS should be developed in Europe, while the trend is the opposite.

The first set of argument is obviously related to environmental issues. The replacement of LIFS – which were the dominant use of the European territory in 1950 – by HIFS has led to most of the environmental problems identified in Europe. The pollution of the water resources, the drop in biodiversity, the increase of erosion problems can be associated, in broad view, with the withdrawal of landscape ecology features (and notably the *saltus*) and, consequently, the increased use of inputs (Baldock et al. 2002).
The environmental concern for LIFS has been recently supported by health arguments. While nutrients are causing some diseases in particular populations (methemoglobinemia of the new-born), the pesticides are probably recognised as a wider concern for the whole population, with impacts associated with cancers and fertility disorders, identified as "environmental diseases". The health costs of intensive agriculture is a rising concern which, notably, supports the development of organic farming. Nevertheless, one might note that LIFS should not simplistically be associated with the absence of health problems (e.g. bacteriology).

Alongside with the environmental and health concerns another field of justification of LIFS can be found in the quality of products issue. Some traditional or typical products are more likely to be produced under low-input patterns (e.g. some dairy Products of Denominated Origin), though the relationship between such products and low-input farming is somehow ambiguous while value-added on products is also an incentive to intensify the production (Poux 2007a).

Reciprocal to these macro-societal justification of LIFS, one can also defend the micro-economic justification. We have discussed above that LIFS have a lower physical productivity. On the other hand, however, this can be more than compensated in terms of economic productivity by:
- higher prices on products (e.g. organic farming, PDO,…);
- lower proportional costs (fertilisers, pesticides, animal food,…);
- lower structural costs (machinery, financial costs…).

The following figure shows how a LIFS can compete with a HIFS on the same surface.

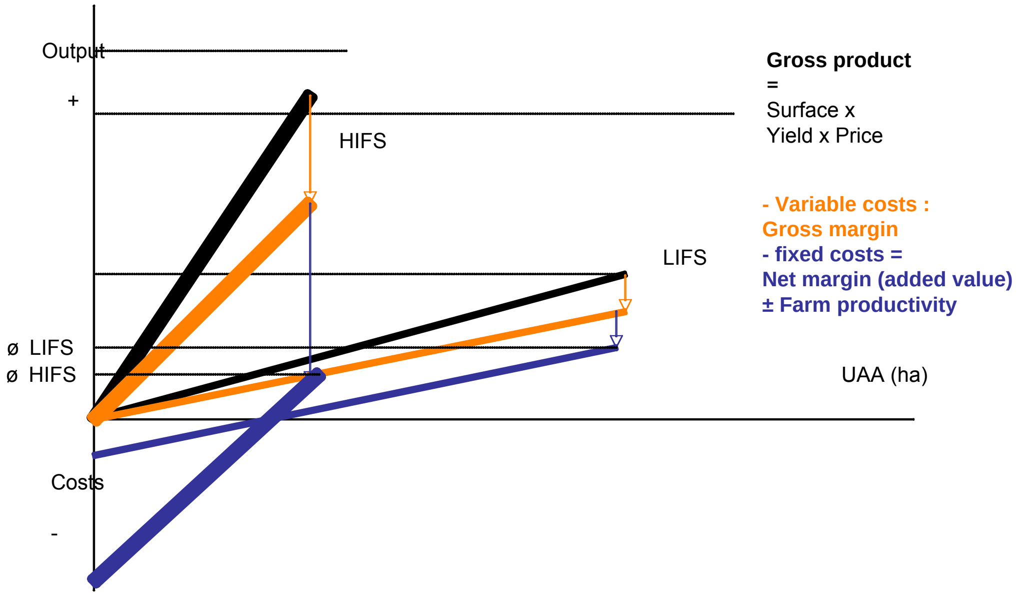

Figure 3: How can a LIFS can compete with a HIFS?

The black lines represent the overall farm gross product (surface x *yield* x *price); the orange one is the gross margin, i.e. the gross product less the variable costs; the blue line is the net margin, i.e. counting the fixed costs. The economies on variable and fixed costs allow the LIFS to get a higher overall farm productivity (∏ LIFS) compared to the HIFS (∏ HIFS).*

In some cases, the LI strategy has been deliberately adopted by farmers previously engaged into HIFS (réf pays de Loire). Another economic dimension is, while the ratio between economic products and costs is higher (compared to HIFS), the dependence on subsidies is less. Reducing costs can also be sometimes a way to get a higher number of farms and farmers in a given territory, though this argument should be carefully analysed while some extensive farming systems might mobilise more land/labour unit than intensive ones.

Apart from such strict economic arguments, farmers find other reasons to get involved in LIFS: health concerns (e.g. professional cancers), less dependence on suppliers advice and less debts, a more meaningful activity. In order to avoid a too rosy picture of LIFS, one must also point the difficulties of adopting such a strategy: more demanding management and know-how and increased technical risks (compared to relatively secure conventional patterns); possible social isolation in the conventional agricultural world (including the pressure from suppliers and retailers); less subsidies through the CAP until recently (see below).

All this set of arguments strongly supports the line of argumentation for LIFS at European scale. As pointed in the introductory part of the paper, a non-uniform model of low intensity should be defended across Europe (being organic and/or HNV and or sustainable agriculture and/or …). But in general terms, one can consider that there is room to promote LIFS in order to replace HIFS accordingly a "double dividend" strategy (Potter 1999).

At this time of the discussion, promoters of LIFS generally meet a certain scepticism based on two arguments:

(a) at the farm level, how to explain that HIFS farmers seem to get a higher income that most LIFS? In other words: 'if it works so well, why most farmers are not adopting LIFS?'
(b) More fundamentally, is it feasible to develop LIFS at large scale: if the physical productivity is lowered in LIFS, is there enough land to produce for the whole Europe and an increasing World market. Do we even have the right to reduce the European production when the Third World countries are starving?

In order to fully address these criticisms, we will propose a coherent analytical framework to better understand what is at stake in the European agriculture development.

The cerealisation of the European agriculture: the major force against LIFS With regard to the first argument — (a) the farm productivity —, one must recognise that HIFS are best placed in order to get the maximum on-farm income. As discussed above, LIFS require a significant amount of work in order to be managed and, thus, meet a maximum physical size expressed in ha and/or number of heads. HIFS are a way to get the maximum physical productivity with less work per unit produced; in other terms, they heavily depend on scale economy. Thus, while an average LIFS might get a higher productivity than an average HIFS, the largest HIFS will be those with the highest productivity both in physical and economic terms. To say it in a different way, for 90% of HIFS with mediocre productivity, you will have 10% with a high productivity which make dream the other 90% to get into the top 10%. In response of figure 3, figure 4 shows how an increase in size is able to compensate the higher costs.

This economic mechanism is paramount to take into consideration in order to understand why LIFS do not develop more at a regional level. While some LIFS will know a higher productivity than average HIFS (figure 3), the most productive systems in a given region will be HIFS. They thus be in best position to purchase the land left by the 'mediocre' HIFS (not to mention the sociological barriers for a conventional farmer to leave his land to an 'alternative' farmer), while there can be some exceptions at local level. In other words, if in a given situation, LIFS might have a better productivity, in the long term it is more difficult for them to compete with HIFS (Poux and Ramain 2007).

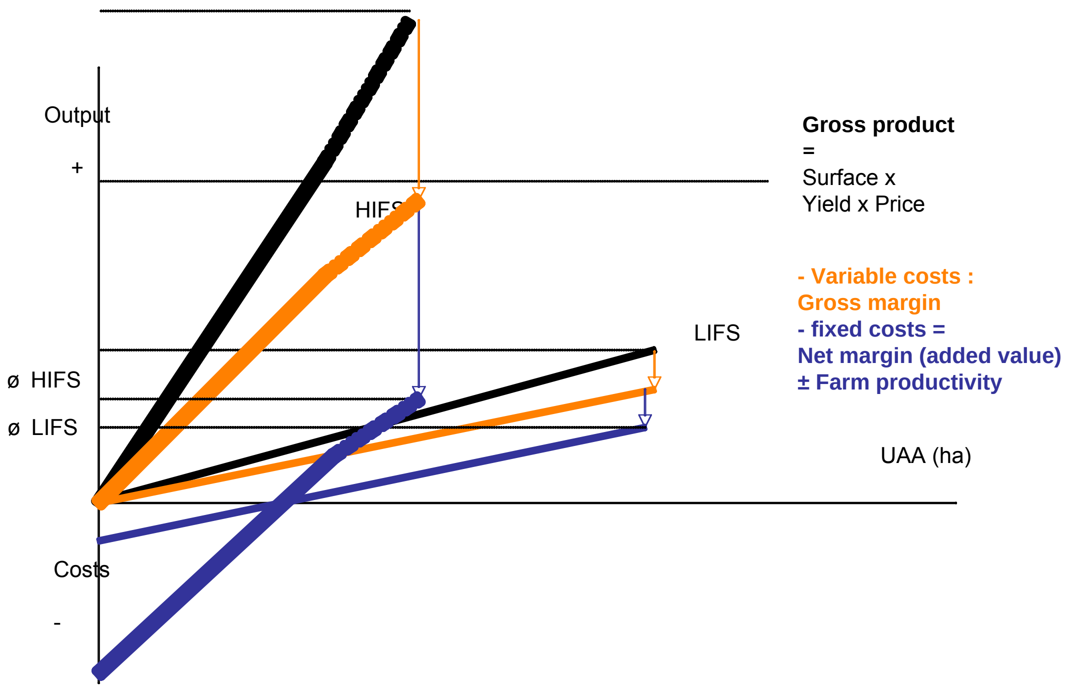

Figure 4: Why HIFS generally outcompete LIFS in a competition process
An increase in dimension of HIFS is allowed through the use of more inputs, while optimised LIFS will face difficulties in getting larger. The increase of gross product, gross margin and farm productivity in HIFS (dashed line) makes the HIFS more profitable than LIFS ∏ HIFS > ∏ LIFS, even with higher variable costs (increased gradient of the cost line in the dashed section).

This general rule can be detailed with regards to the most common farming systems in Europe dealing with livestock and crops. Following an historical discussion, we might start from the situation in the 1960's, described in the following figure (taken from Poux and Ramain, id.).

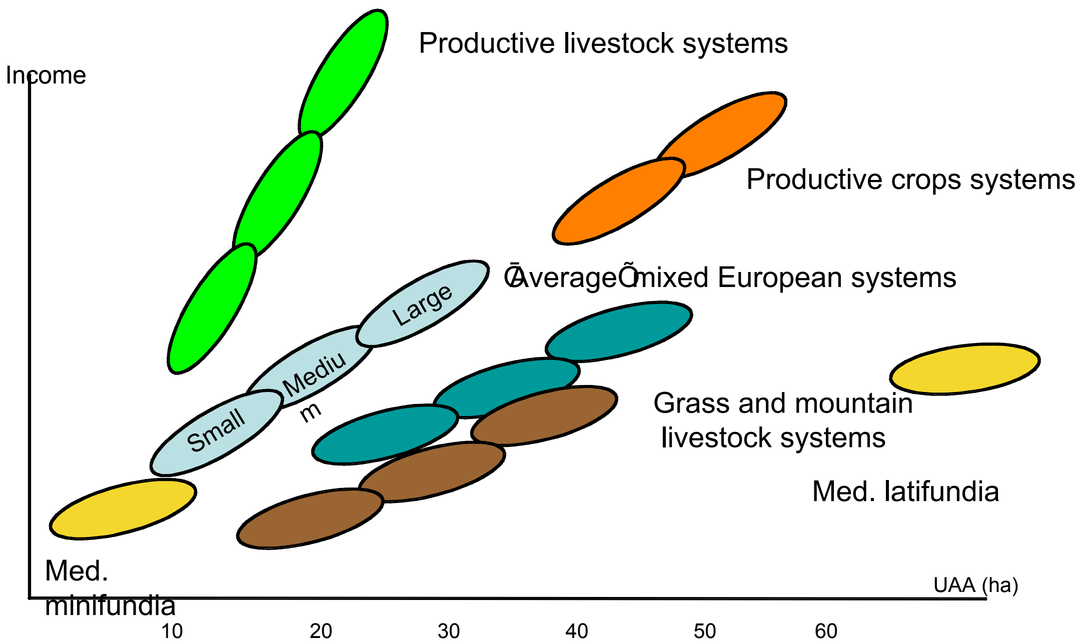

Figure 5: The main European farming systems in the 1960s

The core of European agriculture was composed of mixed crop-livestock systems, with a productivity limited by natural conditions (as most systems were LIFS at this time), as represented in figure 2 above. Depending on the soil and climate conditions, one could distinguish (from Limouzin 1996):

- the ‘average’ mixed systems, in pale blue in the figure, with distinction between the size class (small, medium and large);
- the mixed systems in more difficult areas being grassland areas (dark green) or mountain areas (brown), whose productivity was, on average, lower compared to the mean productivity and with a higher share of livestock production in the whole farm economy;
- mixed systems in the most favourable areas, with a higher share of crops in the continental plains with rich soils (dark orange - typically the Bassin Parisien) and a higher share of livestock in the regions with high grassland productivity (green – typically the Netherlands or Denmark). One should note that, even in these ‘pre-specialised’ regions, livestock and crops were still combined.
- The Mediterranean systems (yellow) stand on other rationales due to the nature of production and land structure (mini- and lati- fundia). Though they are represented in the figure, they will not be discussed in this paper.

The main changes from the 1960s have been largely identified and discussed (Mazoyer and Roudard 1997). We will simply very briefly remind the main technological and economic factors:
- Increase in physical yield through the combined use of inputs, machinery and genetic progress. One must stress that, for the latter, more progress has been made for crops, dairy and pig and poultry products. Relatively, permanent grassland and grass-fed beef have experienced little changes (still one calf a year).
- While the productivity gains have been quite significant, the overall demand has raised at a much lower rate, leading to a continuous fall in prices.
- The CAP has buffered the decrease in prices (more than sustained prices as frequently mistaken). Most productive systems have been comforted in their relative position.

The following figure, based on the same principle than figure 5 (with the same colours codes), summarises the consequences for farming systems.

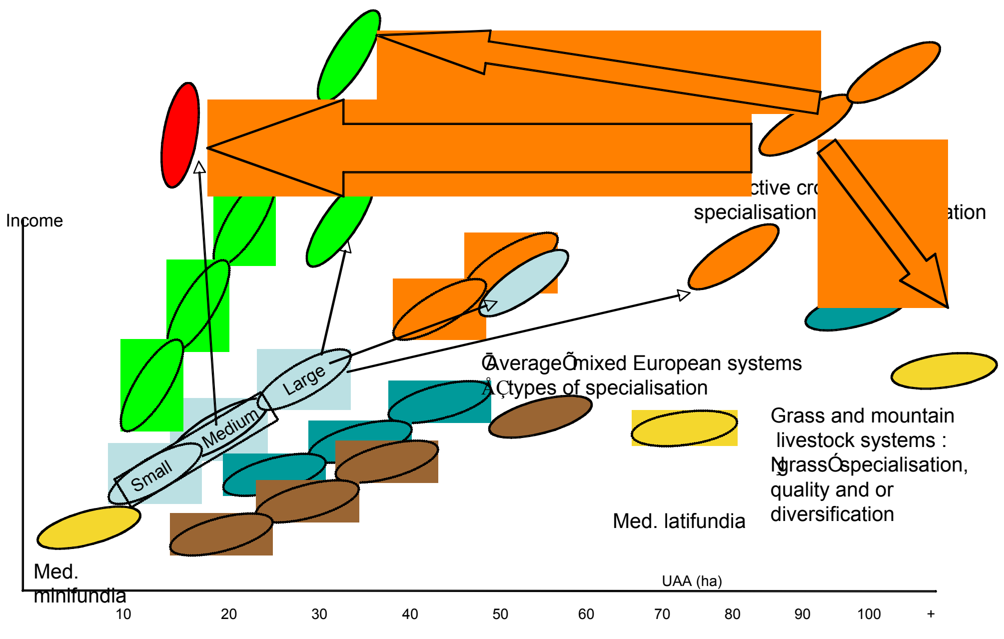

Figure 6: Changes in European farming systems from 1960 to 2007

The main changes occurring on the period are:
- the enlargement of most of the farming systems: the farm sizes observed in the 60s no longer exist 40 years later – the dashed limits symbolise this idea (they represent the former farms in the 60s);
- most average mixed farms have specialised: towards crops whenever possible (due to less labour demand and favourable prices in the 70’s-80’s) or towards large livestock facilities. Indoor livestock systems (red) appeared in this period of time.
- Systems in less favoured areas – though the term did not exist at the beginning of the period – had a more limited range of choice: they mostly specialised in a ‘grass’ strategy (which can be assimilated to a LIFS strategy) and/or a quality strategy whenever possible.

- The already specialised systems in the 60s have followed the same track and comforted their relative advantage.

What is paramount to consider is the fact that most productive farming systems have competed and still compete the less productive (including the LIFS) at the European scale: except for some products geographically linked, it is frequently cheaper for a milk factory to truck e.g. some Danish milk all across Europe. The competition between LIFS and HIFS is not only at play at a regional level, but also at the EU level, inside the Common market.

The second key issue is that the technological processes have led to an increase in cereal production (for example, from 45,000,000 tons in 1960 to more than 100,000,000 in 2005 (for EU 15 countries; 114,000 Mt for EU27 in 2005). This unprecedented increase in the production has mainly been incorporated into the animal sector, which represents around the 2/3 of the whole use of cereals at the EU level (data AGPB 2007). The cereal price is an indicator for the whole chain of food in Europe. This is presented by the large orange arrows in figure 6, illustrating the fact that the cereals regions are indeed feeding the rest of European livestock regions.

This massive use of cereals, that we name here "the cerealization" of the European agriculture, can be discussed through a LIFS perspective:

(a) Specialised cereal systems are frequently HIFS in order to maximise their production on larger and simplified land structures.
(b) Specialised livestock systems are themselves HIFS in the way they import most of their food. One must note that the use of cereals goes along the one of proteins, mostly imported under the Blair house agreement of the 60's with the USA.

The local closed cycles have been replaced by intra (cereals) and extra (proteins) European open cycles.

Is it still relevant to promote LIFS in the changing context of European agriculture? In the recent past, Europe had been experiencing overproduction, as the result of driving forces described above. The CAP of 1992 introduced set-aside in order to limit the cereal production, the dairy quotas were set in 1984 for the same reasons and a set of rules to the CAP payments has been introduced in order to reduce overproduction.

But while the overabundance has been the rule since 1970 (when Europe reached the goal of self sufficiency), observers note that the recent period experiences some tensions on commodities. The cereals, notably, have experienced an increase in prices of around 50% between 2006 and 2007, due to a combination of factors (bad climatic conditions, rise in biofuel demand and tension on the world market due to the ethanol strategy of the USA combined with the development of China). The same has happened for the milk powder.

All these factors make some observers point the issue of a change in area: after a long period of overabundance – which advocated strongly for LIFS as above – the World and Europe are entering a period of tensions on commodities. LIFS can be defendable in some particular cases (for biodiversity hotspots for example), but not in general terms.

As long as no general strategy has been set, our concern is to defend the idea that is probably more open that it might appear at first sight. The set of reasons are the following:

- the sustainability of biofuel strategy is questionable in the long term as the competition with the fossil oil depends on very low prices on bio-wheat or bio-rapeseed (INRA 2005). The development of bio-fuels on large scale will increase the prices and, thus, contradict the conditions of its self-development.
- Tensions on commodities and needs of intensification at the EU scale stand on assumptions on the localisation of production: if the agricultural production is to take place where it has used to be, the tension on land is high and pushes towards more intensification. But the magnitude of land availability is probably higher than expected when counting the new member states (30% of surface in cereals for only 20% of production – 2004 figures).
- More significantly, what is at stake in the European land use is the share of cereal-fed livestock production in the whole European diet, with regards to grassland and legumes-fed livestock. Keeping in mind that 7 Kcal of animal feed are necessary to produce 1 Kcal of meat, only a slight reduction in meat consumption might considerably lower the pressure on land use – or even optimisation of channels with less waste in the whole food chain.
- And more fundamentally, the idea that Europe must feed the World has been battled by many economists (notably M. Griffon and the FAO). This does not mean that some markets for commodities will not sustain, but their necessity is probably not as large as a simple projection of population trend may suggest.

Our point is not to say that the question of the intensity of European agriculture can easily be answered. It is to defend that the share of LIFS relatively to the one of HIFS does not only depend on extrapolations of the present situation (including biofuels) but on more fundamental choices regarding the use of cereals and protein crops. LIFS can be productive as well and optimise many flows which, presently, are not necessarily the most efficient in terms of energy use. Research needs to be undertaken with the aim of understanding more clearly what the possible choices of agricultural intensity in Europe are.

Conclusion: the policy issues, reorienting the CAP towards LIFS Developing LIFS at European scale needs radical changes in the EU policy. We have seen in our analysis that the economic competition between LIFS and HIFS was structurally favourable to the latest.

Without developing the analysis any further, one can argue that the former Common Agricultural Policies (CAP), until the 2003 reform, mostly accompanied the process of competition explained above. It must be stressed that, nevertheless, the structure of the CAP payments has been one driver amongst others in the cerealization process described above (IEEP 2002). The very nature of the technological progress have probably been of a major influence in the developments of the European agriculture, as it is suggested by the changes which occurred in the pig and poultry sectors – which experienced specialisation, concentration and highest level of off-farm inputs – without having been supported by any CAP payment. On the contrary, it has been argued that the CAP was a two-sided policy: on the one hand, by regulating the markets and the prices, it indeed benefited the most intensive farms – and undoubtedly favoured an intensification process. But, on the other hand, it allowed some extensive ones to sustain while volatile prices would have probably led to the disappearance of the most fragile farms.

Keeping this in mind allows a specific *ex ante* assessment of the recent reform of 2003. Notably, while decoupling has been thought as a way to promote LIFS (EC 2003), the analysis proposed shows that the competition mechanisms is likely to achieve the opposite results on a large scale (Chatelier 2004, Chatelier et Jacquerie 2004; Poux and Ramain 2007). As a matter of fact, there is no reason why, under the new structure of decoupled payments, the farms with comparative advantages in the most productive regions will be able to continue the same intensification pattern that they used to follow. Indeed, some farms in intermediary regions, with an average productivity, might adopt LIFS instead of HIFS – which still needs to be observed at large scale. Some irrational strategies and, notably, irrigating because of a payment, not because a higher net margin, might also be abandoned due to the decoupled payments. But the question remains open: if some farms reduce or quit production – which is likely to happen in the intermediary regions – isn't it an incentive to produce more in the most fertile regions?

More fundamentally, more volatile prices on commodities, with alternate periods of high and low prices has shown to be beneficial to the most productive farms, which are able to maximise the profit of high prices to resist in the hard times of low prices. The farms more on the edge will indeed get some profits in the high tide but will not be able to resist in the low tide, as observed in the pig and poultry sector already mentioned. In this process, leading to larger farms, average LIFS will be able to resist to low prices better than average HIFS (see figure 3); but again the largest HIFS shall be the best placed at end (figure 4).

The figures below summarise this analysis:

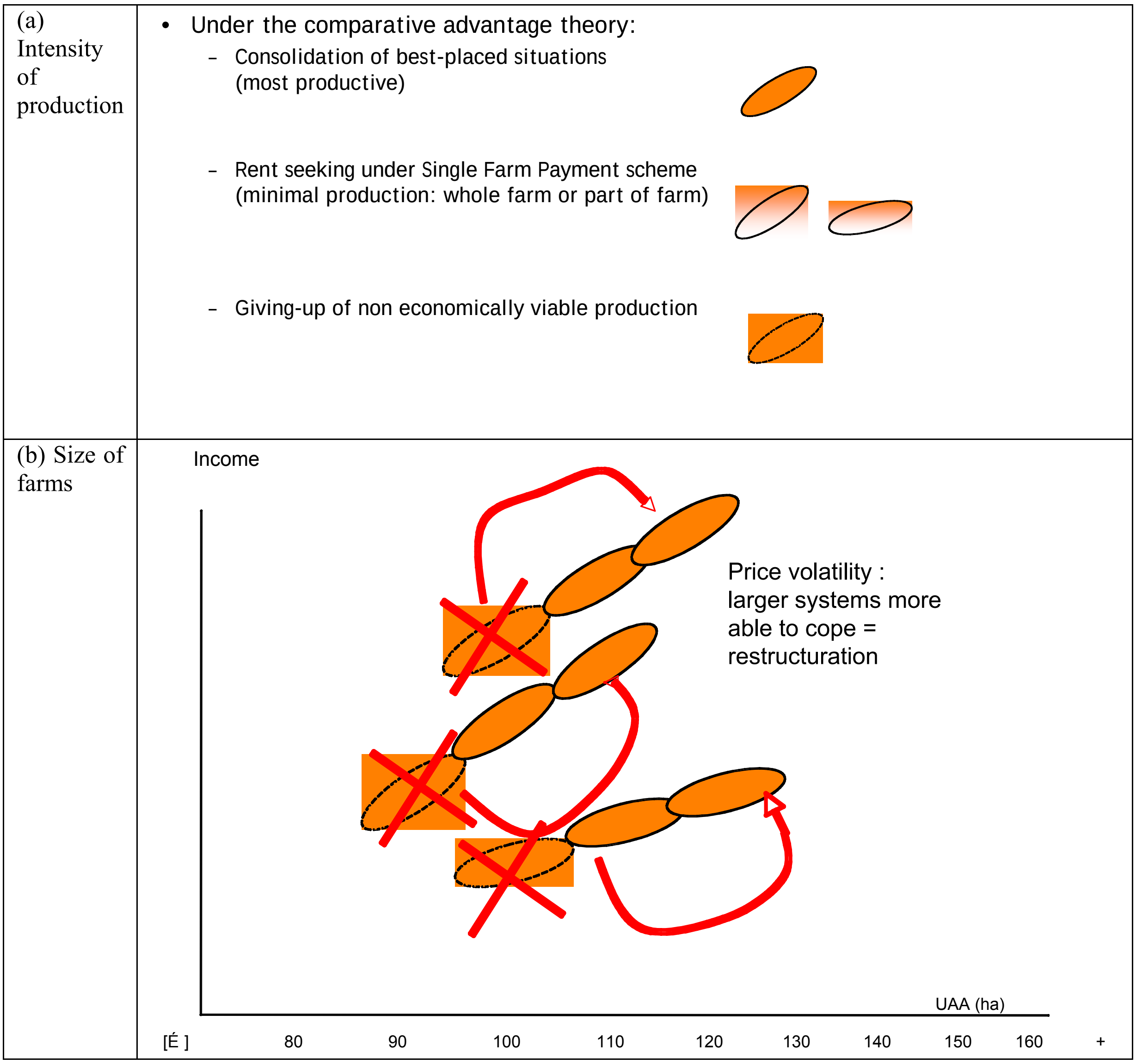

Figure 7: The likely strategies of farming systems to the 2003 CAP reform signals

On this basis, on can defend the idea that what is at stake for the CAP is to promote and thus specifically support LIFS, without supporting at the same time their competitors (i.e. HIFS) – which has been the ambiguity of the whole CAP till now . What is at stake for LIFS, which benefits have been surveyed in the section above — *Why Europe needs more LIFS* — is thus a radical reform of the CAP (Pflimlin et Poux 2005, Beaufoy et al. 2003). In the line of what has been developed above, the issue is not to go further on more flexible markets but, on the contrary, to voluntarily re-couple the intensity of production to the territories — what commodities markets are not currently capable of doing — through the mobilisation of a coherent set of instruments. The question of the overall intensity of the European agriculture is what is at stake; to the vision of highly productive areas surrounded with abandoned areas, we defend the necessity for European farmers, consumers, tax-payers and citizens of LIFS evenly distributed on the European territory. Such LIFS shall be diverse, as is the European agriculture, but they shall share a common principle: sustainable agriculture is now the one which can close local cycles and do not depend on off-farm resources, while producing food for the consumers. Europe is large enough for this project.

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Low-input farming systems: Their general characteristics, identification and quantification

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Abstract This paper first discusses the different types of farming systems that can be characterised as Low Input Farming (LIF) and their contribution to maintaining the environment, biodiversity and landscape in the European countryside. LIF systems have low input use in common but there are also other typical extensive farming practices according to which these systems need to be identified, classified and valued. In this paper we identify three important groups of farms that are part of the European LIF population; organic, High Nature Value (HNV) farms and low input farm systems. These different LIFS are characterised by a complex suite of characteristics which requires their identification to be based on more than one variable. The FADN database is therefore the most powerful tool for quantification and estimation of the geographical distribution of LIFS in the EU. At the end it will therefore be concluded that rough identification of most types of LIFS is possible with existent European data sources, but for a more precise identification, geographic representation and further analytical assessments of the LIF population considerable improvements are needed in European data collection and data accessibility.

Characterisation of LIFs There are many different types of LIF systems in Europe. They all have in common no or relatively low use of external inputs such as agro-chemicals, artificial fertilisers, concentrate feedstuffs and water (irrigation). This generally goes together with lower outputs per hectare but also higher non-commodity values in terms of environment (water, air, soil and climate), biodiversity and/or landscape. In the case of organic farming lower outputs are usually compensated for by higher prices of organic products. Several low input systems also participate in agri-environmental schemes to become compensated for the lower output levels and/or higher management costs. Most of these schemes still predominantly pay for ‘income foregone’ so overall it is clear that in most cases the monetary compensation for the production of non-commodity values produced by these systems is low. The type of non-commodity values which low input systems may produce depends also on the broader characteristics of their practices of which lower external inputs is usually only one of the aspects.

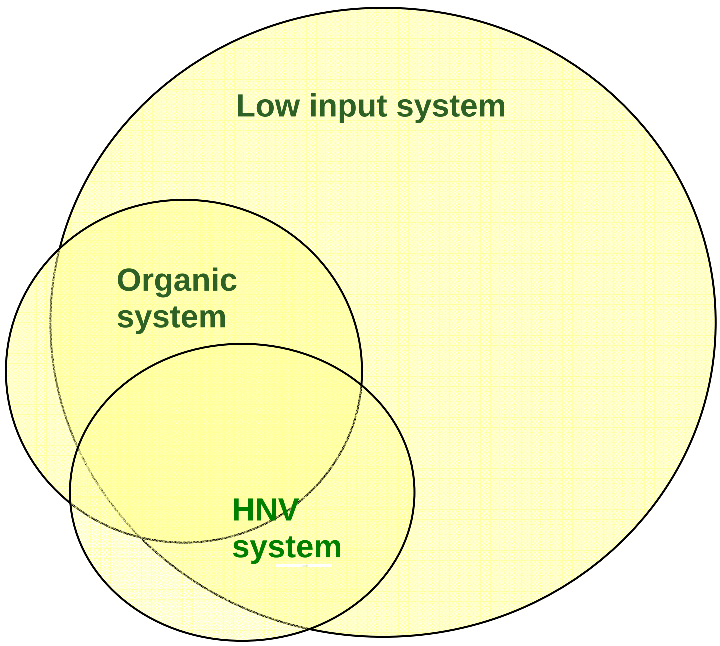

Figure 1 Overlap and difference between different LIF systems

In this paper we will concentrate on three types of LIF systems because these have already been identified in former studies using European data sources:

1. Low input farms
2. Organic farms
3. High Nature Value (HNV) farms

It is clear that there is an overlap between the three types of LIFS in number but not necessarily in their contribution to non-commodity values such as biodiversity and landscape values (see Figure 1) as this is very much determined by a suite of farming practices applied and the specific environmental context in which they take place. At the same time, a limited number of farms in the HNV or in the organic group will have an input use that is not sufficiently low to qualify them as a low input system. This, however, very much depends on the threshold chosen between low and high input and until now it is generally known that minimising inputs is beneficial for the environment, but there is often a lack of understanding at which input levels negative externalities start to occur.

Overall it is however clear that the high input use in farming has been a major cause for wider environmental problems and loss of farmland biodiversity (see EEA, 2005; Buckwell & Armstrong-Brown, 2004; Wadsworth et al. 2003 and Boatman et al., 1999). Higher input use is one of the main factors of the intensification process and it usually leads to an increase in the level of production per unit of land, per livestock unit and per agricultural working unit. Intensification often goes together with an increase in efficiency of the agricultural production process but also with negative externalities on the environment especially in terms of loss of habitat quality through pollution of soil, water and air and even direct poisoning and loss of food supplies for certain species (Poiret, 1999; Pau Vall, 1999).
On the other hand not only intensification but also abandonment shows a heavy impact on farmland biodiversity (EAA, 1999; Baldock, et al. 1996). This process of polarisation, in which abandonment and an increase in stocking density both occur and sometimes within short distances, poses a threat to biodiversity especially in semi-natural areas created by extensive livestock farming. It was estimated by the European Environment Agency (1998) that during the 20th century, semi-natural habitats declined by over 90% in most parts of Europe as a consequence of such polarisation. The IRENA indicator 28 (Population trends in farmland birds) shows that the majority of the farmland birds in the EU-15 suffered strong declines, but this decline levelled out since 1990, which is not surprising as levels have become very low already, especially in the intensively farmed areas (EEA, 2005). IRENA indicator 33 (Impact on habitat types and biodiversity) also showed that 80% of all agricultural Prime Butterfly Areas (PBAs) in EU-15 experience negative impacts from intensification, abandonment or both. 43% of all agricultural sites suffer from intensification, whereas abandonment is a significant problem in 47%. Both impacts occur simultaneously in 10%. Some interesting information was also provided by Birdlife international on the new Member States. They estimated that of the 571 International Important Bird Areas in these countries 27% were negatively affected by abandonment and 33% by intensification.

It is important to realise that abandonment and intensification have gone and still go together with the disappearance of low input traditional farms (see Baldock, 1999, Beaufoy et al., 1994, Bignal et al., 1994, Bignal & McCracken 1996; Andersen et al., 2003). The disappearance of these systems is a result either of a shift towards more intensive and specialised farming and/or abandonment of whole farms or only the lower productive parts. There is a clear coincidence between the places where farmland biodiversity has remained relatively stable and where the low input farming systems have continued to exist, while the opposite is true for the decline in farmland biodiversity and the shift towards more intensive and efficient farming systems (e.g. EEA, 2005; Buckwell & Armstrong-Brown 2004; Wadsworth et al., 2003; Heath et al., 2000)

In the following an overview is given of the extent and geographic distribution of three types of LIFs based on European data sources.

Low input farms in the EU were identified in different projects using the Farm Accountancy Data Network (FADN). Low input livestock systems were first quantified in the project European Livestock Policy Evaluation Network (ELPEN) (Andersen et al., 2004a, 2004b). For IRENA (Indicator Reporting on the integration of ENvironmental concerns into Agricultural policy) the ELPEN typology work was further elaborated to show trends in intensity of farming in all sectors (EEA, 2005) (see Figure 2). From the IRENA typology and the mapping of the results it becomes clear that in 1990, low-input farms managed 26% of the agricultural area and this share increased to 28% in 2000 (for EU-12 only).
The intensity of farming in terms of low-, medium- and high-input systems was defined by using the expenditure on selected inputs (fertilisers, crop protection and concentrate feedstuff), as this is the only information available

at farm level. The global breakdown of expenditure on inputs for all farms in EU-15 in 2000: 22% of the expenditure is on fertilisers, 18% on crop protection and 60% on concentrate

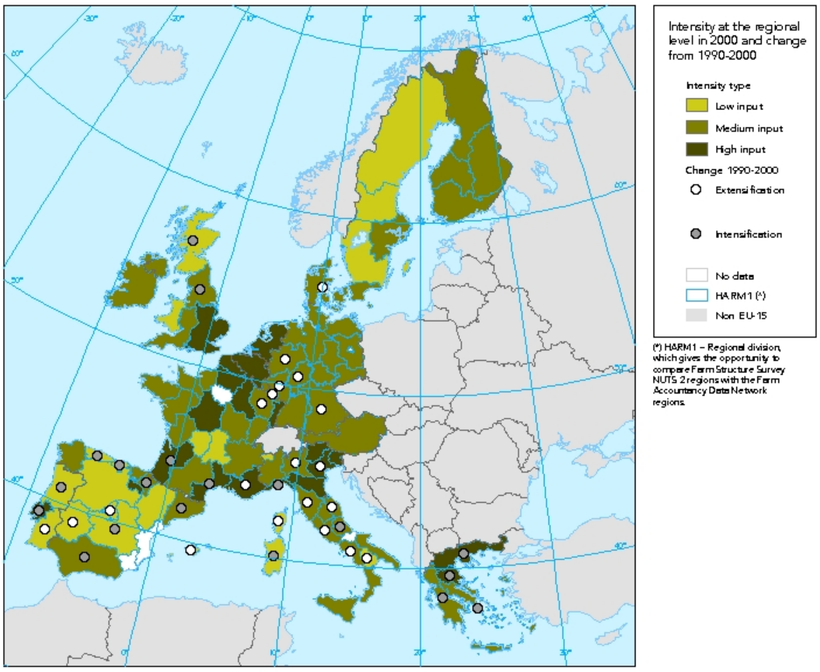

Figure 2 Regional importance of low-input, medium-input and high-input farm types[1] and the trend 1990-2000 [2]
.
Source: IRENA indicator fact sheet 15 (Intensification-extensification). Data derived from FADN-DG Agriculture; adaptation LEI
Note: Extensification = a decrease of more than 15% in the average regional expenditure per ha of agricultural land on inputs[1], Intensification = an increase of more than 15% in the average regional expenditure per ha of agricultural land on inputs[2].

feedstuff. It was also estimated in the IRENA fact sheet that this means that an average low-input farm uses 19 kg of nitrogen per hectare per year, whereas the same figure for the medium- and high-input farms are 69 kg and 126 kg respectively. The average use of pesticides on a low input farm equals to an average of 0.2 kg active ingredients per hectare per year, whereas the same figure is 1.4 for medium-input farms and 3.7 for high-input farms (IRENA indicator fact sheet 15).
Low-input farm types were found predominantly in regions of Sweden, United Kingdom, France, Italy, Spain and Portugal. The regions where low-input farming were most dominating were Valle d´Aosta, Madrid, Extremadura, Alentejo-Algarve and Sardegna where the average expenditure on inputs were less than 33 Euro per ha. Many of the low-input regions were dominated by grazing livestock farms (either cattle or sheep).

Organic farms All farms included in the organic farming category comply with Council Regulations (EEC) No 2092/91 and No 1804/1999 which implies that they comply with the regulated standards and are part of official certification procedures, receive regular inspections and sell their products under a specific labelling scheme. The main characteristics of the organic production system are closed nutrient systems, practically no use of synthetic chemical inputs such as artificial fertilisers, pesticides and growth promoters/regulators, no GMOs and large emphasis on environmental protection, animal welfare and traditional management practices. Data on organic farming in the EU are collected by Eurostat both in the Farm Structure Survey (FSS) and in a separate, Organic farming questionnaire on Regulation (EEC) No 2092/91 (Agriculture DG questionnaire: 1998-2002). The data from these sources were used in IRENA (Indicator fact sheet 7: Area under organic farming) to produce an overview of the share of organic farming area in the total utilised agricultural area in the EU-15 (See Figure 3). Overall it was shown that the present share of organic farming area were 3.8% which equals to 4.9 million ha

[1] The low-input regions are the 20 regions with the lowest average expenditure on inputs, high-input regions are the 20 regions with the highest average expenditure on inputs, and medium-input regions are the rest.
[2] Information on trends in Finland, Sweden, Austria, and in the New Bundesländer in Germany is not available.

in EU-15. A quarter of the organic farmland was located in Italy, with the UK having the second largest share followed by Germany, Spain and France.

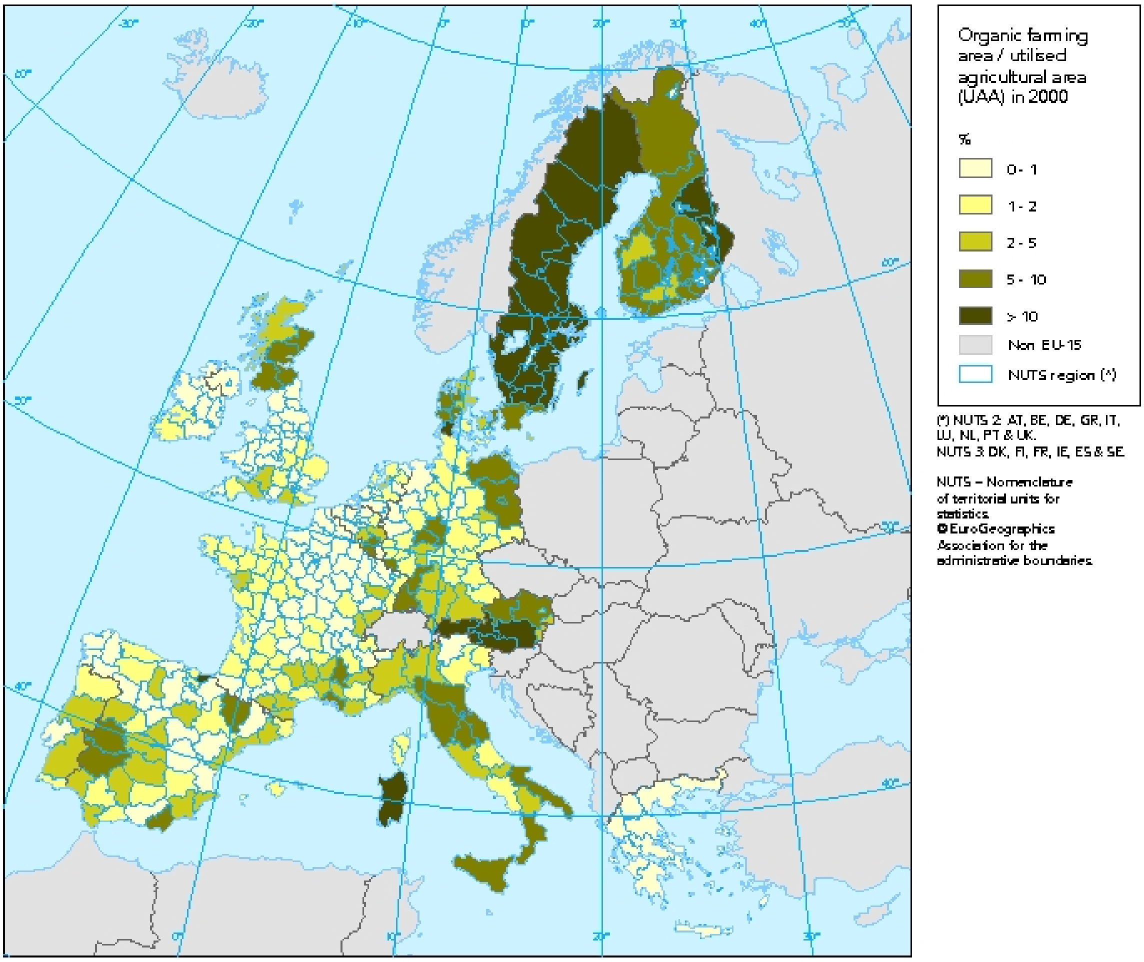

Figure 3: The share of organic farming area in the total UAA in 2000
Source: IRENA (Indicator fact sheet 7: Area under organic farming). Data derived from the Community survey on the structure of agricultural holdings (FSS), Eurostat (for some Member States this includes also areas not certified under Regulation (EEC) No 2092/91).

High Nature Value (HNV) farms Although HNV farms have not (yet) like organic farms been officially recognised in Council Regulations, nor are there official certification schemes for HNV farming, the concept of HNV farmland has become a growing policy priority in recent years. Article 22 of Rural Development Regulation (1257/1999) states that support shall be given to *'the conservation of high nature value farmed environments which are under threat'*. Also the 'Message from Malahide' an outcome of a conference on 'Biodiversity and the EU – Sustaining Life, Sustaining Livelihoods' jointly organised by the Irish presidency and the European Commission in Malahide (May 2004) formed the basis for future priority action in reaching the 2010 EU target of halting the loss of biodiversity (the Gothenburg objective). One of its targets was that 'high nature value areas should be identified, and measures to address the threats to these areas be provided' (Objective 5.2) (Conference, 2004).

The concept of HNV farms was first conceptualised in Baldock et al. (1993): *"High Nature Value (HNV) farming systems are predominantly low-intensity systems which often involve a relatively complex interrelationship with the natural environment. They maintain important habitats both on the cultivated or grazed area (for example, cereals steppes and semi-natural grasslands) and in features such as hedgerows, ponds and trees, which historically were integrated with the farming systems. […] The semi-natural habitats currently maintained by HNV farming are particularly important for nature conservation in the EC because of the almost total disappearance of large scale natural habitats"*. More EU-wide studies followed developing the concept of HNV farmland further and identifying where HNV farms and farmland was occurring in Europe

(Beaufoy et al., 1994; Bignal et al., 1994; Bignal and McCracken, 1996; 2000). In 2003 the European Environment Agency commissioned a study to identify HNV farmland in the EU. This resulted in the Andersen et al., (2003) report. In this study HNV was defined as "*those areas in Europe where agriculture is a major (usually the dominant) land use and where that agriculture supports, or is associated with, either a high species and habitat diversity, or the presence of species of European conservation concern, or both*".

From this, three types of HNV farmland were distinguished:

- Type 1: Farmland with a high proportion of semi-natural vegetation;
- Type 2[3]: Farmland with a mosaic of low intensity agriculture and structural elements, such as field margins, hedgerows, stonewalls, patches of woodland or scrub, small rivers etc.
- Type 3: Farmland supporting rare species or a high proportion of European or World population.

In Andersen et al. (2003) HNV farmland areas were identified using CORINE land cover (CLC), farming data from FADN and bird distribution data. In the period 2005-2007 JRC and EEA have carried out a further update of the CLC-based HNV map of Andersen et al. (2003) applying an up-dated methodology (Paracchini et al., 2006). It is based on European environmental datasets, including CLC data, and additional spatial data sets such as the European soil map and mapped agricultural Natura 2000 sites and International Bird Areas (IBAs). This work has led to a further improvement of the identification of HNV farmland areas in the EU. However, it did not further add to the FADN based identification of HNV farm types as developed in the Andersen et al. (2003) study.

The study by Andersen et al. (2003) delivered a first EU-15 overview of what the extent of the different types of HNV farms was and where they were mostly occurring. In Annex 1 an overview is given of the 6 types of HNV farming systems distinguished and how they were identified using variables from FADN. The classifying variables and thresholds have been determined at three levels: (1) A common level covering EU-15, (2) a regional level covering Western Europe and Scandinavia and (3) a regional level covering Southern Europe.

As a first step input use was used to define HNV versus non-HNV systems. This input use relates to spendings on fertilisers, crop protection and concentrate feedstuff and not the exact amounts of input as these are not available in FADN. The exact threshold values in the typology were expert based and, for the off-farm grazing systems, the permanent grassland systems and the arable grazing livestock systems, additional statistical analyses were applied. The off-farm grazing systems were identified based on the variable 'grazing days outside utilised agricultural area' in FADN. Ideally this variable identifies systems grazing on common land and systems practising transhumance. However, it was also noted that the quality of this FADN variable across EU-15 was not very good, and, therefore, a lot of farms of this type were not correctly represented in the results. The identification of the 6 groups of HNV farm types was also mapped and the results are shown in Figure 4. It shows that HNV farms are more often occurring in the Southern Mediterranean parts of Europe and the North, while in western countries their share is very low.

[3] The description of Type 2 was altered in 2006 by the EEA-JRC. The original formulation by Andersen et al. (2003) was: *'Farmland that is dominated by either low intensity farmland or a mosaic of semi-natural and cultivated land and small-scale features'.*

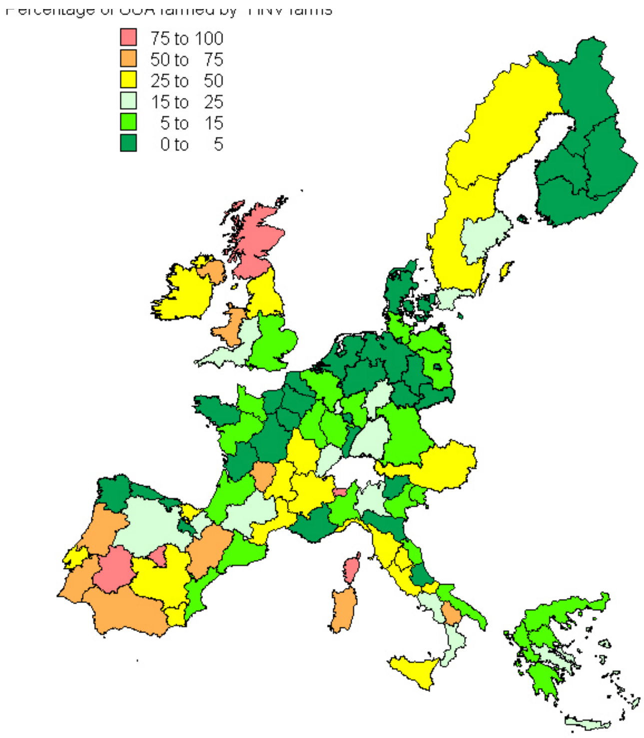

Figure 4: The share of HNV farming area in the total UAA in 2000
Source: Andersen et al. (2003). Data derived from: FADN (2001)-CCE-DG Agriculture/A-3

Identification of LIFs with European data sources From the former we have illustrated that for the identification of low input and HNV farms the FADN database seems at this moment the only source with which these farms can roughly be identified at an EU level as it contains information on the intensity of farming. At present the FADN database is gradually also becoming available for most new Member States making it possible to extend the typologies presented to the whole EU. The identification of organic farms can both be done with Eurostat data and with FADN data as for this LIF type a separate data collection is done.
If we look more closely to the type of variables available in both FADN and FSS according to which LIF systems can be identified (see Table 1) there is quite a choice and also a clear difference between both databases.

Table 1 Selection of variables in FSS and FADN according to which LIFs can be identified

	FSS (average farm, EU-farm type)	**FADN (individual farms)**
Low input systems	LU/ha, ESU/ha, % irrigable/irrigated land	Spending on inputs/ha (pesticides, fertilisers, concentrates), Output/ha, LU/ha, ESU/ha, Irrigation spendings/ha, Energy spendings/ha
Organic farming systems	Number & % organic farms, area in organic farming	Number & % organic farms, area in organic farming
HNV farming systems	LU/ha, ESU/ha, % irrigable land, % permanent grassland and rough grazing, % fallow land	Spending on inputs/ha (pesticides, fertilisers, concentrates), Output/ha, LU/ha, ESU/ha, Irrigation spendings/ha, Energy spendings/ha, area irrigated, area fallow land, area permanent grassland, area rough grazing

LU= Livestock Units
ESU= European Size Units

Table 1 shows that also with FSS data low input systems and HNV systems should in theory be identified. However, the large difference between the FADN and FSS data is that users of FSS can only work with grouped farm data while in FADN individual farm data can be used making it possible to group farms according to a suite of LIF characteristics. In FSS this is not possible and this makes identification impossible since LIF systems are generally too complex to be identified by only one dimension.

Overall it is clear that at present the FADN data sources is most suited for giving a general picture of extent and geographic distribution of LIFS in Europe. However there are several limitations connected to FADN which should be taken into account when interpreting the extracted data results. These limitations were already described extensively by Andersen et al. (2003).

The most important limitation is that the sample farms that occur in FADN might not represent all LIFS farms very well. In total the FADN represents 52% of the farms and 86% of the Utilised Agricultural Area in EU-15, when compared to the data in the Farm Structural Surveys (see table 2). The reason for this under-representation is mainly related to the exclusion of economically small farms in FADN. FADN-farms are therefore almost completely representing the market share per sector, but not the number of farms and UAA. The problem of representation is making the use of FADN even more problematic because the LIFS in most countries are relatively small and 'non-professional' farms. In fact in many cases these ‘small farms’ may actually be physically large and apparently full-time, particularly in marginal areas where the land has low productivity but alternative employment is scarce.

Table 2 The number of farms and area of utilised agricultural area (UAA) represented in FADN and the share of the farms/UAA covered compared to FSS (Farm Structural Survey).

	No. of farms represented in FADN	UAA represented in FADN	Share of FSS-farms represented in FADN %	Share of FSS-UAA represented in FADN %
Belgium	42464	1442890	63	104
Denmark	49934	2595416	79	97
Germany	282429	15282780	53	89
Greece	484566	2993321	59	86
Spain	539907	16551642	45	65
France	387210	25301779	57	89
Ireland	128737	4904409	87	113
Italy	998375	11603783	43	78
Luxembourg	1763	107154	59	85
Netherlands	82512	2102937	76	105
Austria	86220	2139713	41	63
Portugal	301846	3664020	72	96
Finland	52137	1832882	57	84
Sweden	38021	3331265	42	107
United Kingdom	128110	16945535	55	105
EU 15	3604231	110799526	52	86

Source: Andersen et al. (2003). Data extracted from FADN (2001)-CCE-DG Agriculture/A-3; Farm Structural Survey (2001); adaptation LEI.

From Table 2 it becomes clear that an average of 36% of the farms and 11% of the Utilised Agricultural Area are not represented by FADN data due to the elimination of the small farms. This varies from Ireland, where only 12% of the farms and 4% of the Utilised Agricultural Area are not included, to Austria, where 58% of the farms and 38% of the utilised agricultural area are not represented. For the new Member States this representation will be even worse, since the FADN samples will be much smaller. Especially in countries like Poland where the share of (very) small farms is very high, FADN data are expected to have severe limitations for LIFS identification.

In addition, comparison between FADN and FSS data has also revealed that mixed livestock farms and beef cattle farms are not well represented in FADN, though considerable differences occur between the different Member States. This problem is of course worse in the cases where specific types of farming systems with a high probability of being LIF systems are not included in FADN.
The second limitation of the FADN approach is that the variables available to identify LIFS are not always the best ones. This is related to the strong economic bias of the FADN data source. It is obvious that using input

costs is not the most optimal indicator for the pressure from the farming practices, but no information is available in FADN on the amount (and in some cases on relevant types) of inputs used.

The third limitation is that all FADN data is gathered and presented at the farm level. It is not possible to discriminate between the intensity in the use of different parts of the farms. Especially in cases where farms run more than one enterprise, for example dairy cattle and sheep, it can be difficult to identify potential LIF farming practices. So with FADN data there is a risk the farms are identified as LIF while only parts of the farm are really fitting to this definition but also the opposite can be the case.
A fourth weakness of FADN is that its major unit of data collection is the UAA, *not* the area actually occupied by the agricultural business. Seasonal lets (common in several countries, such as Ireland) or wintering/summering arrangements, as well as the use of common land and the grazing of fallows, are in most cases excluded from consideration. The only proxy variable for identifying the involvement of these lands in the system is the 'number of grazing days outside the farm'. However, it has been proven that this variable is not always specified correctly in the FADN database.

Finally there are also problems connected to disclosure rules and spatial presentation of FADN data. FADN is useful for identifying LIF farms but less suitable for identifying where the LIF farms are located since the regional level at which FADN data are presented is very coarse (FADN regions which equals NUTS 1-2 level). In terms of disclosure the rule is that FADN data can only be published if they are represented by at least 15 sample farms. When making multi-dimensional typologies farms are usually grouped into much smaller numbers increasing the risk that these farms can no longer be disclosed. This problem will be most difficult to tackle in new MS where the FADN sample sizes are still much smaller than for the old MS.

Conclusions Overall we conclude that at this moment FADN is the most powerful database to identifying LIF farms at an EU-wide level. The strength of the FADN approach is that it provides insight in the rough extend and concentration of LIF farms. The consistent yearly updates of the data is a great advantage. It can be used to monitor short term changes in LIF farming systems and thus also in the pressure on LIF systems and it offers insight into the way policy should be targeted to support LIF farming. However, there are many limitations to using FADN of which the main is the under-representation of the LIF population. Additional case study research is therefore imperative to get a better understanding of the type, extend and values of LIF systems.
New data sources need to be explored to better identify and analyse LIF systems in Europe. Possible sources to be explored are combinations of national and regional Farm Structural Survey information and the possibility to work with this information at an individual farm level. Other good national databases that are being up-dated yearly and that may have potential are:

- Land use parcel information systems (LUPIS)
- IACS
- Animal registry

IACS (Integrated Administration and Control System for the management of CAP payments) and the associated LPIS (Land Parcel Identification System) and the animal registry would potentially be one way to capture information at the farm level, especially if these three information systems are linked at farm level and this is already the case in many Member States. These three types of databases are developed for monitoring and control of CAP subsidies. Since the introduction of Cross Compliance the type of information collected and the spatial resolution of these sources has been improved considerably and in the new MS the implementation of these information collection systems has progressed a lot.

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Annex 1: Detailed identification of 6 different types of HNV farming systems using FADN data (From Andersen et al., 2003)

	Common Level	**Maximum level**		**Minimum level**	
	EU-15	**Western Europe and Scandinavia**	**Southern Europe**	**Western Europe and Scandinavia**	**Southern Europe**
1. HNV Cropping systems	EU-type 1 and 6 and input cost < 80 Euro per ha	As common level	Fallow systems: >12,5% of UAA in fallow Dryland systems: Not fallow systems and < 10% of UAA irrigated	Input cost < 40 Euro ha	Fallow systems: >20,5% of UAA in fallow and input cost < 40 Euro ha Dryland systems: Not fallow systems and < 10% of UAA irrigated and input cost < 40 Euro ha
2. HNV Permanent crops	EU-type 3 and Input cost < 80 Euro per ha	No data	Systems with GLS: < 10% of UAA irrigated and >= 5 LU GLS Systems without GLS: < 10% of UAA irrigated and < 5 LU GLS	No data	Systems with GLS: Input cost on crop protection < 10 Euro/ha and no irrigation and >= 5 LU GLS Systems without GLS: Input cost on crop protection < 10 Euro/ha and no irrigation and < 5 LU GLS
3. HNV off-farm grazing systems	EU-type 4, 7.1,8.1 and >= 120 grazing days outside UAA	As common level	As common level	>= 150 grazing days outside UAA	>= 150 grazing days outside UAA
4. HNV Permanent grassland systems	EU-type 4, 7.1,8.1 and input cost < 150 Euro per ha and >= 55% of UAA in grass and <40% of grass in temporary grass and not common type 3	Rough grassland systems: Rough grassland >=66% of UAA and stocking density < 0,5 Permanent grassland systems: Rough grassland <66% of UAA and stocking density < 1,5	Stocking density < 0,5 LU/ha	Rough grassland systems: Rough grassland >=66% of UAA and stocking density < 0,3 Permanent grassland systems: Rough grassland <66% of UAA and stocking density < 1,0	Stocking density < 0,2 LU/ha
5. HNV arable grazing livestock systems	EU-type 4, 7.1,8.1 and input cost < 150 Euro per ha and not common type 3 or 4	As common level	Input cost < 80 Euro/ha and ((>= 12,5 % of UAA in fallow) or (<10% of UAA irrigated))	Input cost < 40 Euro/ha	Input cost < 40 Euro/ha and ((>= 20 % of UAA in fallow) or (0% of UAA irrigated))
6. HNV other systems	EU-type 5, 7.2,8.2 and input cost < 80 Euro per ha	As common level	(>= 12,5 % of UAA in fallow) or (<10% of UAA irrigated)	Input cost < 40 Euro/ha	Input cost < 40 Euro/ha and ((>= 20 % of UAA in fallow) or (no irrigation))

EU-type = Type of farming used in FADN: (1) Specialist field crops, (3) Specialist permanent Crops , (4) Specialist grazing livestock , (5) Specialist granivores, (6) Mixed cropping (7.1) Mixed livestock, mainly grazing livestock,(7.2)Mixed livestock, mainly granivores, (8.1) Field crops-grazing livestock combined and (8.2) Various crops and livestock combined. (2) Specialist horticulture has not been included in the study

Life cycle assessment of low-input farming systems

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Keywords: life cycle assessment, environmental impacts, farming systems, low-input farming systems, organic farming, integrated production, eco-efficiency

Abstract The impacts of organic, integrated and conventional farming systems as well as of intensive and extensive management practices on the environment were assessed by means of life cycle assessment (LCA) in a comprehensive study for Switzerland.
The environmental impacts of organic farming (OF) were assessed more favourably compared to integrated production (IP). OF showed clear ecological advantages particularly for the impact categories eco- and human toxicity, resource use and biodiversity. This positive assessment of OF only partly applies to nutrient losses and cannot be extended to all single products.
Beyond the conversion to integrated or organic farming the farmer has the option to reduce the intensity within a given farming system. The results tend to show lower environmental impacts for lower input systems, but care must be taken that the production intensity does not fall below the ecologically optimal level. For grassland systems, a combination of intensively and extensively management plots may give more favourable overall results than the management of the whole area at a medium intensity. The reduction of fertilising and soil cultivation intensity led to a general reduction of environmental impacts, while the ban of certain classes of pesticides reduced ecotoxicity potentials and increased biodiversity potentials, while leading to a higher energy demand and higher nutrient losses per product unit.

Introduction High-input farming systems (HIFS) practised in the last decades are held responsible for numerous environmental problems like water pollution or loss of biodiversity. Low-input farming systems (LIFS) that use only little external inputs are considered as an alternative that should help mitigating many of these problems. But are LIFS really more environmentally friendly than HIFS once their lower productivity is considered? To evaluate this question we need a tool able to assess the most relevant environmental aspects and to consider also the manufacture and delivery of the inputs. Environmental life cycle assessment (LCA) is a method that satisfies these needs. This paper gives a brief introduction to the LCA method, its application to the analysis of farming systems and to the results from a comprehensive study analysing Swiss farming systems.

Life cycle assessment method (LCA) The LCA method is an environmental management tool, which aims at helping decision-makers to take environmentally sound decisions. It can be used in process optimisation, where the environmental „hot spots“ are identified, or to choose the best out of several alternatives in comparative assessments. LCA aims to analyse the whole life cycle of a product, starting from the extraction of the resources (like oil, coal, phosphate ore) to the disposal of the waste („from cradle to grave“). By considering the whole life cycle we avoid a displacement of environmental problems from one process step to the other.

LCA has the objective of making a comprehensive assessment, by considering all relevant environmental impacts as far as possible. Impacts typically included are energy demand, global warming potential, ozone formation, eutrophication, acidification, ecotoxicity, human toxicity, but also impacts relevant for agriculture like biodiversity and soil quality should be addressed. The environmental impacts are not measured, but calculated by means of models. The environmental impacts are set in relation to the so-called functional unit, serving as a reference representing the function of the system and allowing a comparison between different scenarios.

The LCA method as described in the ISO 14040 standard (2006) is divided into four phases (Fig. 1):

1. Goal and scope definition: aims at defining the goal of the study, the system boundaries, the allocation rules, the requirements in terms of data quality, etc.
2. Life cycle inventory: in this phase the data collection for the analysed product system takes place and an inventory of emissions and resource use over the whole life cycle is calculated.
3. Impact assessment: the life cycle inventory is aggregated to a number of impact categories for easier interpretation and communication.
4. Interpretation: in this phase the results are analysed in order to set priorities for action and to choose the best alternative.

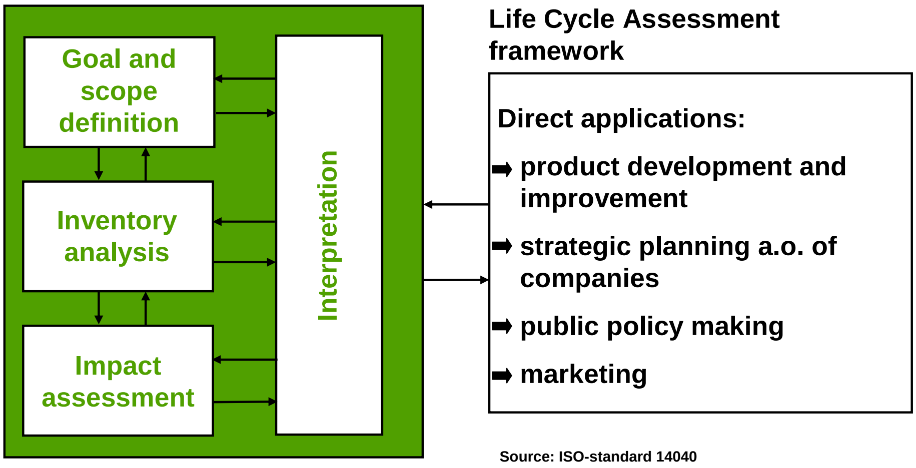

Fig. 1: The four phases of life cycle assessment according to the ISO standard 14040 (2006).

The SALCA method SALCA (Swiss Agricultural Life Cycle Assessment) is a LCA method and database developed by Agroscope Reckenholz-Tänikon ART for the purpose of analysing and optimising agricultural production systems in environmental terms. SALCA comprises the following elements:

- A *database* with agricultural life cycle inventories. The SALCA database is developed in close cooperation with the Swiss Centre for Life Cycle Inventories (ecoinvent, Frischknecht *et al*., 2004).
- *Models* for the calculation of *direct field and farm emissions*, such as nitrate (Richner *et al*., 2006), nitrous oxide (Schmid *et al*., 2000), methane (Minonzio *et al*., 1998), ammonia (Menzi *et al*., 1997), phosphorus (Prasuhn, 2006) and heavy metals (Freiermuth, 2006).
- A selection of *methods for assessing environmental impacts* that are particularly relevant to agricultural systems: demand for non-renewable energy resources, global warming potential, eutrophication, acidification, ozone formation, human toxicity and ecotoxicity (aquatic and terrestrial).
- Methods developed by ART for assessing the impacts on *biodiversity* (Jeanneret *et al*., 2006) and *soil quality* (Oberholzer *et al*., 2006), which have mostly been disregarded in LCAs until now.
- *Calculation tools* for frequently studied agricultural systems (crops at field level and farms at farm level).
- An *interpretation scheme* for agricultural LCA.

Analysis of farming systems Since the further processing, transport, retail and consumption of food products are mostly not directly dependent on the type of agricultural primary production, agricultural LCAs are normally limited to the farm gate. Fig. 2 shows an example.

To account for the multifunctional character of agriculture, three functions and functional units should be considered according to Nemecek *et al.* (2005):

1. *Land management function*: it describes the cultivation of land so as to minimise the environmental impacts per area and time unit, which is usually achieved by lessening the land use intensity. This function mainly reflects the perspective of society willing to preserve land for agricultural production. The land management function is measured by *hectare times year*.
2. *Financial function*: from the perspective of the farmer, income is the main motivation for agricultural production. The goal is to minimise the environmental impacts per currency unit, so as to maximise the eco-efficiency. For the financial function, the *gross profit* (expressed in CHF) is used (total receipts including direct payments).
3. *Productive function*: agricultural activity aims at producing food, feed or biomass for other uses (bioenergy, renewable materials). The goal is to minimise the environmental impacts per product unit (maximise eco-efficiency). This function mainly reflects the perspective of the consumers. The productive function is quantified by physical units. *Kilogram dry matter* (DM) and *MJ net energy for lactation* (MJ NEL) are the units used in this study.

For a sound analysis of farming systems it is crucial to set the appropriate system boundaries. Farming systems need to be compared at the level of the crop rotation (as in Fig. 2) or at farm level. A comparison e.g. between a conventional and an organic product gives insight into the environmental burdens of that particular product, but cannot serve to evaluate the farming systems as a whole. Nemecek *et al.* (2001) have shown that comparing single products out of a crop rotation may lead to erroneous conclusions.

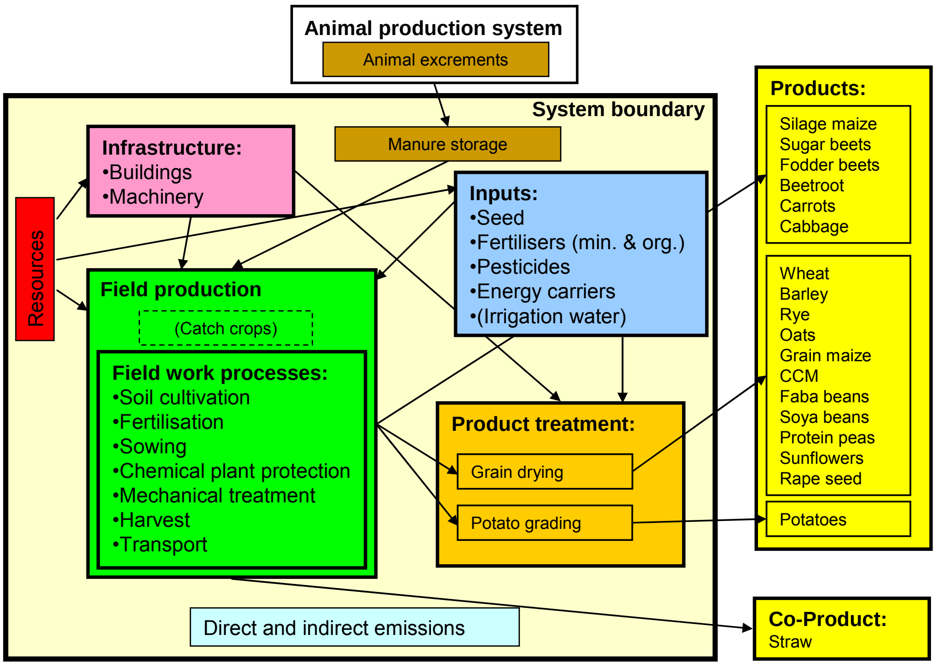

Fig. 2: System boundaries for the analysis of farming systems by life cycle assessment (from Nemecek *et al.*, 2005).

Life cycle inventory To obtain representative data on the studied farming systems, data are collected either on a sufficiently large number of farms or by means of modelling, using different data sources (see Nemecek & Erzinger, 2004). The first method is likely to provide a good database, but is often not feasible. Therefore the production data are often modelled based on statistics, farm accountancy data networks (FADN), pilot farm networks, surveys, data from agricultural extension services, field experiments and expert knowledge.
In addition to the production data we need (i) databases containing life cycle inventories of all inputs and processes occurring in the studied system and (ii) models to calculate direct field and farm emissions, since the measurement of these emissions is not feasible.

Life cycle impact assessment Agricultural systems have a number of specific aspects that need to be considered in the life cycle impact assessment. The cultivation of agricultural land has various impacts on the environment, like effects on biodiversity, impacts on soil quality (physical, chemical and biological) and effects on the landscape. Furthermore, emissions to the agricultural soil present a higher risk of pollution, since the pollutants may enter the human food chain. These specific aspects need to be considered in the assessment of farming systems; big progress has been made in the last ten years in this respect.

Interpretation A correlation analysis between the different life cycle impact categories revealed some close relationships allowing to identify three groups of impact categories (Fig. 3), which have a direct relationship with the farmer's management: The *resource management* (energy, mechanisation and infrastructure) is strongly related to the energy demand, the global warming potential and the ozone formation. The *nutrient management* (fertilisation) has an effect on the eutrophication and the acidification potentials. The *pollutant management* (plant protection measures) is related to the aquatic and terrestrial ecotoxicity potentials as well as to the human toxicity potential. The impacts on the *soil quality* and the *biodiversity* are related to all three management axes and therefore treated separately. The whole analysis could therefore be covered by these five environmental areas.

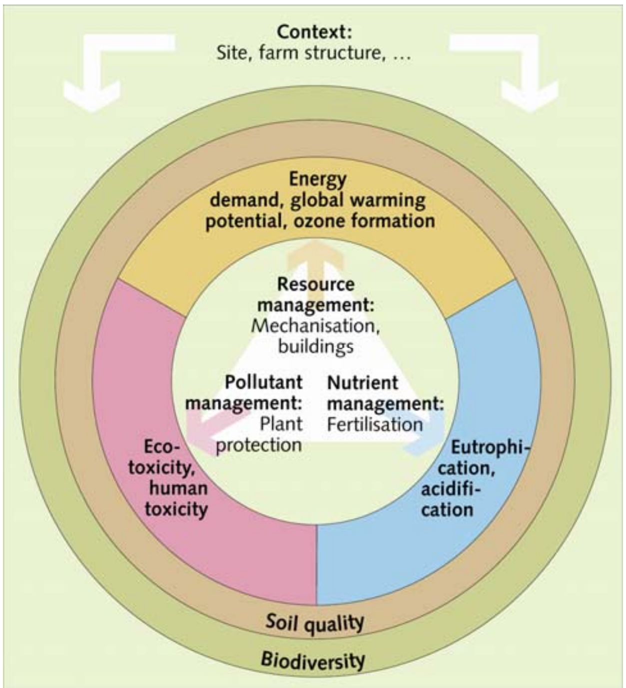

Fig. 3: Management triangle of farming systems (from Nemecek *et al*., 2005).

From high-input to low-input farming systems The farmer has two basic options in order to turn from a HIFS to a LIFS. He can

1. *convert the farming system* from conventional/intensive to integrated or organic farming or
2. *optimise within a given farming system*. This can be
    a. an *overall extensification* of the farming system, like for grassland systems the reduction of management intensity (cutting frequency and level of fertilisation) or
    b. a *partial extensification*, where only certain inputs are reduced. We studied the reduction of plant protection, of fertilisation and of soil tillage (management axes according to Fig. 3).

Here we summarise the results. Nemecek *et al*. (2005) and Schaller *et al*. (2006) report the full results. Tab. 1 gives a synthesis of the findings.

The potential environmental impacts of *organic farming* (OF) were on the whole favourably assessed compared to integrated production (IP, Tab. 1). This is particularly the case for the areas pollution management, resource management and biodiversity. However, the advantages of organic farming with respect to biodiversity cannot replace those of the ecological compensation areas. The positive assessment of organic farming only partly applies to the nutrient management and cannot be extended in all cases to single products: Per kg of organic product, higher impacts were often found for global warming potential, ozone formation, eutrophication and acidification compared to IP. No systematic differences to IP resulted for soil quality for the same crop rotation and an equivalent amount of organic fertilisers. The principal improvement needs for OF lie mainly in the increase of the yields with the limited inputs – especially for the potatoes and the cereals – as well as the minimisation of nitrogen losses.

Conventional farming – analysed for wheat and rape seed – was clearly unfavourable especially for pollutant management by comparison with IP. For eutrophication and biodiversity the evaluation was also less favourable.

The *overall extensification of forage production* caused a significant reduction of environmental impacts per area unit. At the plot level, extensive grassland is also environmentally more favourable per MJ NEL (net energy lactation), but the differences between intensive and extensive management depend on the considered impact category. A combination of plots managed at high and low intensity tends to be environmentally more favourable than the management of the whole grassland area at medium intensity.

The *partial extensification of plant protection* in the case of the so-called «*Extenso*» *production* (ban of fungicides, insecticides and growth regulators in cereals and rape seed) led to an improvement in pollutant management and biodiversity. If considered per area, we found small advantages for resource and nutrient management. However, the product-related environmental impacts were often higher, due to the yield losses in the extensive production.

The *partial extensification of fertilisation* had positive effects with respect to almost all environmental impacts, when considered per area unit. The only exception is soil quality, where a reduction of organic fertiliser input can have negative impacts due to a lower supply of organic matter. Related to the product we found lower impacts mainly for nutrient management. Reducing fertiliser input can therefore have positive effects on the environment, but will probably reduce profitability.

The *partial reduction of soil cultivation intensity* (analysed for a no-till system) showed advantages it terms of a lower energy demand (ploughing is an energy-intensive process), slightly lower nutrient losses and an improved soil quality (improved soil structure and higher earthworm biomass). A question remained about the impacts of the frequent glyphosate applications on ecotoxicity; no clear conclusion could be drawn.

Tab. 1: Synthetic representation of the assessment of the impacts on the environmental of different factors (from Nemecek *et al.*, 2005 and Schaller *et al.*, 2006).

Factor:	Farming system					Production intensity				Form of fertiliser	Fertiliser quantity		Soil tillage	
Level:	organic			conven-tional		Plant prot.: extensive		Grassland management: extensive		Organic	Reduced		Reduced	
Reference:	vs integrated					vs intensive		vs intensive		vs mineral	vs normal		vs normal	
Functional unit:	ha	kg[1)]	kg[2)]	ha	kg	ha	kg	ha	NEL		ha	kg	ha	kg
Resource management	++	++	+/-	0	0	+	-	+++	+	+++	+++	0	+	+
Nutrient management	++	0	+/-	-	0	0	-	+++	++	--	+++	++	+	+
Pollutant management	+++	+++	+++	---	---	++	++	+++	+	+	+	0	+/-	+/-
Biodiversity management	++			-		++		+++		0	++			
Soil quality management	0			0		0				+++	-- [3)]		++	

[1)] on farming system level
[2)] on crop level
[3)] for organic fertilisers

Int = intensive
Ext = extensive

Assessment classes:

---	Very unfavourable	+	Favourable tendecy
--	Unfavourable	++	Favourable
-	Unfavourable tendency	+++	Very favourable
0	No relevant difference	+/-	Favourable and unfavourable results
(grey)	No assessment		

Eco-efficiency analysis By using a theoretical model for eco-efficiency, we could show that the ecologically optimal management intensity strongly depends on the particular situation; an extensification as well as an intensification of management practices may be environmentally sound. Farming systems at a moderate intensity level are often environmentally optimal, but in some cases this intensity level is less favourable than intensive or extensive management. The model could be illustrated by examples (Nemecek *et al.*, 2005b). In IP an input-oriented optimisation leads to an improvement of eco-efficiency (optimising inputs in relation to the yield), whereas in OF improvements can be achieved mainly by output-oriented measures (making best use of the available inputs to achieve a high yield with a good quality).

Conclusions In Swiss farming systems, both paths towards a low-input farming system can lead to reduced environmental impacts, namely the conversion from conventional to integrated or organic farming or the optimisation within a given farming system.

Several environmental advantages can be achieved by conversion to organic farming. The improvements lie mainly in a lower resource consumption, a lower ecotoxicity potential and a higher biodiversity potential. Lower yields and high nutrient losses relative to the yield were identified as the main weaknesses of organic farming. Most organic products were found to be more eco-efficient than integrated products, but the contrary was also true for some products. The differences between organic and integrated farming were larger for arable crops than for forage production systems.

The conversion of a high-input to a low-input farming system should improve the eco-efficiency in most cases. However, care must be taken that the production intensity does not fall below the ecologically optimal level. It is important to optimise the whole farming system and not to take isolated measures only, since a punctual improvement of a few impacts can be nullified by a deterioration of the overall eco-efficiency. The reduction of fertilising and soil cultivation intensity led to a general reduction of environmental impacts, while the ban of certain classes of pesticides reduced ecotoxicity potentials and increased biodiversity potentials, while leading to a higher energy demand and higher nutrient losses. A combination of intensive and extensive management may be more eco-efficient than a management at medium intensity of the whole area, as shown in the example of grassland management. Bigger differences between intensive and extensive management were found for forage production systems than for arable crops.

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Characterization and Elements for a Definition and Analysis of Low Input Farming Systems

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Keywords: intensity, efficiency, energy balance, low input farming, ecological data network

Abstract Development of low input and high efficiency agricultural systems is a priority for the future. This objective requires improvements in farming practices (such as nutrient balances, pesticide reduction, use of renewable energies, adaptation to climate and soil, green manure, crop rotation, biological control etc.). The definition and assessment of low input/high efficiency systems are key issues. For each farming system, the level of input used per hectare or per quantity of product can be calculated. To analyse, at the farm level, the different levels of input used, the link between intensity and efficiency, and the environmental impacts SOLAGRO developed two methods: PLANETE (energy balance) and DIALECTE (environmental assessment). The results show that there are positive links between farming practices and low intensity systems such as a low percentage of maize in the main fodder area in dairy farms or organic practices in general. With regard to efficiency, however, there is a great variability among farm types, as well as in a homogenous farm group (e.g.: dairy farms). Efficiency is also linked to farmer skills, global coherence of farm management, etc. More data are necessary to explain why a farm can be at the same time a low input and a high efficiency system. The same conclusion is also valid to analyse the potential for greenhouse gas mitigation.

LIFS : the definition and the concept LIFS can be defined as "a way to optimise the management and use of internal production inputs (i.e., on-farm resources) ... and to minimise, wherever and whenever feasible and practicable, the use of production inputs (i.e., off-farm resources), such as purchased fertilisers and pesticides to lower production costs, avoid pollution of surface and groundwater, reduce pesticide residues in food, reduce the farmer's overall risk, and increase both short- and long- term farm profitability" - (Parr et al. 1990).

Material and methods To analyse, at the farm level, the different levels of input used and the environmental impacts SOLAGRO developed two methods: PLANETE (energy balance) and DIALECTE (environmental assessment).

PLANETE converts all agricultural inputs and outputs into energy. Figure 1 below describes the PLANETE methodology.

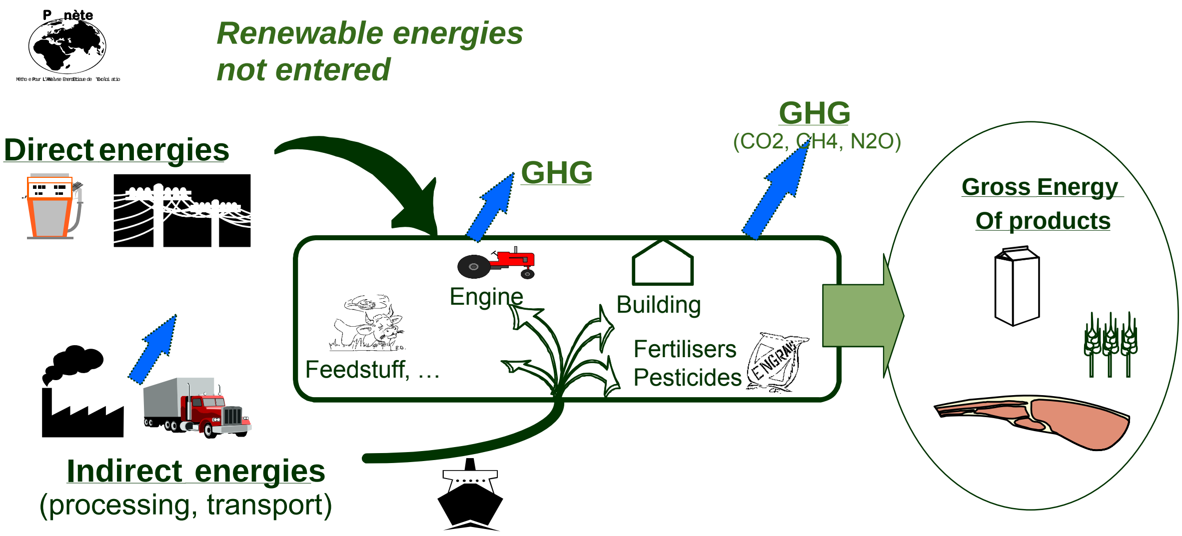

Figure 1. The PLANETE methodology

The main results concern input intensity (energy/ha of UAA, energy / Livestock Unit, …) and input efficiency (energy/litre of milk, energy per ton of dry matter produced, …). PLANETE can also calculate the quantity of greenhouse gas emitted per farm.

PLANETE uses a single unit, the Litre Equivalent of Fuel (LEF), for all inputs or outputs. This unit is more appropriate for farmers. As an example, see in Table 1 below some inputs converted into LEF.

Table 1. Some agricultural inputs and their energy value.

Inputs	Unit	LEF/Unit
Electricity	kwh	0,28
Fuel	litre	1,17
N mineral	Kg N	1,52
Soy cake	Kg	0,21
Cereal seeds	Kg	0,07
Pesticides	Kg	8,6
Machinery	Kg	2,4-2,9

(note :1 LEF = 35 MJ = 10 kWh)

DIALECTE is an overall assessment that takes into account not only the practices but the agricultural farming systems as well. DIALECTE indicators contribute to the quantitative assessment of the environmental impacts at the farm level. The environmental performance is based on an analysis of mixed character of farm and farming practices (nitrogen management, use of pesticides, irrigation etc.). Mixed farming system is represented by crop diversity, breeding and ecological infrastructures. DIALECTE takes into account the impact of a farm on the main environmental components: water (quality and quantity), soil (erosion and fertility), biodiversity, and non-renewable resource consumption. DIALECTE is also a free access data base, available on the internet, to compare environmental results (http://dialecte.solagro.org).

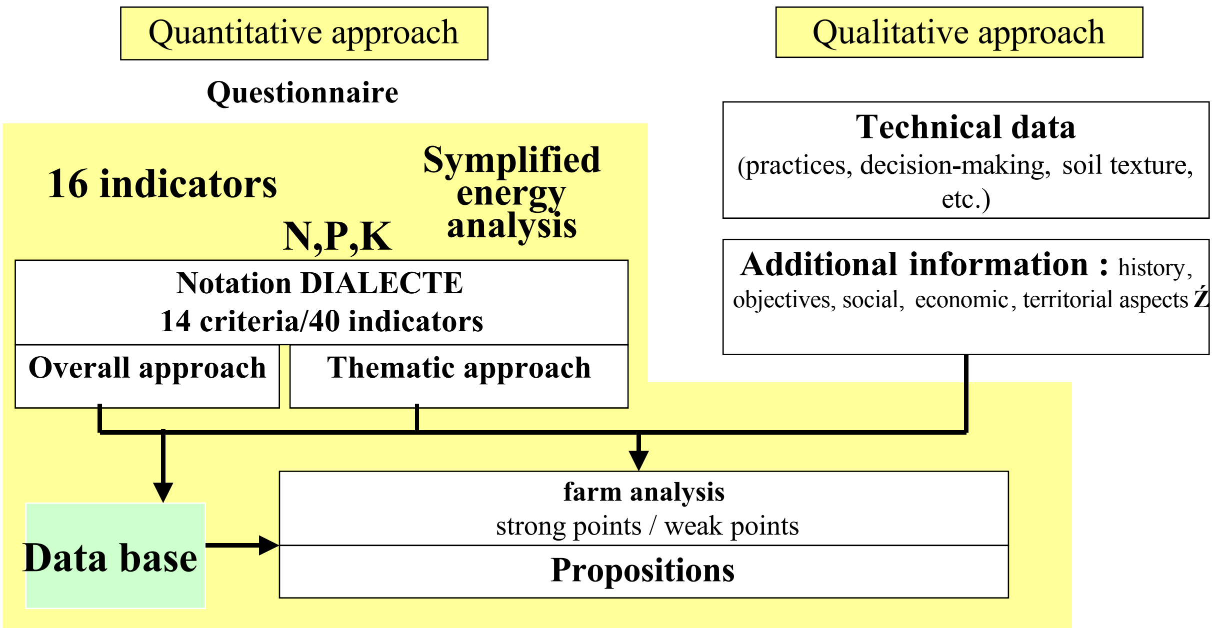

Figure 2. The DIALECTE methodology

The PLANETE method results A sample of 950 French farms were analysed with PLANETE (Bochu, 2007). All farm types are represented in this sample (dairy farms with or without marketed crops, crop systems, mixed systems etc.). The objective was to establish a typology of farms based on energy consumption and energy efficiency.

The average energy consumption is 560 LEF/ha. Four main inputs represent 75 %of the total energy consumed on a farm. They are: fuel for machinery (20%), feedstuff (21%), fertilisers (19%) and electricity (15%, including irrigation). There is a high variability in this sample and the energy consumption per hectare (intensity) goes from 100 to 10 000 LEF/ha. A high variability can also be found inside a homogenous farm group (e.g.: specialised dairy farms).

We have analysed a specific homogenous farm group: dairy cattle farms (without marketed crops). Figure 3 below compares 201 farms in terms of intensity (LEF/ ha UAA) and efficiency (LEF/1000 litre of milk). The average intensity is 457 LEF/ha and the average efficiency is 122 LEF to produce 1000 litres of milk.

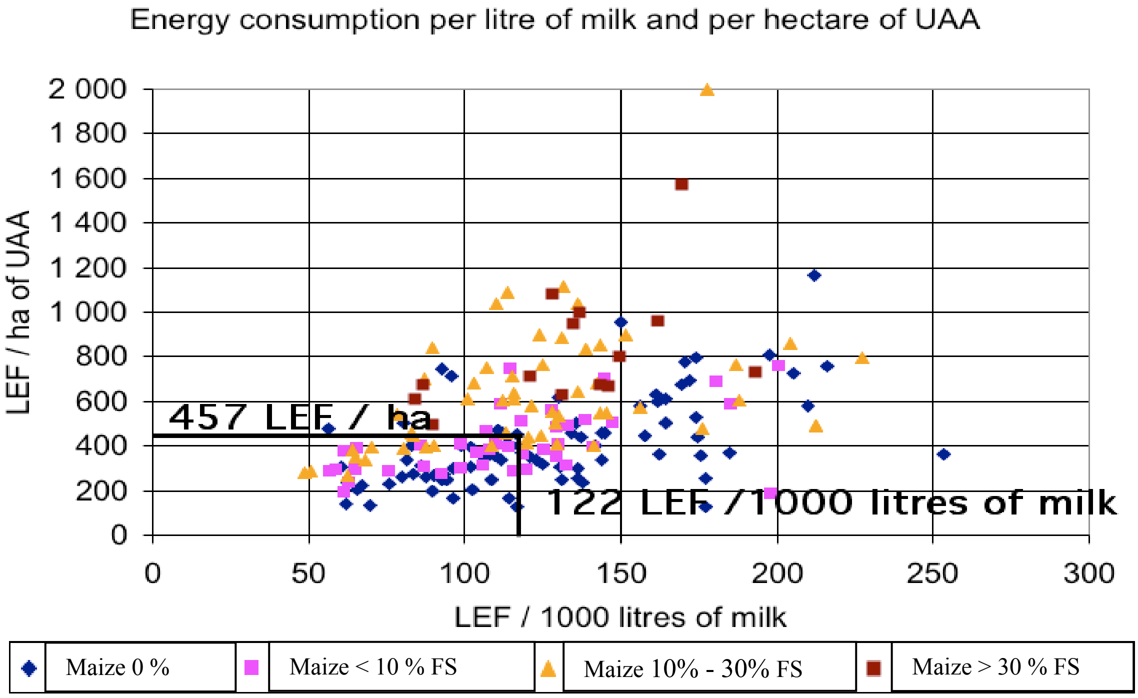

Figure 3. Intensity (LEF/ha) and efficiency (LEF/1000 litre) of dairy cattle farms, according to the percentage of maize silage in the main fodder area (source : PLANETE – SOLAGRO)

Figure 4 shows great variability inside this homogenous farm group. The main conclusion is that no simple link exists between intensity and efficiency. Among the low input farms (less than 400 LEF / ha), one group is very efficient (less than 100 LEF / 1000 litres of milk) whereas another group shows a low efficiency. The same kind of results is obtained with other homogenous groups. The dairy cattle farm group was also divided into sub-groups, using the percentage of maize in the main fodder area (MFA) as a variable. We note a positive link between the percentage of maize and the intensity, but no link between efficiency and the percentage of maize.

Another method is to compare farms with different farming practices. In Figure 5 below, green marks represent organic farms, pink are sustainable farms and blue represents conventional farms.

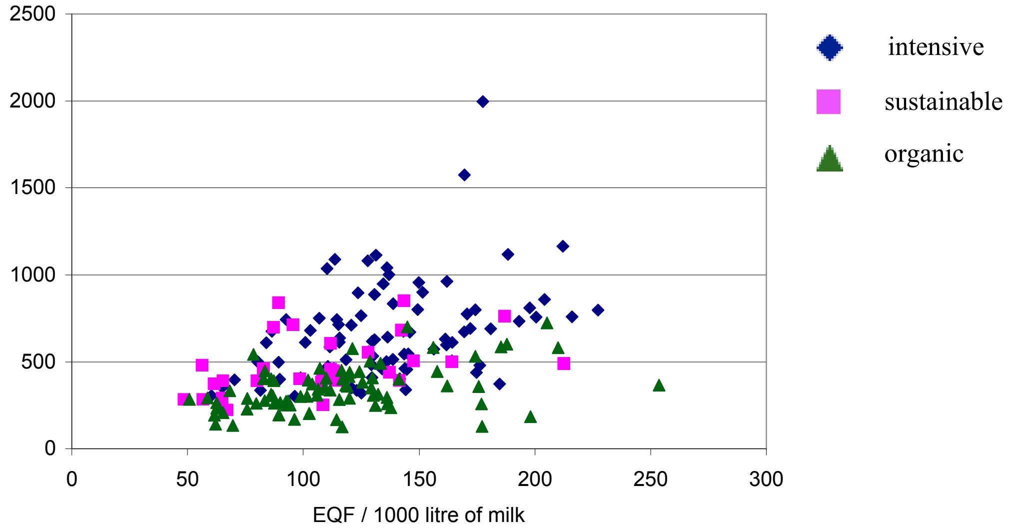

Figure 4. *Intensity (LEF/ha) and efficiency (LEF/1000 litre of milk) of dairy cow farms with different farming practices : intensive, sustainable, organic (source : Planete – SOLAGRO)*

We note a positive link between farming practices and intensity, but no link with efficiency. Organic farms are less intensive.

The DIALECTE method results We compared the environmental efficiency of two dairy cattle systems. The first farm group is a sample of conventional dairy cattle farms and the second is a sample of organic dairy cattle farms. The comparison (see Table 2 below), shows that, for the main agro-environmental indicators (crop diversity, share of leguminous plants, fodder autonomy, percentage of ecological infrastructures in the UAA, nitrogen surplus, energy intensity and efficiency), organic farms obtain the best results. This means that organic dairy cattle systems are better adapted to face the environmental challenges (water quality, soil fertility, biodiversity).

Table 2. Environmental efficiency of conventional and organic dairy cattle systems (source : DIALECTE data base)

Indicator	Threshold	**Conventional**	**Organic**
Mixed character of the farm			
Crop diversity and soil coverage			
Crop diversity	10	7	**9**
Share of leguminous plants (% UAA)	33 %	13%	**28%**
Soil coverage in winter (% UAA)	100%	83%	**97%**
Livestock diversity, autonomy			
Livestock diversity (number of herds)	8	1	1
Fodder autonomy	100%	92%	96%
Concentrate autonomy	100%	24%	**53%**
Natural infrastructures			
Ecological compensation area (% UAA)	100%	7%	**18%**
Average plot size (maximum 10ha)		6	7
Input management			
Nitrogen			
N Pressure (mineral and organic) (kg N /ha)	200	139	42
N surplus (kg N /ha UAA)	50	81	**44**
Phosphorus			
P Pressure (mineral and organic) (kg P2O5/ha)	100	62	22
P surplus (kg P2O5/ha UAA)	30	31	6
Water			
Volume (1000 m3)	150	33	5
Pesticides			
Pesticides (number of treatments/ha UAA)	10	1	0
Energy			
Consumption (LEF/ha UAA)	1000	630	**321**
Efficiency		2	**2**

Conclusion Positive links exist between intensity and some farming practices such as the percentage of maize in the main fodder area or organic practices. Organic farming is also a way to preserve the environment. But with regards to efficiency, there is a great variability among farm types as well as inside a homogenous farm group. Efficiency and environmental impact are mainly linked to farmer skills and to the global coherence of the farm. More data are necessary to explain why a farm can be at the same time a low input and a high efficiency farming system. The same conclusion is also valid to analyse the potential for greenhouse gas mitigation.

The development of low input and high efficiency agricultural systems is a priority for the future. This objective requires improvements in practices (such as nutrient balances, pesticide reduction, use of renewable energies, adaptation to climate and the soil, green manure, crop rotation, legume use).

Tools to analyse farming systems must be implemented and statistical environmental data must be improved. More data and references are necessary in order to accurately establish, for each farm type, the thresholds of low input farming systems for each relevant indicator

Current low input and high efficiency systems exist today, but there are not enough data to characterise them and explain how they work. One way to improve this analysis will be to create the FEDN: Farm Ecological Data

Network, to collect and analyse agricultural practices at the farm level, and input uses as well (e.g.: natural constraints, farmer skills, rotations, direct drilling, fertiliser rate, grazing period, use of renewable energies etc.).

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LIFS & livestock production – grassland and dairy farming in Austria

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Keywords: low input farming, low cost farming, sustainability, organic farming, bio-diversity

Abstract In some countries, especially in disadvantaged areas, a stronger tendency for low input farming systems (LIFS) can be noticed nowadays aiming at aspects of sustainability. Sustainable agriculture refers to the ability of a farm to produce food indefinitely without causing irreversible damage to the health of the ecosystem. There is a set of different LIFS-elements available, which have to be chosen and combined according to the specific situation on farm. Most of the LIFS-elements directly aim at the reduction of production costs, which are rather high in alpine and mountainous regions compared with favourable lowland areas.
Several studies have been carried out by the Federal research and education centre for agriculture (HBLFA) Raumberg-Gumpenstein during the last years to identify different effects of low input farming systems on ecology, economy and socio-economy. The results clearly indicate beneficially effects of LIFS on nutrient fluxes, floristic biodiversity and economy. LIFS not automatically means organic farming but also can be realized on integrated and conventional farms. In Austria the majority of grassland and arable farms follow the principles of LIFS, which are also included in the Austrian agri-environmental program ÖPUL that is highly accepted by the farmers.

Introduction In many European countries agriculture has developed from traditional and natural farming to highly productive and industrial farming systems during the last decades. High loads of farm external inputs have increased environmental problems like nutrient leaching, contamination with pesticides, soil degradation and erosion. Such intensive systems mainly focus on an increase of output, which very often does not reflect in a rising economic efficiency.
In some countries, especially in disadvantaged areas, a stronger tendency for low input farming systems can be noticed nowadays aiming at aspects of sustainability (Brundtland, 1983). Sustainable agriculture refers to the ability of a farm to produce food indefinitely without causing irreversible damage to the health of the ecosystem (Ikerd, 1990). Furthermore such systems must be resource-conserving, socially supportive, commercially competitive and environmentally sound.

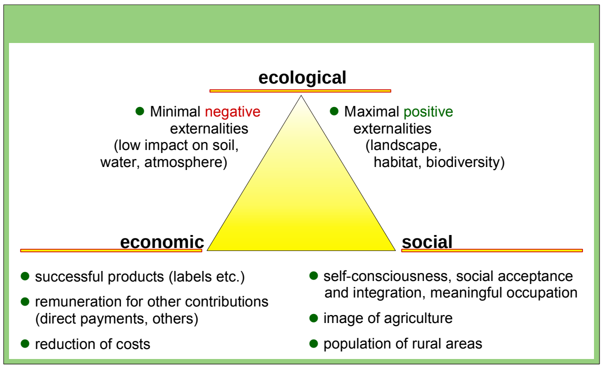

Figure 1 Conception and main criteria of low input farming systems

What could be the elements and strategies of low input farming systems (LIFS) and what are the resulting consequences of implementing these elements and strategies in practice? In Table 1 possible elements of LIFS are listed, which affect different parts of agricultural production. Due to the manifold farm structures (size, focal point of production, location, production conditions, financial situation …) there is no general and fixed set of LIFS-elements, which covers all different aspects and conditions. Therefore farm specific LIFS have to be implemented, using a selected combination of existing LIFS-elements, which consider natural and structural conditions, interest and capability of the farmers and also agri-political conditions including subsidies.

Table 1 Basic elements of low input farming systems

elements	necessities/consequences/advantages
Reduction of external resources (concentrates, mineral fertilisers especially mineral nitrogen, pesticides, fossil energy)	improve forage quality, legume based forage systems, enhance manure efficiency, mechanical and biological weed control, use of renewable energy
Maximisation of grazing	full grazing systems, harmonisation of lactation time with vegetation period, improve forage conversion efficiency, synchronisation of calving, animal welfare and health reduce forage conservation costs, natural hay drying systems, no or little maize
Optimized animal husbandry	low replacement rate of dairy cows, high life-performance, site adapted local breeds – lightweight animals to avoid sward damage
Cheap and labour extensive animal housing systems	free-range husbandry, wooden stable houses and farm buildings, stable co-operations
Reduction of costs for farm machinery and other farm equipment	Use of machinery rings, inter-farm co-operations, management co-operations for larger areas (valleys)

Most of the mentioned LIFS-elements directly aim at the reduction of production costs, which are rather high in alpine and mountainous regions compared with favourable lowland areas. There are e.g. much higher costs for special machinery but also higher costs for buildings. Considering the full costs of dairy farming in Austria the highest proportion of costs is caused by labour, which additionally has a strong impact on the personal and social situation of farmers (Kirner, 2004).

Basically it has to be taken into account, that:

- LIFS not automatically means low cost in any case (e.g. abdication of chemical weed control may increase the work load, grazing in wet regions may result in sward damage and regeneration costs …)
- LIFS is not a simple extensification but is a strategy which is closer to nature and more sustainable than high input farming systems (even LIFS can - depending on the existing production conditions - be high yielding systems)
- LIFS can be but have not necessarily to be organic farming (organic farming compulsory include many elements of LIFS, but also in integrated and conventional farming some LIFS-components are considered)

Material and methods Several studies have been carried out by the Federal research and education centre for agriculture (HBLFA) Raumberg-Gumpenstein during the last years to identify different effects of low input farming systems on ecology, economy and socio-economy. The main focus was given on grassland and dairy farming systems which are of great importance in the disadvantaged area that amounts to nearly 70% of the total Austrian agricultural area. Within the Man and Biosphere (MAB) project “Mountainous grassland in Austria” a comprehensive field study was carried out in the test region of Ennstal in the province of Styria. The project region includes different geological and topographical conditions and ranges from the valley bottom with about 650 m to an altitude of more than 1100 m. On about 200 farms, which manage more than 3,700 ha of farm land investigations on nutrient fluxes, yield productivity, forage quality, soil properties, floristic diversity and economy have been made (Poetsch et al., 1999).

Results and discussion Nutrient and energy balances are generally considered as practicable tools for the documentation of long term ecological impacts and as indicators for the evaluation of environmental measures. Due to the environmental relevance of nitrogen farm gate balances for this central and important nutrient have been set up within the MAB Project. The main input components of the farm gate balances were mineral fertiliser, feedstuff, livestock, external farm manure, N-deposition and biological N-fixation by legumes. The used output components were animal and plant products, organic fertiliser and unavoidable N-losses.

The total set of dairy farms was grouped into organic farms, integrated farms and conventional farms. Table 2 contains the most important structural data about the investigated dairy farms which clearly indicate that the use of farm external resources (mineral nitrogen and concentrates) is on a very low level. Even on conventional dairy farms the average use of mineral nitrogen is just at 20 kg ha^{-1} year^{-1} and the yearly input of concentrates per cow was at 800 kg, which is about 2.5 kg cow^{-1} and day^{-1} during the lactation period.

Table 2 Structural data about the dairy farms in the MAB project region (Taube and Poetsch, 2001)

	Organic farms	Integrated farms[1]	Conventional farms
kg milk ha^{-1} forage grassland	5,801	5,583	8,883
Ø milk production in kg dairy cow^{-1} year^{-1}	4,710	4,650	6,095
Input of mineral nitrogen, kg ha^{-1} year^{-1}	0	0	20
Input of concentrates, kg cow^{-1} year^{-1}	276	437	806
LU[2] (livestock units) ha^{-1}	1.14	1.12	1.73

[1] farms with renunciation of the use of mineral nitrogen, herbicides
[2] based on 500 kg liveweight

The relative importance and size of the different input and output components varied between the investigated farming systems. On organic and on integrated farms, biological N-fixation was the main N-input component, whereas on conventional farms concentrate and mineral fertiliser were the main N-input sources. Independent of the farming system, milk-N and unavoidable N-losses were the most important output components.

There was no significant difference between organic and integrated dairy farms concerning N-input, N-output and the N-surplus, which was around 280 kg farm^{-1} year^{-1} (Figure 2). On the conventional dairy farms both a much higher input and a higher output of nitrogen was observed, which resulted in a significant N-surplus of around 400 kg farm^{-1} year^{-1}. If the average farm size of the different farm types is taken into account there is no more significant difference in the N-surplus per ha AA (+ 14 kg to +16 kg N).
These well balanced results could be reached either by the combination of low input + low output or high input (of concentrates) + high output, when unavoidable losses were taken into account. Even at the highest intensity level of about 1.7 LU ha^{-1} on conventional farms only a minor surplus was found. It is evident, that the main reason for these minor differences in N surplus are due to the small differences in fertiliser application rates.

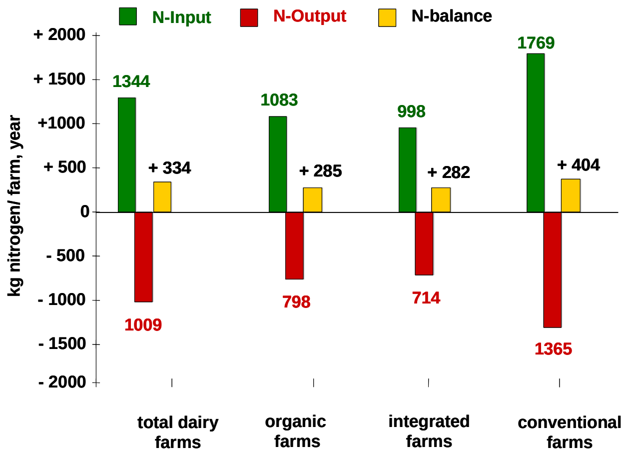

Figure 2 Farm gate nitrogen-balance for dairy farms in the Austrian test region "Ennsvalley"

Concerning the results of the farm gate balance, the tolerable range of surplus/deficit has to be discussed as well as the term of "unavoidable losses". Due to the limited nitrogen efficiency in the process of milk production, it is evident, that also the nitrogen balance of a specialised dairy farm results in a considerable surplus even in organic farming systems, especially if unavoidable losses are not taken into account. Therefore, comparisons between organic and conventional farming systems in terms of nitrogen surplus are only appropriate when data of stocking rates per hectare are taken into consideration.

The comparison of some international studies (Table 3) shows remarkable differences in efficiency indices of dairy production systems in Europe. Compared with very intensive dairy production systems, significant lower nitrogen surpluses and a therefore much higher N-efficiency could be observed in the Austrian study. It can not be concluded that specialised organic dairy farms are generally superior in relation to conventional ones as long as LU ha^{-1} are rather low in both systems. This conclusion is also confirmed by recent results from Scheringer and Isselstein (2001).

Table 3 N inputs and outputs (kg N ha^{-1} $year^{-1}$) on dairy farms in Europe (Taube and Poetsch, 2002)

	A	NL 1	NL 2	CH	DK 1	DK* 2	G 1	G 2
Nitrogen inputs	64	486	226	152	287	156	252	144
Nitrogen outputs**	24	78	74	43	47	32	53	34
Nitrogen surplus	40	407	153	109	240	124	199	110
N-surplus (g kg-1 milk)	6	34	13	15	-	-	25	22
N output/N input (%)	38	16	32	28	16	21	21	24

* without mineral fertiliser ** not regarding unavoidable losses

A : Austria, commercial farms MAB-project (Pötsch, 2000)
NL1 : Netherlands, commercial conventional farm (Aarts et al., 1999)
NL2 : Netherlands, De Marke experimental farm (Aarts et al., 1999)
CH : Switzerland, commercial conventional farms (Thomet and Koller, 1996)
DK1 : Denmark, commercial conventional farms (Halberg et al., 1995)
DK2 : Denmark, commercial organic farms (Halberg et al., 1995)
G1 : Northern Germany, „modelled conventional farms„ (Taube et al., 1997)
G2 : Northern Germany, "modelled organic farms" (Taube et al., 1997)

Additional benefits of LIFS The reduction of external nutrient and energy resources not only influence the result of farm gate balances but also beneficially effects water quality, soil fertility and biodiversity. In Austria a strong decrease in the use of mineral nitrogen and of pesticides in agriculture can be noticed (BMLFUW, 2007). The Austrian agri-environmental program "ÖPUL", which is offered nationwide, has stimulated many grassland and dairy farmers to participate in organic and integrated farming as well as in special measures aiming at environmental friendly land use. The Austrian "Aktionsprogramm Nitrat" which is the national implementation of the European Nitrate Directive has in general a very positive effect on the quality of groundwater resources in Austria. This program includes some restrictions in the use of farm manure concerning e.g. time of application, apportioning, minimum distances to waters and upper limits of nitrogen load. Nevertheless there are some small scaled vulnerable areas in the eastern and south-eastern part of Austria with higher nitrate concentration in the groundwater under arable land.

Maintenance and improvement of biodiversity can be seen as an international objective. The results of the above mentioned MAB-study clearly show that LIFS provide both a various number of grassland types and an impressively high floristic diversity (Figure 3).

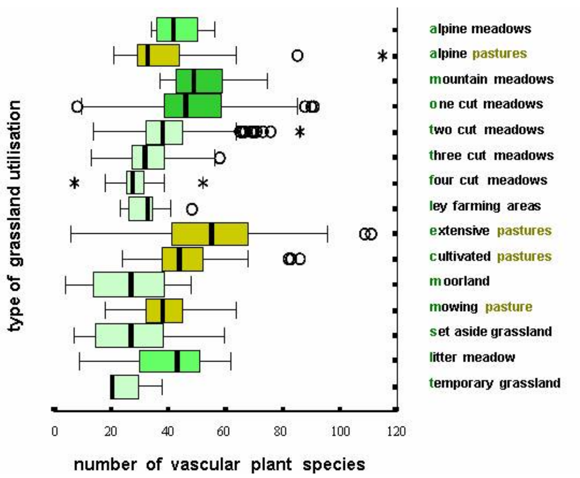

Figure 3 Floristic biodiversity on different grassland types in the Austrian test region "Ennsvalley"

Austria still leads the organic farming in Europe both with respect to the proportion of total AA (13.5%) and the proportion of all farms (11.5%). In 2006 the number of subsidized organic farms raised to 20,104 which means an increase of 2.7% compared to the previous year. The majority of organic farms in Austria are grassland and dairy farms, but a significant increase of organic farming in other land use systems is to be noticed.
In addition to organic farming around 65,000 grassland farms take part in special measures, which require an abolition or reduction of resources leading to yield increase such as mineral nitrogen, easily soluble fertilizer and pesticides. These farms represent a huge potential for the increase of organic farming in the near future.

Conclusions LIFS can be seen as resource-conserving, socially supportive, commercially competitive and environmentally sound production systems in agriculture. There is a set of different LIFS-elements available, which have to be chosen and combined according to the specific situation on farm. On-farm nutrient balance assessment is a valuable tool for identifying efficiency of nutrient use in the soil-plant-animal system as well as detecting the potential for pollution of the environment. Farm gate balances can be used as an indicator for Codes of Good Agricultural Practice in Europe, but input/output parameters have to be standardised and acceptable surpluses need to be regionally validated.

It takes strong efforts to maintain grassland and dairy farming in less favoured areas and to keep the landscape open. Different strategies have to be considered and adapted to the special conditions and requirements. In Austria there will be productive agricultural land use systems, both intensive dairy farming (around 5,000 farms each with 40-50 dairy cows and 300-400 t milk quota) and more traditional dairy farming (around 35,000 farms each with 10 cows and 40-50 t milk quota). Another 30,000 farms will focus on extensive livestock production including sheep and goats, suckler cows, heifer and beef fattening. The already existing system of income combinations has to be enhanced and different types of farm co-operations have to be forced to reduce costs and work load.

In some regions there will also be productive but non-agricultural land management systems with an alternative use of grassland biomass. Grassland could be the basis of a green refinery providing energy, isolation and insulation material, lactic and amino acids, enzymes or even secondary metabolites for special usage. Another strategy to keep the landscape open will be non-productive and non-agricultural land management via cutting or mulching without any use of the biomass.

In future strong efforts have to be made to inform the public about the multifunctional role of agriculture for the whole society. The awareness and sensibility of consumers should be increased to improve sympathy for this endangered economic sector and to raise the acceptance for support. The farmers themselves must improve their efforts for a sustainable management at least by following all relevant laws, guidelines and regulations for production to advance their image.

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Integrated farming systems: a form of low input farming

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Key words: integrated farming, farming system, low input farming system, arable crop, environment, Western Europe.

Abstract Conventional arable production has seen its environmental impact increase during the last decade. A more environmentally friendly agriculture helps preserve natural resources and protect wildlife and landscape. This paper proposes IFS (Integrated Farming System) as an alternative, halfway between conventional and organic farming, and as a form of LIFS (Low Input Farming System). These systems require a holistic approach to crop production, with special attention given to rotation, cultivars (according to their disease sensitivity and quality), sowing dates and seed rates, crop protection (adjusted according to disease pressure and growth stage), fertilisation (adapted to soil potentials and plant needs). Some experimental results and sustainability assessments are presented, based on a large number of experiments started in the '90s.

Introduction The search for sustainable agricultural production systems inevitably leads to an investigation of the feasibility of a Low Input Farming System (LIFS). But in our opinion, this solution, which certainly helps to save non renewable natural resources as well as to limit the environmental impact of agriculture, is not well enough defined: On the one hand, it is possible to produce a crop using few inputs without necessarily preserving biodiversity and some chemicals, such as insecticides, are cheap but have a very significant impact on the environment. On the other hand, too great a reduction in inputs leads to a significant reduction in yields and therefore in total agricultural production, which poses problems regarding the social sustainability of this type of system. The important point is the agronomical efficacy of inputs, rather than their level per say. That is why we favour the concept of Integrated Farming Systems (IFS). Here follows our definition of IFS:
"An integrated system is based on a holistic approach to soil utilisation for agricultural production, which aims to reduce the use of inputs coming from outside the farming business (energy, chemicals…), whilst capitalising as fully as possible on the natural resources used, and maximising natural control processes."

Although this concept can be applied to all aspects of agricultural production, we will focus below on arable production systems.

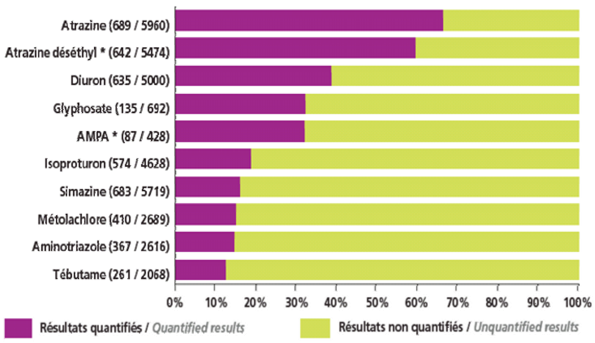
The concept of integrated farming was inherited from the concept of "integrated disease and pest control and integrated crop protection". Integrated protection was first developed by Baggiolini and Steiner in the '70s, as a crop protection method. Those two scientists developed this concept mainly for arboriculture and viticulture. Baggiolini thought that there was a middle road between biological control, based entirely on utilising beneficials, and chemical control: this was "integrated control". In 1977, scientists working under the umbrella of OIBC[4] published information about the concept of integrated production, which "promotes the optimisation of production through the management of all the factors playing a part in the agroecosystem". Following on from this work, several scientists adopted this concept and broadened it to arable crops. In 1990, we were then able to start a network of trials on this theme through the CAMAR European programme (Vereijken P. Viaux P., 1990; Viaux P. 1994). Nowadays, this "integrated production" approach is implemented by almost all Swiss farmers.
Producing quality produce whilst doing everything possible to protect the environment requires a combination of specific agronomical techniques described below. Taken individually, those techniques are generally well known. The main characteristic of integrated systems is the way those techniques are combined.
Agriculture and environment *The way agriculture has evolved over the past 40 years has led to enormous increases in the French (as well as global) agricultural production. In France, this intensification took the form of a rise in soil productivity (roughly, yields have doubled), as well as in labour productivity (multiplied by five) because of the development of machinery (but at the cost of low returns on capital investments).*

We know, however, that this increase in production did not occur without impacting on the environment. IFEN (Institut Français de l'Environnement) publishes regular updates on the overall impact. This shows that water quality is deteriorating as a result of nitrates, phosphates and pesticides. Active ingredients found in aquatic environments are increasing steadily. Glyphosate and AMPA (aminomethylphosphonic acid: glyphosate degradation metabolite), rarely found in water a few years ago, now figure among the most commonly detected products (Figure 8).

Figure 8: Environmental impact of agriculture: pesticides in water

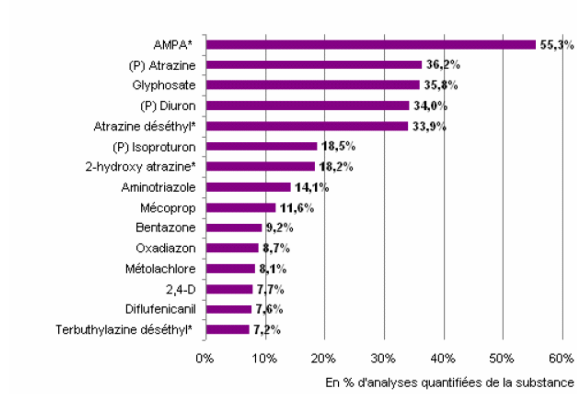
[4] International Organisation for Biological and integrated Control of noxious animals and plants

Frequency of main active ingredients in surface water in 2000



Source IFEN 2002

Frequency of main active ingredients in surface water in 2004



Source IFEN 2006

- *En % d'analyses quantifiées de la substance* = As a % of quantified analyses of the active ingredient
- *Mécoprop* = Mecroprop
- *Métolachlore* = Metolachlor
- *Diflufénicanil* = Diflufenican

Agriculture contributes to the deterioration of air quality, because of emissions of greenhouse gases (CH_4, N_20) and gases causing acid rain (NH_4), as well as pesticide aerosols, the impact of which we are only beginning to measure. Erosion, which is getting worse in some French regions, causes landslides, with an impact on water quality (turbidity and eutrophication), as well as diminished soil quality through loss of fine elements, organic matter and fertilisers. Agriculture consumes more and more non-renewable natural resources (energy, fertilisers). There is also evidence of an increase in water consumption for irrigation, to the extent that it creates problems for other water resources users. Finally, we must examine the impact of some fixed elements disappearing from the landscape (hedges, copses, paths, grass margins) on soil quality, water pollution, fauna and flora, as well as on the beauty of the countryside.

We have already shown (Viaux P. and al 2007) that the fields of an organic farm south of Paris, which had never received any herbicides, contained around 200 plant species (four of which figure on the European red list), compared with around 40 on the neighbouring conventional farms. This example highlights the benefits of organic farming to preserve floristic biodiversity and confirms other study results showing that specific plant diversity is greater in organic crops than in conventional crops (Bengtsson J. et al 2005).

A more environmentally friendly agriculture should therefore protect water and air quality, save non-renewable natural resources, as well as protect natural biodiversity and the landscape.

Main principles of IFS *In accordance with the definition of IFS, the aim is to build autonomous, economical and environmentally friendly systems. This can be achieved by following a few agronomical principles that can be simply described, even though they are not necessarily easy to put into practice on farm. Here is a short outline of all those basic principles, with a slightly more in-depth presentation of some of the major ones.*

Mixed farming systems

On a farm or a group of farms, annual crops must be combined as much as possible with perennial crops (permanent pasture, orchards, woods, etc.) and animal production (herbivores or monogastrics). It is the best way of utilising animal manure and saving on mineral fertiliser inputs. Mixed farming is a means of limiting economic risks for a farmer and therefore of alleviating the impact of yield and price fluctuations.

Long rotation and balanced "cropping pattern"

Rotations should be as long as possible, with the order in which crops succeed each other minimising the risk of diseases and weeds developing, and helping to save fertilisers. Keeping fields reasonably small and taking into account the spatial distribution of crops also help avoid potential plant health problems, by reducing potential attacks as well as the risk of run-off and erosion.

The fact that most farmers are abandoning rotations (to the extent that many agronomists currently feel they can only refer to a "succession of crops") is probably the current practice which, directly or indirectly, has the most serious agronomical and financial consequences. The last 30 years have seen a dramatic increase in maize, wheat, and even sunflower monoculture, as well as pea and oilseed rape crops grown every other year. Such technical feats have only become possible thanks to the existence of increasingly effective fungicides, insecticides and herbicides. But conversely, the fact that rotations are getting shorter "forces" farmers to resort increasingly to the use of chemicals.

Farmers who preclude the use of chemical pesticides on their organic farms know that they can only control weeds, diseases and pests through long rotations (5 to 10 years).

The spatial distribution of crops (cropping pattern) is taken into account even less. Over the last few decades, land consolidation has helped to increase average field size. This was justified in order to improve mechanical efficiency. However, some farmers tend to go overboard: fields of over 20 ha are becoming commonplace in certain regions. Those enormous parcels are responsible for numerous agronomical and environmental issues and exacerbate some parasitic problems.

Disease and weed development are probably the two main reasons for extending the rotation and diversifying species.

Long rotations also help to reduce the need for fertiliser, in so far as the different crops are able to recycle and/or extract soil nutrients in different ways. Experience has proved that in the case of wheat after wheat, the need for phosphorus is greater than when wheat is part of a rotation.

The introduction of leguminous plants, which fix nitrogen from the atmosphere, helps to save on the amount of nitrogen applied, not only for the leguminous crop itself, but also for the following crop. The advantage of leguminous crops is therefore that they help improve the energy balance of farms.

Ecological infrastructure: Good management of uncultivated areas

Preserving, developing and maintaining uncultivated areas: hedges, groves, grass margins... Those areas play a vital role in the conservation of wild fauna and landscapes; in addition, along streams, their buffer effect contributes to protecting water quality.

Non inversion tillage

Where possible, simplified cultivation techniques should be implemented in order to increase organic matter content and biological activity in the soil. Those techniques require greater vigilance regarding weed development in crops and during the intercropping season.

The past thirty years have seen the development of sowing techniques involving less and less use of a plough and deep cultivation. Those techniques, called "simplified techniques", actually cover a huge range of techniques.

Simplified techniques have in common the fact that they do not involve ploughing (non inversion tillage). Farmers who choose this route are often aiming to decrease their mechanical costs and speed up crop establishment. However, other motivations might be agronomical and environmental objectives or the improvement of soil fertility. Simplified techniques do help to increase the organic matter content of the soil and the level of biological activity on its surface. This reduces nitrogen leaching, slows down erosion and cuts fuel consumption.

However, the use of simplified cultivation techniques cannot be widened to all types of soil and all crops. In addition, those techniques create a weed development problem. This issue is well known for perennial weeds: thistle (Cirscium arverse), couch grass (Elymus repens), convolvulus dock (Rumex acetosella), etc., but it also seems to be spreading to some annual species: cleavers (Galium aparine), sterile Brome (Bromus sterilis), etc., which can be extremely difficult to control. Simplified cultivation can therefore require a more frequent use of herbicides, especially during the intercropping season, with the added problem of having to resort to total herbicides such as glyphosate, which, alarmingly, is increasingly present in water.

Target yield strategy

The yield target should be average (attainable at least every other year). A higher yield target would lead to applying inputs which will be fully utilised only one or two years in ten.

Choice of cultivar, sowing date and seed rate

The varieties chosen should be resistant to diseases and premium market quality. Yield potential must not be considered as a priority when choosing a variety. Over the last few years, a network of trials established in France has helped to identify wheat varieties suited to cropping systems involving low inputs (Loyce C., et al 2006; Felix I. et al 2005). If a wide area is devoted to one species, several varieties should be grown, in order to limit parasitic and climatic risks.

Managing fertilisation with the balance method

The level of fertilisation must be based on a nutrient balance, taking into account the mineral elements contained in the organic manure applied. We must remember that feeding the plant is more important than feeding the soil, and that agronomists have given up the idea that accumulation of nutrients in the soil maintains yield potential after you cease fertilising. In a significant number of cases, P and K applications are lower than their level of offtake in the crop.

Integrated pest management

Pesticides must be considered as a last resort, when everything possible has already been put in place to reduce diseases, pests and weeds. This is usually possible if everything mentioned above has been properly implemented.

We must never lose track of the fact that all pesticides are potential health and environmental hazards. The marketing of those products is heavily regulated. Those regulations have recently been tightened, but the fact that a product has been approved does not mean that it is harmless.

That is why the use of pesticides must not be considered as a means of production but as a possible means of controlling some parasites, a disease or a weed. The reasoning applied must be the same as the one behind the use of medicine. Medicines must only be used when we are ill and not as a performance enhancing drug. All pesticides must be considered as a potential health and environment hazard because, like all medicines, each pesticide has unintended side-effects.

Reducing plant health risks must always involve, in the first instance, a combination of all the above mentioned cropping techniques (well thought out rotation, choice of varieties, sowing dates and seed rate, limited field size, conservation of areas encouraging the presence of beneficials, reduction of nitrogen dosage, etc.). In addition, beneficials, and more generally all wild fauna, must be protected. If available, alternative methods should be used as much as possible (mechanical weed control for instance, biological control). When using pesticides, applications must be carried out in optimum conditions (weeds at an early growth stage, optimum weather conditions), and, as far as possible, must not be used as preventative treatment, using observation-based forecasting models and treatment thresholds. Finally, the active ingredients used should vary in order to avoid selecting the flora and developing resistance to disease and insects.

Prioritisation of principles

The order in which we have just mentioned the different technical aspects of an integrated system is not accidental. For example, long rotations will be easier with a mixed farming system thanks to the presence of herbivores: the forage crops needed for this type of farming will make long rotations much easier to achieve. Likewise, the longer the rotation is, the more moderate the nitrogen dosage is, etc., the easier it will be to reduce pesticide usage. This is why crop protection is mentioned last.

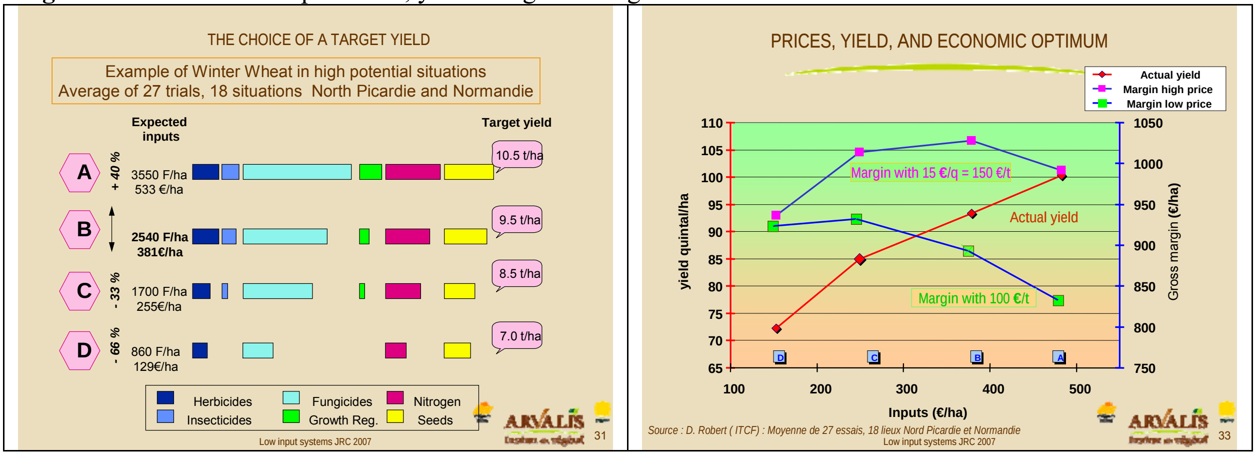
Economic considerations are not mentioned in this first part, because economic efficiency must not be assessed technique by technique. It is the implementation of all those techniques and the way they interact that helps to reduce inputs effectively and significantly.

Some economic and environmental results *The first experiments carried out in the '90s in six European countries (as part of the CAMAR programme) had shown that it was possible to reduce arable farming inputs by 30 to 40% without affecting economic results. From that point of view, integrated systems (IFS) are therefore real low input farming systems (LIFS). Those results have been the subject of numerous published papers (Viaux P. 1999).*

We have shown, through a host of experiments, the very strong link between input levels and yields.
Figure **9** shows an example of this type of result, obtained in the high potential yield areas of northern France. We note that optimum economic results are heavily dependant on the input and agricultural produce price ratio. The input level needed to maximise the gross margin rises from 200 to 400 €/ha when the price of wheat rises from 100 to 150 €/t. We must however note that when the price of wheat remains stable, the margin varies little between 200 and 400 € of inputs. So, very often, the farmer's technical competence is what makes the difference. Low input systems require a higher degree of technical ability.

The graph (
Figure **9**) also shows that it is difficult to define a low input farming system (LIFS). Seed cost apart, it is possible to achieve agricultural production regardless of the level of inputs used. This is why we prefer using input efficiency as an indicator, i.e. the (produce-inputs)/inputs ratio, as explained below.

Figure 9: Link between input levels, yield and gross margin for winter wheat



To approach those results in a more general manner we propose to examine economic and environmental sustainability indicators for four systems (Figure 10): one system illustrating a high yield target with irrigation, one with a high work productivity target with simplified cultivation and no irrigation, one integrated system and one organic system. The results shown (Figure 11) come from long-term experiments (except for the system with irrigation which corresponds to a real farm situated south of Paris) and cannot be extrapolated into a general rule, but they show some significant differences between indicators. For example, wheat yields vary from 3.8 for an organic crop to 9.1 in an irrigated system. Labour per ha goes from 1.8 hours per ha for the high work productivity system to 7.6 hours for the irrigated system. Differences in net margins between systems are relatively low considering how widely different all the strategies being considered are. Input efficiency reaches its maximum in an organic system, which only requires the purchase of seed, and is very low in the high work productivity system. From an environmental point of view, the Treatment Frequency Index (TFI) shows that the integrated system easily meets the pesticide reduction objective. Not surprisingly, we note that the energy consumption of the systems increases with the level of intensification and that the production level is linked to the yield level.

Figure 10: Description of four production systems

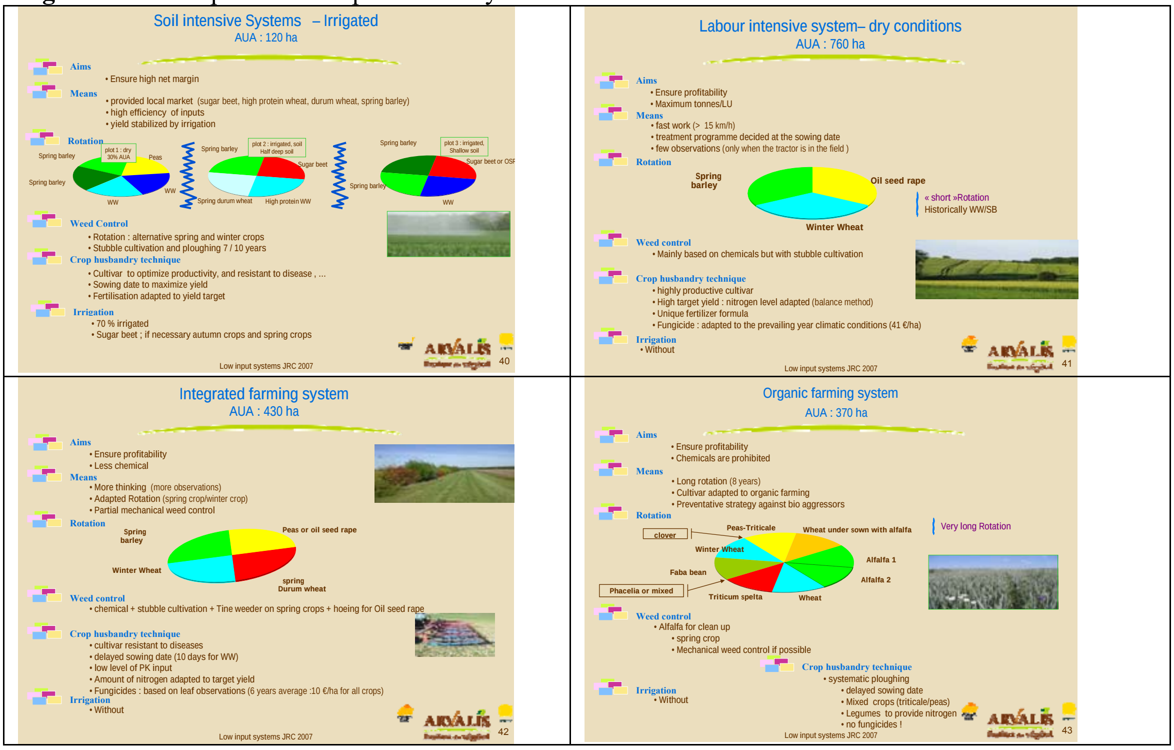


Figure 11: Characterisation of four production systems, using sustainability indicators

Farming Systems	Irrigated (70% of AUA)	High labour productivity	IFS	Organic(3)
TECHNICAL INDICATORS				
IVAN(1) (€/ha)	2339	911	1617	1211
Ha/Labour Unit	121	380	215	148
Labour (h/ha)	7.6	1.8	3.4	6.2
N (kg/ha) for W Wheat	207	200	153	0
Yield Winter Wheat (t/ha)	9.1	8.1	6.9	3.8
ECONOMIC INDICATORS				
Gross output W Wheat (€/ha) (without EU subsidies)	935	835	678	784
Total wheat production cost (€/t)	123	114	121	269
Wheat gross margin (€/ha) (without EU subsidies)	629	441	461	680
Farm net margin (€/ha)	345	311	264	367
Variable cost efficiency (gross margin/input)	2.26	1.04	1.94	13.1
ENVIRONMENTAL INDICATORS				
Soil winter green cover index	50%	58%	56%	75%
Global nitrogen Balance (kg N/ha)	- 16	23	11	-14
TFI(2) W Wheat	3.78	5.45	2.77	0
TFI at farm level	3.50	4.92	3.16	0
Energy Input (MJ/ha)	12 035	9 669	8716	4 445
Energy output (MJ/ha) (4)	136 072	86 937	62 140	57 675
CO_2 balance absorbed/produced (ratio)	3.28	2.65	2.04	5.59
Irrigation water productivity (kg MS/m3)	3.28	-	-	-

(1) IVAN: machinery value; (2) TFI: Treatment Frequency Index; (3) Without specific subsidies;(4) Grain only Straw not removed from the field

CONCLUSION Integrated Farming Systems help to significantly reduce input levels whilst maintaining relatively high yields. Although those systems have been shown to be feasible, they are too seldom used by French and European farmers (except in Switzerland!). However, some factors hinder their development. They require greater technical knowledge than conventional systems. Farmers who implement an IFS must be knowledgeable enough in order to resist the advice given by private companies or cooperatives: although from a microeconomic point of view (the farmer's) an IFS is financially viable, from a macroeconomic point of view, using less inputs and producing less agricultural produce leads to a drop in the turnover of commercial organisations. But the environmental assessment of those systems highlights their benefits. We can therefore see that it is difficult to increase GDP whilst preserving the environment.

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Conservation Agriculture, a way to High Efficiency Farming Systems

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In Europe, and in the whole word, more and more farmers reduce soil tillage, either partially (minimum tillage or shallow cultivation) or totally (direct drilling or no tillage). The goal is to save money, time and machinery costs, but also to preserve and improve soil productive capacity. However, practicing direct drilling cannot be improvised and needs agronomic and technical skills; requiring also comprehensive understanding of the local agro-ecosystem. With a view to sustainable development, Conservation Agriculture (CA) is a concept trying to reconcile ecology, economy and performance. Grasslands and forests are very productive and completely autonomous ecosystems: the no-till systems try to copy them in order to achieve high productivity with the lowest negative impacts on the environment and aiming to enhance the quality of soil, water, atmosphere and biodiversity. The method is based on three simple principles:

1. **Minimizing soil tillage** to preserve soil cover, organic matter, structural organization and the biological activity of arable soils;
2. **Maximizing soil vegetal cover** to protect the soil against climatic aggressions, to recycle and to produce nutrients, to feed soil and surface biological activity, to develop deep and organised structure;
3. **Improve crop rotation**, to reduce weeds and predators and also to increase biodiversity in order to enhance soil fertility through reduction in pesticide use.

There is no one way to practice Conservation Agriculture: each farmer has to adapt soil tillage, covercrop and rotation to his own system. All the experience related to these farming practices gathered since 1930s has shown that there is paractically no limit of CA systems, regardless of the soil, climate or crops. Today, even if it is only practised on 5% of cultivated soils, Conservation Agriculture represents a quickly growing type of agriculture and currently covers about 90 million hectares in the world. Most of the direct drilled surfaces are in the Americas: about 20% of arable land in the US is cultivated without any tillage (and 50% with minimum tillage), 50% in Argentina or Brazil. In Europe, due to the growing cost of energy and inputs, farmers are now following the same way without much support of research, governmental or private structures.

Minimizing soil tillage leads to soil improvement and then to inputs reduction

In agriculture, the only way to improve production in terms of both quality and quantity is to conserve or to improve soil fertility. Good soil structure and permanent cover allow the reduction of mechanisation, fuel consumption and irrigation. Good soil fertility can reduce the need of fertilisers; healthy soil life means less pesticide use. Conservation Agriculture is an effective way to ensure soil protection and fertility and therefore to reduce inputs without compromising yields, or even achieving better production level.

Result of an enquiry in the "no till web" comparing different tillage real systems in Brittany, France. (Chambre d'Agriculture de Bretagne, 2007).

		Ploughing	Deep cultivation (>10 cm)	Shallow cultivation (0 to 10 cm)
Fuel consumption (L/ha)		51	36	9
Work load	Wheat	2,10	1,32	0,35
	Maize	2,45	1,45	0,25
pesticides (kg/ha)	Wheat	1,0	0,8	0,4
	Maize	1,12	0,55	0,09
Glyphosate on covercrop	Treatments	1 to 2	2 to 3	2 to 3
	Total dose (L/ha)	3 to 6	3 to 4,5	
Fungicide dose (g/ha)		440	375	

Our agriculture is strongly related to fossil energies. Fertiliser consumption represents about 60% of the direct energy used on the farm[5], out of which 52% used for mineral nitrogen production (one litre of equivalent oil is needed to produce one kilogramme of ammonium). The remaining 40% are used by farm machinery and other farming operations such as irrigation, drying…

Today, with the increasing cost of fossil energies, i.a. due to increased demand from China and India and also forecasts of the future peak oil, the cost of agricultural production is growing fast in a long term. At the same time, it seems that human population will not stabilize until the end of the century and according to the Food and Agriculture Organization estimates production needs to be multiplied by 3 to feed the expected human

[5] If the global average yield has grown by 250% between 1960 and 2000, the fertilizer consumption has grown of 660%.

population of 9 to 10 billion in 2100. Moreover, in a context of arable land degradation[6], urbanisation, depletion of biodiversity, climate change and reduction of water resources we have to preserve our various agro-ecosystems.

Input reduction needs organic carbon After several years of no-till system soils achieve higher fertility, become able to structure naturally and allow the development of soil life. In fact, it is possible to reduce the part of fossil energy if the "life's energy" took over. For example, soil biological activity may replace soil tillage in favourable conditions, supporting various functions of the soil, such as crop protection, pests and disease management. This complex soil ecosystem needs energy to work: organic carbon from photosynthesis is the fuel for the soil[7]. For that reason, high efficiency farming systems need to preserve, create and recycle a lot of organic matter. In that way, no tillage reduces the injection of heat and oxygen in the top soil layer, reducing mineralization of organic matter by bacteria and fungi. Moreover, the reduction of the period between harvesting and seeding allows to grow more biomass (crop, cashcrop or covercrop) per hectare and per year.

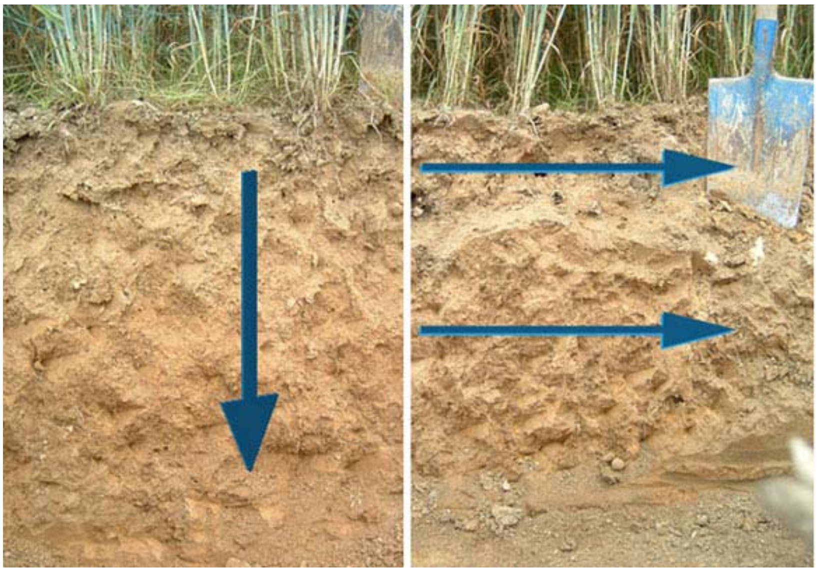
Comparison of no-till and ploughing system on the experimental field of Zollikofen in Switzerland (Schaller, Nemecek and al., ART – Chervet and Sturny, Inforama Rütti, Swiss, 2007)

	Effects on environment	**per ha and per year**		**Percentage**	**per t of DM**		**Percentage**
		D	**P**	**(P = 100%)**	**D**	**P**	**(P = 100%)**
Resources management	Energy consumption (eq. MJ)	14'747	16'050	92	1'459	1'655	88
	Ozone potential release (kg eq. C_2H_4)	0,485	0,595	82	0,05	0,06	78
	Greenhouse effect gases potential (kg eq. CO_2)	2'070	2'141	97	205	221	93
Nutrients management	Eutrophication potential (kg eq. N)	45	48	93	4,47	4,99	90
	acidification potential (kg eq. SO_2)	13,2	14,13	93	1,3	1,5	87
Toxins management	Aquatic ecotoxicity potential	840'749	1'006'119	84	83'163	103'714	80
	Human ecotoxicity potential	517	716	72	51	74	69

D: direct drilling + covercrop
P: ploughing + covercrop

[6] In the north with the excess of tillage and the lack of organic carbon in the soils and in the developing countries with slash and burns in high population density areas.
[7] The transformation of organic wastes and crop residues as "agrifuel" is a tragic mistake.

Water management in Conservation Agriculture



Intensive and deep tillage, practiced in our farming systems for thirty years, quickly degrades the soil surface and structure (picture on the right – after 4 years) and consumes organic matter. Repeated tillage, heavy traffic on the field and the lack of organic matter and bioactivity lead to a horizontal layering of the soil. During the cool season the rainfall infiltration is reduced and bare soil is exposed to erosion and run-off: the water is not stored in the soil and pollution problems occur (nutrient and pesticide leaching, mudslides and increase of flood risk). Other production problems occur during the growing season: drought risks with bad water storage during the winter and poor capillarity, and/or weak roots colonization in the soil profile.

Conversely, no tillage preserves the natural cover on the soil surface and the vertical organisation of the profile due to roots, earthworms and biological activity in general. Rainfall does not destroy the surface, better infiltration and the reduction of crusting, run-off and erosion is achieved. The soil is capable to store water quickly during the winter and to release it during growing season; soil particles, pesticides and nutrients remain on the field: the farmer saves inputs, avoids pollutions and reduces flood risks.

A five years trial in Brittany, France, since five years compares direct drilling (left), minimum tillage (middle) and ploughing (right):

The long term trial of the soil conservation service of Bern, Swiss, compares ploughing and direct drilling Conservation Agriculture since 12 years:

No tillage and pesticides uses

There is a strong link between no tillage and herbicides. In the 30's in USA, soils were ruined during the "dust bowl" due to intensive tillage; Nebraska's department of agriculture found that soils need a cover to prevent erosion: reduction of soil tillage, maintaining crop residues on the surface could preserve soils. The difficulty, however, was connected with weed management. In European countries inversion tillage was essentially used to control weeds and also to fertilise crops by activating the mineralization of organic matter: no tillage frequently led to weed Infestations.

In the 70's the launch of new herbicides, such as Paraquat and then Glyphosate, allowed chemical weed control without any tillage. The possibility of cleaning up the field simply with chemicals helped to overcome weed management problems and to increase quickly no-till and minimum tillage area in the world. At the same time the development of intensive agriculture in South America, and therefore ploughing, led to the quick destruction of arable land due to the hot and wet climate. Brazilian pioneers developed direct drilling on dead or alive vegetation. Those techniques were supported by chemical companies such as Monsanto, Syngenta, BASF and others.

Classical intensive farming systems and agronomy. With the development of modern farming systems, including development of crop genetic resources, machinery and agricultural chemicals, farmers don't need to apply basic agronomy anymore: tractors and tillage machineries ensure the top soil structure and seedbed preparation, fertilisers feed crops, pesticides manage weeds, diseases and pests. This type of farming, associated with specific cultivars, is very productive but strongly related to fossil fuels[8] and has a strong negative effect on environment and biodiversity.

If one basic element of those productive systems is removed, some problems could occur, such as lowering of the production level, weed and pest management difficulties… then farmers need to go back to agronomy to find a solution. That was happening when organic farmers decided to remove chemicals and industrial fertilisers: to succeed they needed to develop new rotations, use green manure, etc.

It's the same for farmers abandoning soil tillage: they are essentially confronted with weed infestation and have to find a solution. In a conventional way, they can decide to suppress weeds with chemicals tools (and today easily with GMO glyphosate resistant crops). In conventional systems, this solution leads to weed and pest resistances and farmers need to put more and more inputs in their system (chemicals, tillage, irrigation…), the costs are growing and systems are moving from economic and ecological sustainability. This can not be described as Conservation Agriculture but rather a case of no-tillage: chemistry replacing soil tillage.

[8] This is not a problem as long as energy is cheap.

No tillage in France (BVA enquiry for TPT, 1999):

Soil tillage	Percentage
Ploughing	54%
Ploughing and shallow cultivation	40%
Minimum tillage	4%
Direct drilling	2%

There is a misunderstanding in Europe between shallow cultivation and no tillage or minimum tillage: even if a lot of farmers stop ploughing for some winter crops in their crop succession, soil tillage is already intensive with the repetition of shallow cultivation. Moreover, they do not grow efficient covercrops or use appropriate rotation.

The real way to Conservation Agriculture is to replace soil tillage by agro-ecosystem management such as rotation and covercrop management. That is sustainable and profitable. In fact, the difference between conventional no tillage and Conservation Agriculture could be compared to the use of mouldboard plough: farmers use it in intensive systems and also in organic farming systems. No till is just a tool but a very powerful tool. However, the whole system (soil, ecosystem, farmer…) needs to progress at their own rhythm. Farmers who reduce soil tillage are discovering step by step their soils and ecosystems, with setbacks and successes, mastering techniques, developing covercrops and new rotations. This progressive improvement of their systems reduces gradually the necessity of tillage, chemicals or irrigation. No-tillage drives farmers to develop more their technical skills, acquire more agronomic and ecological knowledge and then to sustainability.

Conclusion

Due to the global situation, we need to develop high efficiency farming systems. Today, farmers have technical, agronomic and ecological tools to solve their problems (such as machinery, plants, rotation management, chemicals…). However, the solution will not come with the development of a specific tool but with the capacity of each farmer to organise those tools to fit their own system. Conservation Agriculture seems to be a sustainable way to succeed, provided farmers have access to the information and the knowledge.

Low-Input Farming Systems in Southern Europe: the role of grasslands for sustainable livestock production

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Abstract Due to physical and climatic constraints farming systems under rainfed Mediterranean conditions are usually extensive with a low use of pesticides, fertilizers, concentrates and irrigation. Many typologies of farming systems exist in Southern Europe, schematically it is possible to identify four main representative types with a decreasing incidence of natural forage resources: silvo-pastoral, agro-pastoral, cereal-based and fodder crop-based farming systems. Forage legumes can contribute to efficient low input and low cost production systems, especially annual pasture self-regenerating legumes. Under sub-optimal and variable environmental conditions, it is unlikely that single species will provide all of the required traits, where an improvement of the native sward is necessary, a focus towards pasture mixtures is appropriate. Farmers are more and more engaged in undertaking a series of functions related to the so called 'agriculture for services', aimed the production of non-food goods and environmental externalities. These can be summarised as follow: biodiversity, nature conservation and landscape, aesthetics and recreation, water and soil protection, CO_2-sequestration, and cultural heritage. Farming systems based on diversified forage resources and grazing represent a good perspective to meet sustainability and animal welfare principles.

Keywords: Mediterranean farming systems, sustainability, integration of feed resources, pasture legumes, multifunctionality.

Introduction In Mediterranean areas the climatic, physiographic, edaphic heterogeneity associated with a large variety of vegetation types and the effect of socio-cultural traditions have induced a complex mosaic of feed resources and their integration into land use. About half of the total world surface under Mediterranean climate is located in southern Europe and over 50% is represented by grasslands, rangelands and woodland surfaces. In the last decade several papers have been published concerning forage resources and grassland systems in the Mediterranean Basin (Papanastasis & Mansat, 1996; Porqueddu & Sulas, 1998; Hadjigeorgiou *et al.*, 2005). These papers, as well as many others, pointed out on the peculiarity of the environmental conditions and constraints, one of the most important of which is the concentration of rainfall during late autumn and early winter and its total absence during the hot summer season, associated to a very large intra- and inter-annual variability. These conditions determine a highly seasonal growth cycle that favours annual species and drought-resistant perennials. Forage production under rainfed conditions is limited usually ranging from 0.8 to 5.5 t of DM ha^{-1} $year^{-1}$.

Animal production systems in Mediterranean Europe are dominated by small ruminants and cattle belonging to local races which, with respect to dairy cows exploit better unfavourable areas and uplands under all year round open-air grazing. Due to physical and climatic constraints farming systems are usually extensive with a low use of pesticides, fertilizers, concentrates and irrigation and most of them could be considered a sort of low-input farming systems (LIFS). Despite the dramatic constant reduction of the shepherd number in the last thirty years, traditional extensive pastoral systems can still be found in southern Europe, especially on public lands, where short vertical transhumance is still present.

Grassland-base farming system typologies in Southern Europe Many factors affect the type of farming system in a region, thus many typologies exist, schematically it is possible to identify four main representative types of the farming systems existing in southern Europe with a decreasing incidence of natural resources.

i) Silvopastoral farming systems. This typology is based on the utilization of native forests by domestic animals by providing foliage (lower branches, basal resprouts, litter and fruits). It is a very common type in Mediterranean oak coppices grazed by sheep, cattle or goats. "Dehesa" in Spain and "Montado" in Portugal represent the most relevant examples of agro-silvopastoral systems that cover in total about seven million hectares in the Iberian peninsula. Such systems show the highest level of complexity because of the contemporary presence of pastures, crops, shrubs and/or trees often under mixed 'gerarchic' grazing (beef cattle, sheep, goats and pigs) and multiple products. Pastures are the main component of animal feed and annuals usually dominate with a low forage production and quality. Oak trees (*Quercus ilex* and *Q. suber*) contribute to the animal diet: acorns are reserved for pigs while leaves and fine branches for cattle (Olea & Viguera, 1999). Ruminants use native shrubs as a complement of herbage particularly in summer and winter. Most of the animal requirements are covered by the herbaceous-shrub-tree combined utilization. Another example is the "phrygana" in Greece, a typical formation of low, often spiny and open shrubland, that is managed by grazing and occasional fires.

ii) Agro-pastoral farming systems. These are widespread all over the hilly and mountainous Mediterranean regions. It is mainly based on natural and sown pasture utilization and in some cases a relatively small portion of the animal nutritive requirements are covered by annual forage crops. These are usually based on mixtures of cereals (barley, oats) grasses (Italian ryegrass) and annual legumes (vetch, crimson and berseem clover). One of the main limits of this system is the difficulty of matching the energy requirements of the flock with the available forage from the native pasture. The problem is still often resolved by short distance transhumance and by concentrates, cereal grains or/and hay supplementation. Sheep farming systems are prevalent but sometimes mixed livestock farms (sheep or goats and local races of cattle) are present.

iii) Cereal-based farming systems. Since ancient times Mediterranean livestock (sheep) is complementary to arable agriculture and a strong link exists between cultivated areas and pastures. Cereals are grazed or harvested depending on total farm forage availability. Animals consume the by-products of arable crops, stubbles and graze fallow land which is unsuitable for cultivation. The predominant crops in rainfed arable systems are winter cereals (wheat, barley and oats). Permanent grasslands represent a small portion of the total farm area; they are confined to marginal soils and they usually present low forage production and quality. Winter cereals due to their easy cultivation and multi-purpose exploitation (herbage, hay, grain and stubbles) maintain a key-role for the flexibility they give to the system. When cereal-based fodder crops are sown early in autumn, they can give high dry matter yield in winter reducing the use of expensive supplements.

iiii) Fodder crop-based farming systems. These specialised systems are located in areas suitable for cultivation (sown pastures, short term forage crops and meadows) a part of which is often irrigated. Dairy cow farming is prevalent with high stocking rates and agronomic inputs while the feeding system is based more on hay and silage than on grazing. Double cropping of Italian ryegrass followed by maize or sorghum for silage in rotation with alfalfa or white clover meadows is common.

According to Roggero *et al.* (1996), Mediterranean rearing systems can be regarded as sustainable when characterized by the following conditions: organization and planning of the local resources and their renewal; use of biodiversity and diversification of resources; integration of multiple uses; adaptation and development of security devices. In general, nutrient losses from extensive farming systems of southern Europe are low if compared to Central and North European countries. Large differences were found in a survey comparing different kind of farming systems in Italy, where the nitrogen surplus from intensive northern areas was up to 8 times higher than extensive Mediterranean areas (Argenti *et al.*, 1996; Caredda *et al.*, 1997; Grignani, 1996, Porqueddu, unpublished data).

Table 1 N-farm gate balance (kg ha^{-1} $year^{-1}$) in different Italian regions (n = no. farms).

	Po valley Dairy cow (n = 66)	**Tuscany** Dairy cow (n = 10)	**Sardinia*** Dairy sheep (n = 20)	**Sardinia**** Dairy sheep (n = 39)
Inputs				
Fertilizers	120	47	54	19
Supplements and hay	303	31	11	15
N-fixation	11	28	16	16
Total inputs	434	106	81	50
Total outputs	126	16	14	12
Surplus	308	90	68	38
output/input (%)	29	15	17	24

* cereal-based farming systems; ** agro-pastoral farming systems.

Moreover several other factors affect the environmental sustainability of Mediterranean low input farming systems. Inadequate machines were often utilised to clear the ground from stones, shrubby and woody vegetation cover irreversibly, removing the topsoil and leading to erosion and soil degradation. The cultivation of annual forage crops on slopes can significantly increase the risk of runoff and soil losses without a great advantage in terms of forage yield when compared to a good quality fertilised permanent pasture, as reported by Porqueddu *et al.* (2001). Fire is also a great problem in southern Europe when it is irrationally applied to remove shrubs and weeds from the pasture causing serious damage to the forests and increasing erosion risk. Unproper stocking rates or grazing management in relation to available forage resources can cause serious grassland deterioration particularly in the upland communal lands of the southern regions (e.g. Greece).

Another factor affecting Mediterranean LIFS in the last decades is the EU agricultural policy. The subsidy per ha or per reared head have played a great role in the choice of the crops, animal stocking rates and management. This tended in many cases to promote the maximization of subsidies income per farm (e.g. increasing the number of animals) in strong contrast with other aims, on which sustainability is based, and with negative cultural, social and environmental consequences. As reported in table 2, agro-pastoral farming systems strongly depend on public subsidies, but recently aspects linked with their environmental role and animal welfare are considered (i.e. South France).

Table 2 Income, subsidies and total income per sheep (€) and subsidies/income ratio in representative farming systems of 8 Mediterranean pastoral regions (data modified from PASTOMED PROJECT unpublished data).

	Languedoc Roussillon	Alentejo	Provence Cote d'Azur	Andalusia	Entre Douro Minho	Abruzzi	Epiro	Sardegna
income/sheep	70	40	69	67	248	174	178	132
subsidies/sheep	84	50	71	32	101	63	60	40
tot income/sheep	154	90	140	99	349	237	238	172
subsidies/income (%)	55	55	51	32	29	27	25	23

Forage legumes to improve sustainability in Mediterranean Europe There is a general consensus on the unsustainability of external input oriented farming and that knowledge and management skills can replace off-farm inputs. Mitigation strategies rather than overcoming seasonality in dry Mediterranean regions should fit into the trends on sustainability, reducing production costs e.g. for fodder conservation, environmental quality and animal welfare. The ways to reduce the impact of seasonal pasture growth were analysed recently by Porqueddu *et al.* (2005) that grouped the interventions in 3 main areas i) changing how pastures grow, ii) changing how pastures are utilised and iii) animal management. A key objective is to extend the grazing season implementing the new concept of nutrition of grazing ruminant based on behavioural variables as 'animal preference' (Provenza *et al.*, 2007) that complement classical nutritional variables (i.e. requirements & feed nutritive value).

Forage legumes can contribute to efficient low input and low cost production systems through N_2 fixation by bacteria in root nodules reducing the need for inorganic fertilizers, and high nutritional quality of forage reducing the need for concentrate feeds (Porqueddu, 2001; Sulas, 2005). When a natural seed bank of pasture legumes is present, a correct utilization and small amount of P-fertilisation without overseeding may be sufficient to obtain satisfactory agronomic results and often agronomically more reliable than the introduction of selected uniform varieties. Within legumes, annual pasture self-regenerating legumes show the adaptive advantage of having an annual cycle combined with a "seed escape" habit. Complex biological and ecological mechanisms involving seed yield and soil seed bank dynamic allow long-term regeneration of perennial-like stands. In presence of low quality pastures, annual self-regenerating legumes are the base for the improvement in agro-silvopastoral and agropastoral systems and for organic farming. While in cereal-based systems they can be utilised to replace fallows. Annual self-reseeding legumes were introduced in other Mediterranean-type areas, and they are the key component of the ley farming system that is based on cereal/pasture legume rotations, supporting wheat/wool industry in Australia. Especially subterranean clovers are utilised in rotations with 2 years pasture and 1 year cereal (thanks to the perfect adaptation to grazing due to their prostrate habit, and ability to bury the seed heads in the soil), while annual medics are utilised in 1:1 rotations (thanks to a high seed production and hardseededness level). These species were re-introduced in Mediterranean basin and seed market for annual pasture legumes became heavily reliant on Australian selections. However, the commercial varieties imported from Australia sometimes proved unsuitable for pasture improvement in southern Europe mainly due to the different climatic conditions and management systems. These reasons have stimulated different European research institutes to carry out selection programmes aimed at the valorisation of local germplasm. In France, Spain, Italy and Portugal varieties of subterranean clover and *Medicago polymorpha* L. were selected. Unfortunately, despite these new varieties proving to be superior than Australian ones, the lack of a European seed multiplication has not allowed their diffusion except for a few Italian varieties of subclovers multiplied in Australia. Recently new species of a second generation of annual pasture legumes were selected and are now commercially available and have been rapidly adopted in Australia (Loi *et al*., 2005). These species have different traits e.g. a deeper root systems. For example, Gloag *et al.* (2004) found that *T. vesiculosum* extended the growing season by 3-4 weeks, had higher digestibility than *T. subterraneum* in late spring, and could increase lamb live weights in late spring by more than 10%.

Beside annual self-reseeding legumes there are some bi-annual and perennial legumes that are very important to improve amino-acid absorption, to lower N excretion and emission of N and CH_4 in the atmosphere and to improve resilience to gastro-intestinal parasites thanks to their moderate level of condensed tannins. For example, *Hedysarum coronarium* (sulla) has recently re-gained interest also for its flexible utilisation. In dairy-sheep forage systems, using two varieties with different growth patterns allows grazing in early autumn and late spring. Sulas *et al.*, (1997) suggest mixed sward management entailing winter grazing and hay or silage making during spring for the first year, and year-round grazing in the second year.

Under sub-optimal and variable environmental conditions, such as in many pastoral farming systems of the Mediterranean basin, the maintenance of high level of inter and intra-specific diversity is essential to achieve satisfactory and persistent pasture swards. Because it is unlikely that single species will provide all of the required traits, where an improvement of the native sward is necessary, a focus towards pasture mixtures is appropriate (Dear and Roggero, 2003). Traditionally, pasture seed mixtures available in southern Europe consisted of a small number of legume species or 4-5 subclover varieties mainly differing in earliness, and sometimes including low rates of annual grasses. In some cases e.g. pasture improvement in areas with higher rainfall, perennial grasses, are utilised in the mixtures. Nowadays, it is common to find in the seed market complex grass-legume mixtures including up to 20 species, mainly annual self-regenerating legumes. Moreover, little experimentation and information is available on the effect of grazing on the persistence and environmental impact of mixed-legume swards (Rochon *et al.*, 2004). These aspects are nowadays studied in the LEGGRAZE UE (2002) project and COST action 852 (2002). The latter is a multi-location and multi-disciplinary project that is being carried out in more than 30 European sites. Encouraging results have been obtained in Sardinia under Mediterranean dry conditions evaluating 4-species mixtures belonging to different functional types as grass/legume and fast-annual/slow-perennial establishing species (*L. rigidum*, *D. glomerata*, *M. polymorpha* and *M. sativa*) in different proportions (1.0, 0.7, 0.4, 0.25, 0.1). Compared with pure stands, grass-legume mixtures provided higher yields with better seasonal distribution and decreased unsown species presence (Porqueddu and Maltoni, 2005).

The existing genetic diversity of Mediterranean grasslands is far from being fully exploited for agricultural and environmental uses. Summer dormant perennial grasses are needed to replace annual forage crops and winter cereals into Mediterranean farming systems, this is one of the topics covered by EU-PERMED project (2005). Permanent pasture based on well adapted perennial grasses are very important to prevent soil erosion, especially on slope areas.

Low-input farming systems for quality food and multi-functions There is a very favourable image of grassland-based food production with opportunities for adding value by exploiting positive health characteristics in animal products. The results of several trials show that less intensive production schemes based on pasture or grass feeding have marked positive direct effects (e.g. high carotene content improves milk, butter and cheese colour) and indirect effects (e.g. the concentration of proteolytic enzyme influences cheese maturation and texture) on several traits on animal products (Coulon and Priolo, 2002). It would be possible to reach higher added value if commercial specifications were linked to a grassland-based territory and if the intellectual property was well protected, e.g. Protected Denominations of Origin and Protected Geographic Indications. Flavonoids and phenolic acids are known for their influence on the taste and preservation of many human foods and to improve consumer's health. High levels of flavonoids are present in natural pastures and this may positively influence milk quality. Milk fatty acid (FA) composition affects the nutritional properties of dairy products. Some polyunsatured FA as conjugated linoleic acid (CLA) and a low ratio of omega-6:omega-3 have a potential anti-teratogenic or anti-carcinogenic role. Stene *et al.* (2002) have shown that the ratio ω-6:ω-3 FA became double in cow milk from increasing daily concentrate levels as well as moving from spring grazing to autumn indoor feeding. While Addis *et al.* (2005) found that including a native pasture species (*Chrysanthemum coronarium* L.) containing high concentration of polyunsatured FA in the diet of dairy ewes increased CLA values in milk and cheese. There is a need to study the whole set of methods with a multidisciplinary approach in order to find the gaps in scientific knowledge able to support strategic choices for valorising regional specialities and niche markets.

Moreover, it is becoming widely accepted that agriculture is just one of several rural landuse functions. Farmers have already been recognised, and in some case compensated, for their role of guardians of the environment. Therefore they are more and more engaged in undertaking a series of functions related to the so called 'agriculture for services', aimed the production of non-food goods and environmental externalities. These can be summarised as follow:

Biodiversity. Within the European Union, concerns about biodiversity have already led to deliberate attempts to develop less intensive sward management systems that achieve aesthetic, amenity and other outcomes. Grazing is very important for maintaining a high number species in the sward (Papanastasis, 1998). If biodiversity is to be achieved as a result of extensification, it must be a specific and integrated objective, as extreme forms of extensification may lead to loss of biodiversity. The number of species, and especially of legumes, increase in organic grasslands, but it seems more difficult to increase the presence of protected, rare or endangered species. However, it is possible to observe little or no differences in plant diversity between organic and extensively managed conventional grasslands. Botanical diversity of grasslands may, however, provide other nutritional and medicinal advantages for livestock through high concentrations of minerals, alkaloids and trace elements (Hopkins and Pinto, 1998).

Nature conservation and landscape. Many of the most valued landscapes and rare habitats of Europe are the product of low intensive livestock production systems. In thousands of years very strong relationships were established between animals and grass- or rangelands under traditional extensive farming systems (e.g. Mediterranean agro-silvo-pastoral systems). The preservation of the traditional landscape, its quality and the large-scale equilibrium at the territorial level are of great importance. From a structural point of view, the landscape is a dynamic puzzle made by different inter related elements, characterised by flows of matter, energy and organisms, resulting from the site-specific human activities. Among various landscape elements the ratio of grasslands, both natural and uncultivated areas, are a fundamental part of people gratification.
Moreover, low input farming systems based on permanent pastures and rangelands close to woody areas and firebreaks management trough oversowing and grazing reduce wildfire risk in Mediterranean regions (Etienne, 1996; Caredda *et al*, 2002).

Aesthetics and recreation. Grassland-base farming systems, are highly attractive for informal recreation activities such as picnicking and rambling. Land use diversification contributes to biodiversity and favours the integration of pastoral farming within the whole national economies. From this point of view the existence of a variety of vegetation types favours the Mediterranean Basin countries compared to other areas of Europe. Agro-tourism, eco-tourism and hunting activity are strictly linked with grassland-based farming systems. Several Mediterranean mountainous areas, most summer pastures, are crossed by signalled pathways and some are utilised as ski-lanes during winter.

Water and soil protection. Soil under grassland is physically stable and coherent. The permanent crop cover decreases the risk of surface losses while high earthworm activity and the continuity of coarse porosity has hydrological benefits, enhancing infiltration. Organic matter contents in grassland soils are higher than in comparable soils of arable fields. Soil aggregate stability under permanent grassland tends to be high, especially with moderate use of organic fertiliser. Grasslands can be considered as a prevention system against natural disasters, particularly in uplands. A number of comparative studies have shown that the N surplus, and hence the potential for nitrate leaching, is lower in legume-based systems, than in intensively fertilised grassland. As know from field and lysimeter trials, leaching losses under permanent extensive grasslands are low and groundwater quality is therefore high (Porqueddu et al., 199). Promising results were also obtained by using perennial and annual self-reseeding species as green manure, living mulch and cover crops on arable land (Nieddu *et al.*, 2000).

CO_2-sequestration. The large amount of land covered by grasslands as well as its relatively unexplored potential for carbon (C) storage has increased interest in relation to the greenhouse effect. To stop CO_2 concentration rise in the atmosphere, countries are actively seeking ways to increase the carbon (C) storage capacity of land. Although it is difficult to give an accurate estimate of the total amount of C stored by grasslands, mainly related to the estimated area of grasslands in the world, their fundamental role is clear. Grasslands store approximately 34% of the global stock of carbon in terrestrial ecosystems (most of it in the soil rather than in the vegetation) while forests store approximately 39% and agroecosystems approximately 17% (WRS, 2002). Compared with forests, oxygen production from agricultural land is higher, due to the use of usually more productive sites and their better management.

Cultural heritage. The existing extensive grassland-based farming systems in Southern Europe are the end product of complex socio-cultural processes, linked with local history and tradition. Even biodiversity has been predominantly considered as a biological concept, although it is possible to link it with cultural and social diversity. Pastures have gained a renewed importance due to the diversities of knowledge, languages and traditions of pastoral people that have been recognised as part of the general diversity. In Mediterranean areas the long and short transhumance, in its specific role, was the traditional response to unpredictable pasture productivity in time and space. Nowadays transhumance is seen as a relic of the past, but in many mountainous and hilly areas of Europe traditional short transhumance for summer alpine pasture utilisation has survived and seems a reasonable land management tool. These historic management systems have an important role in the utilisation of marginal resources and the maintenance of rural populations in unfavoured areas. Public support and valorisation of this kind of low input farming systems located on upland, in relation to typical mountain breeds of sheep and cows that give each mountain product (e.g. milk, cheese) their own character and label, would provide the best protection for these old farming systems. All these traditional systems contribute tremendously to food security, agricultural biodiversity and the world's natural and cultural heritage.

Conclusions The recent changes in the European agricultural policy aimed at greatly encouraging low-input oriented agriculture represent a new challenge for Mediterranean agriculture. Mediterranean farming systems based on the integration of grasslands and other forage resources represent a really good perspective for the general expectations placed on agriculture for quality and for reducing the impact on the environment. This entails the development of more complex farming systems, in fact the management of several combined forage sources implies the organization in time and space both of crops and animals. There is great scope to develop flexible farming systems in which crops (cereals, annual forage crops) and legume-based pastures are adequately balanced in order to lower the production costs, maintain output levels and decrease environmental impacts. Moreover, there are high research needs on the complex interactions between livestock, grasslands and environment in Mediterranean regions under rainfed conditions. The preservation and modernization of the traditional Mediterranean LIFS based on the utilization of diversified natural forage resources, also through the valorization of the products (i.e. organic farming systems, quality of products, PDO, etc.) seems important.

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Development of organic farming in Europe and sustainability

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Introduction The big challenge for agriculture is how to translate the scientific concept of sustainable production into practical farming.

Different approaches are known with different degrees of complexity:

- Improved technologies like minimum/ no tillage;
- Integrated Production (IP, IPM);
- Low External Input Sustainable Agriculture (LEISA);
- Organic Farming.

Organic farming is the system with the highest complexity of measures. The system approach of organic agriculture, which is now also, reflected in the new Council regulation EC/834/, which will replace the current Regulation (EEC) 2092/92 from the year 2009 on.

What is organic agriculture? The principle aims of organic agriculture, as outlined in the new Council Regulation EC/834/2007 from June 2007 are very broad and do include:

- production of food of high quality;
- enhancement of health (soil, plants, animals, humans)
- high animal welfare;
- respect of nature's systems and cycles;
- responsible use of energy and the natural resources;
- appropriate design and management of biological processes;
- avoidance of synthetic pesticides and highly soluble mineral fertilisers;
- high level of biological diversity.

The International Federation of Organic Agriculture movements (IFOAM) characterized organic agriculture with four over-arching principles: the principle of health, the principle of ecology, the principle of care and precaution and the principle of fairness (IFOAM 2005).

Organic agriculture is, in contrast to other farming systems, regulated at European level with the above mentioned regulations. This regulatory framework is relevant for all organic farms in Europe and farms, which want to import to Europe. Organic farming is also ruled on international level with the Codex Alimentarius Guidelines for organically produced food, a common program of the two UN-organisations WHO and FAO, which give guidance for governments. Furthermore, the private sector has been regulated by the Basic Standards of IFOAM since 1980, international standards which are applied in more than 100 countries by 600 organisations.

On national level there are in several countries governmental regulations. In addition there are many private labels with their own standards, which in some areas have additional requirements to the Regulation (EEC) 2092/91 (Schmid et al. 2007). Most of these differences are related to country-specific issues, such as consumer perception, state of development of organic farming or national legislations. A recent study made in the EU funded project EEC 2092/91 (Organic) Revision project showed that the requirements of the current as well as the new Council regulation for organic production are on a relative high level and are in most areas equivalent to the Codex Guidelines for organically produced food and the IFOAM Basic standards (Schmid et al. 2007).

Development of organic farming in Europe Organic farming in Europe has developed strongly in last decade (Willer & Yussefi, 2007). More than 6.9 million ha are farmed organically, of which 6.3 million in the EU representing 4 % of the total agricultural land area.

In Figure 1 the growth from 1985 to 2005 is visualised by area as well as by number of farms.

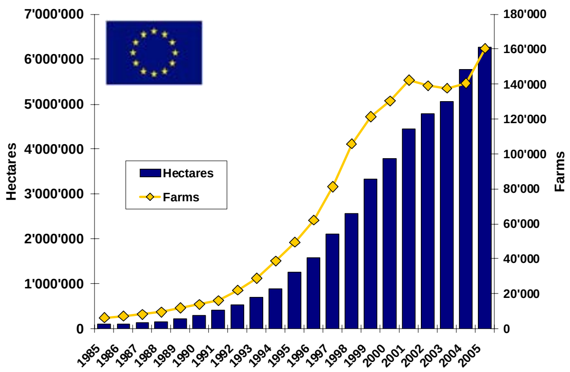

Figure 1 Development of organic farming in the European Union 1985-2005

In Figure 2 the distribution of organic farms in Europe is shown for 2005.

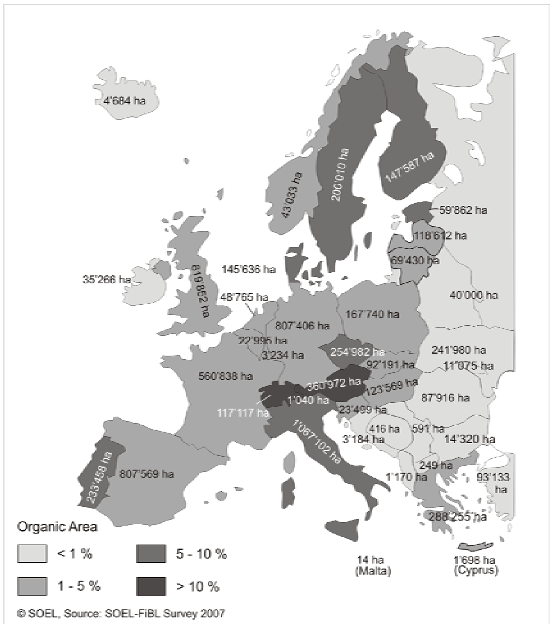

Figure 2 Area of organically cultivated land in Europe

Due to the fact that in many countries large retail chains with supermarkets sell significant amounts of organic products, also the sales of organic products have grown (Fig. 3).

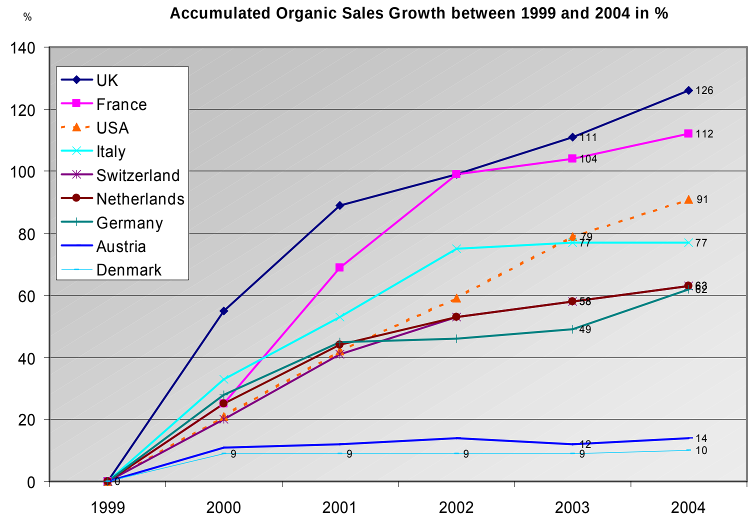

Figure 3. Organic Market Growth in selected countries in Europe and in the USA

Factors driving organic markets are different from country to country. The most important ones are activities of strong market actors who want to develop a sustainable profile, the fact how focussed national policy support measures are (only organic farming or both organic and integrated farming), the degree of competition between organic and low input labels and the susceptibility of consumers for ecological and animal welfare questions. (Willer and Yussefi 2007) .

What does organic crop production mean? Organic crop production is characterised by prevention and recycling.

In plant protection and weed control this means:

- no synthetic pesticides and growth regulators, no GMO;
- prevention (varieties), habitat management, and promotion of beneficials;
- careful soil management, soil coverage;
- non-chemical weed control; mechanical and thermal, no herbicides;
- much less active ingredients than in conventional farming;
- application of highly specific pesticides like microbial pesticides (Bacillus thuringiensis, fungus or virus).

The fertilization and rotation in organic farming is mainly based on:

- no use of highly soluble fertilisers (e.g. nitrate, ammonium);
- wide rotations with 6-8 crops with grass-clover/alfa alfa and green manures, other legumes;
- limited animal stocking density (+/- closed nutrient cycles);
- Plant nutrition with organic fertilisers and specially applied and treated farmyard manure/slurry

As a consequence, the stability of agro-ecosystems are crucial and the management focuses on preventive measures.

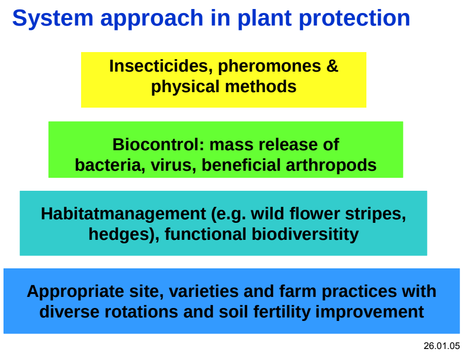

Figure 4 System approach in plant protection in organic farming

Effects of farming systems on weed flora and on fauna diversity Numerous studies have been done comparing different farming systems on the diversity of the weed flora and fauna and most recent studies have analysed effects of diversity on agricultural functions like pest and disease control. Frieben (1997) and Köpke (1999) found 40 to 300 % more weed species in organic cereal and root crops in 15 studies from different site in Central Europe when comparing them to adjacent conventional plots or fields (Fig. 5).

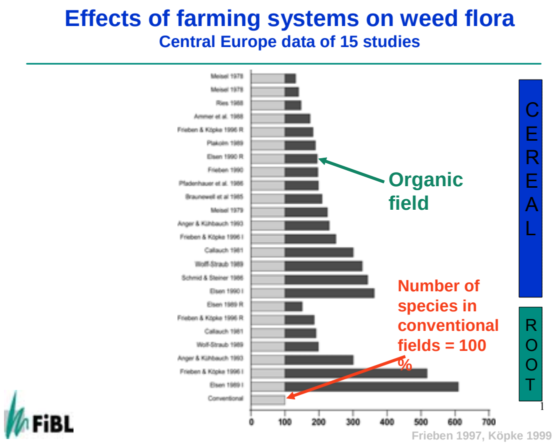

Figure 5 Effects of farming systems on weed flora

A meta-analysis of 76 field studies on flora and fauna in Europe and the USA showed a significant higher number of individuals as well as species, such as earthworms, carabids, spiders and birds when organically managed (Hole 2005) as shown in Tab. 1.

Table 1 Meta-analysis on effects of organic and conventional farming on invertebrates and birds (Hole et al. 2005)

Taxa	Organic better	No difference	Conventional better
Plants	13	2	
Birds	7	2	
Mammals	2		
Earthworms	7	4	2
Arthropods			
• Carabides and staphylinides[1)]	13	3	5
• Spiders	7	3	
• Butterflies	1	1	
• Other arthropods[2)]	7	2	1
Soil microbes[3)]	9	8	
Total	**66**	**25**	**8**

[1)] Carabides, dung beetles& staphylinidae[2)] Mites, bugs, centipedes, flies & wasps [3)] Bacteries, fungus & nematodes

The ban of herbicides and the lower plant density in organic fields are the two major factors increasing the diversity of flora and fauna (Hole et al. 2005, Pfiffner, 2001). Additional techniques are known to enhance the ecological quality of farms, especially wildflower strips, unsprayed field boundaries and rotational diversity and diversified set-aside surfaces. Farmers often question the benefits or risks of such elements. Multi-annual field trials in an intensive vegetable growing area in Switzerland investigating into the impact of wildflower strips showed a higher parasitism rate of eggs of the cabbage fly (*Mammestra brassicae)* in white cabbage, an effect which was relevant over a distance of 20 meters (Pfiffner et al. 2003). The botanical composition, the local design of the strips, the type of crops and pests, the micro-climatic conditions (wind, humidity, etc.) and other site-specific conditions have to be adapted; but the application in practise has shown to have a great potential.

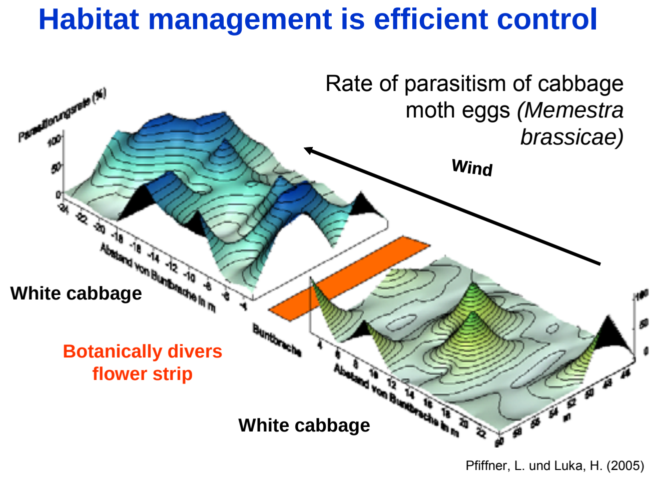

Figure 6 Wildflower strips and parasitism of cabbage moth eggs

Steiner (2006) analysed the typical setting of ecological compensation areas on 300 integrated and 140 organic farms in the Canton Zürich. These agriculturally unproductive areas are state subsidised in order to enhance the overall biodiversity and the quality of the landscape. The investigation showed that such elements were rare and very segregated on integrated farms, whereas on organic and biodynamic farms the number and the surface of these elements was higher and much better linked with each other in order to build corridors for wild animals and to enhance the landscape quality.

It can be concluded that the combination of habitat management with organic farming offers optimal ecological benefits as they have synergistic impacts. Organic farming secures a high basic faunal and floral diversity on the big surfaces with an excellent food supply for many insects and animals. Non-crop habitats on the other hand are essential for survival of natural enemies (over wintering, refugees) and help to make indirect pest control more effective (Pfiffner and Luka 2000).

System approach in organic livestock production In the current Regulation (EEC) 2092/91 for organic agriculture the system approach is outlined very well for securing animal health. It shows that on a long-term perspective animal breeding is important, in a medium-term prevention on animal herd-level and in short term the use of complementary medicine (e.g. homeopathy, phytotherapy, etc.). As shown in Figure 7 only in emergency cases the current allelopathic medicines can be used in combination with stricter marketing restrictions (at least double withholding period). This approach is also integrated in the new Council regulation EC/834/2007. A holistic approach in animal husbandry must therefore always look at the different levels and their interactions (Sundrum 2006) as shown in Figure 8.

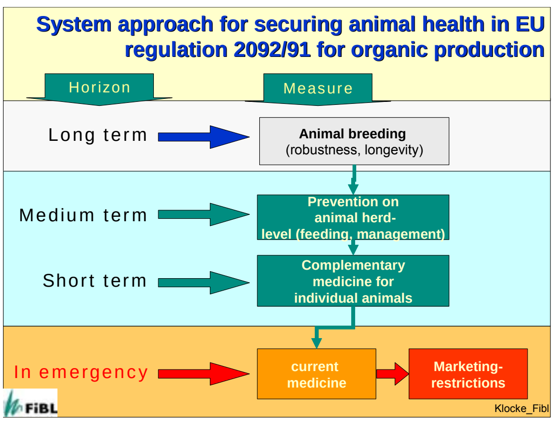

Figure 7 System approach for securing animal health

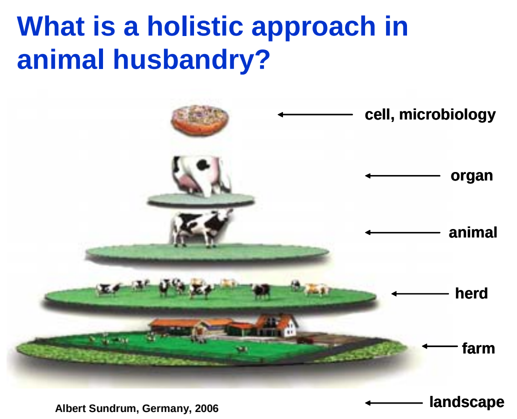

Figure 8 Holistic approach in animal husbandry

How sustainable is organic farming? The added value of organic farming for citizens and for consumers can be weighted by the process quality, especially the ecological, social and economic sustainability and by the quality of the final product, the "product quality".

The sustainability of organic, biodynamic, integrated and conventional farming systems has been the focus of a field trial with a 7 year arable crop rotation running in Switzerland since 1978 (DOK field trial in Therwil, Maeder et al. 2002). Figure 9 shows that the efficiency of the resource use from 1978 until 2001 in this trial was much better in the organic system in particular when looking at the nitrogen and fossil fuel use. With 34 % of nitrogen and only 60 % of energy the average yields over the whole period was only 19 % lower in the organic systems but the soil biomass reached 167 % of the conventional system. This shows that the focus should be not just to look at one crop but to look at the whole rotation to judge the efficiency of a system.

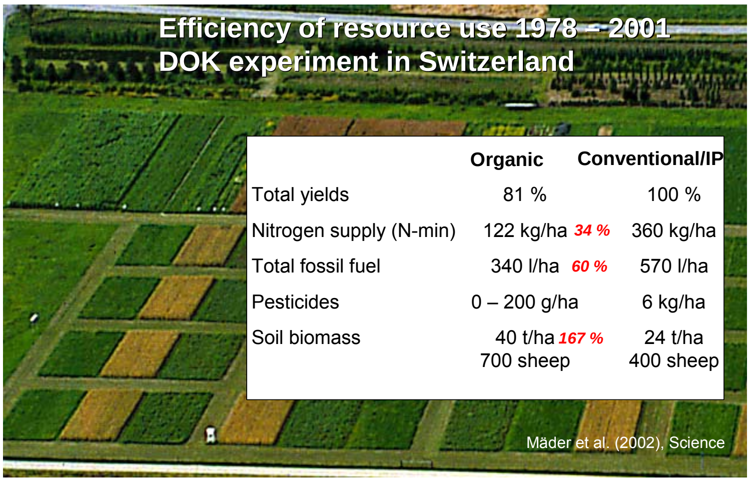

Figure 9 Efficiency of the resource use 1978-2001 in the DOC experiment in Switzerland

Of the many parameters analysed in the DOK field trial, different biological and physical properties of the soils were positively influenced by organic and biodynamic management, especially soil aggregate stability, water percolation stability, organic matter content, earthworm activity and biomass, microbial activity and biomass as well as mycorrhiza colonialization. (Maeder et al 2002):

Regarding the impact of organic farming to climate change, first investigations have started (Aubert 2007), which show that for many areas, but not all, organic agriculture has potential mitigating effects, which certainly have to be researched more (see Table 2).

Table 2 Climate Change: potential mitigating effects of Organic Agriculture (Aubert 2007)

Mitigating effects of OA (compared with CA)	CO_2	CH_4	N_20
Crop production	●		●
No synthetic nitrogen fertilizers	●		●
Best manure recycling livestock -> crops	●		●
Enhanced use of legumes	●		●
Enhanced use of composts	●		●
Best crop rotations	●		
High proportion of hedge rows, field margins etc.	●		●
Careful and reduced soil tillage	●		●
Reduced mineral N concentrations	●		●
Less soil compaction, more stabile aggregates	●	●	●
Less erosion	●		
Soil Carbon stock enhanced	●	●	
Livestock			
Livestock density per area		●	●
Feeding rations (roughage/concentrates)	●	●	
Longevity of dairy cows		●	●

Regarding nitrate leaching in the groundwater a number of several comparison studies show, that organic farming is contributing significantly to the reduction of nitrates losses, which is particular relevant for water protection areas.

Table 3: Reduction of nitrate leaching by organic farming – a literature survey (Stolze et al. 2000)

Reduction by Organic farming	Authors
> 50 %	Smilde (1989)
> 50 %	Vereijken (1990)
57 %	Paffrath (1993)
40 % (Sand) / 0 % (clay)	Blume et al. (1993)
50 %	Reitmayr (1995)
40 %	Berg et al. (1997)
64 %	Haas (1997)

Weaknesses of organic agriculture

Life cycle assessment studies show existing deficiency of organic production technique (see also the paper of Thomas Nemecek). Cormack (2000) showed that in most areas the energy use in organic farming is better, but there also exceptions such as potatoes and tomatoes (mainly due to much lower yields due to not appropriate varieties and disease problems such as late blight), in particular when calculating on a output per ton. These problems have to be solved by future research activities, especially by breeding programs which focus on robustness or resistence towards diseases and pest as well as nutrients uptake from organically fertilized soils and low input conditions.

The energy efficiency of more-animal friendly husbandry systems for egg and poultry production is due to the much higher land use for the outdoor access higher but on the other hand is a desirable and recognized contribution to animal welfare.

Table 4 Energy use of organic farming in crop and livestock production – selected cases (Cormack, 2000)

Crops: Wheat: 29 % less energy use/tonne
- Leeks: 58 % less
- Carrots: 25 % less
- Potatoes: 2 % more (very much depending on yields)
- Tomatoes: 30 % more

Livestock:
- Milk/Beef: 38/35 % less
- Pig meat: 13 % less
- Eggs: 14 % more (outdoor access)
- Chicken: 32 % more (outdoor access)

The quality of organic foods

A lot of field studies and point of sale investigations compared the quality of organic and non-organic foods. These studies have been summarised by several meta-studies (Wooese et al., 1995; Worthington, 1998, Alföldi et al., 1998; Heaton, 2001; Tauscher et al., 2003, summarised in Alfoeldi, 2006). In a number of parameters there are significant analytical differences and some of these are relevant responses to consumer expectations, e.g. better taste and shelf life, lower levels of undesirable substances like nitrates, pesticide residues and mycotoxines or higher levels of nutritionally valuable compounds like plant secondary metabolites, fat soluble vitamins and multisaturated fatty acids like CLA and Omega 3.

Socio-economic performance of organic farming
A comparative study of Nieberg (2004) in eight European countries revealed that organic farms had the same or an even slightly higher economic profitability than non-organic farms.

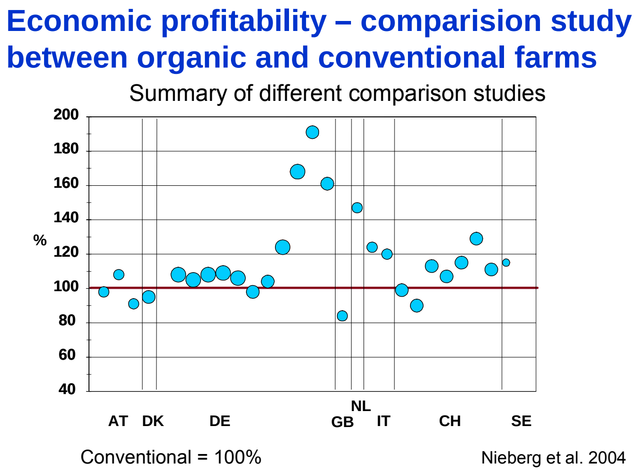

Figure 10 Economic profitability of organic farms (Nieberg 2004)

The economic performance of organic farming cannot be discussed without considering the external costs of conventional agriculture. Pretty et al. (2000) calculated that the annual cost externalised by UK agriculture amounted at 3374 million € or 89 % of the total agriculture income. These costs of negative impacts on the environment, loss of biodiversity, problems of public health, unsustainable use of natural resources etc. made out 300 € per hectare arable and grassland. Pesticide applications of agriculture for instant cost our society 48 € per hectare (registration procedures, maintenance of drink water quality, state monitoring systems, health problems).
It can be questioned if organic products would not be cheaper than non-organic products if all external costs would be internalised.

Organic farming as a multi-targeted approach to sustainability For policy makers it is important to recognize that organic farming is a multi-targeted approach to food production. This can be supported by one measure and by one control system and does not need a complicated system of support measures with complicated administration.
In Figure 11 our research institute has made a comparison of the state of the art of the current organic farming and its potential improvement by setting a best practise bench-mark based on expert judgements. In addition a comparison is made with a no-till system.

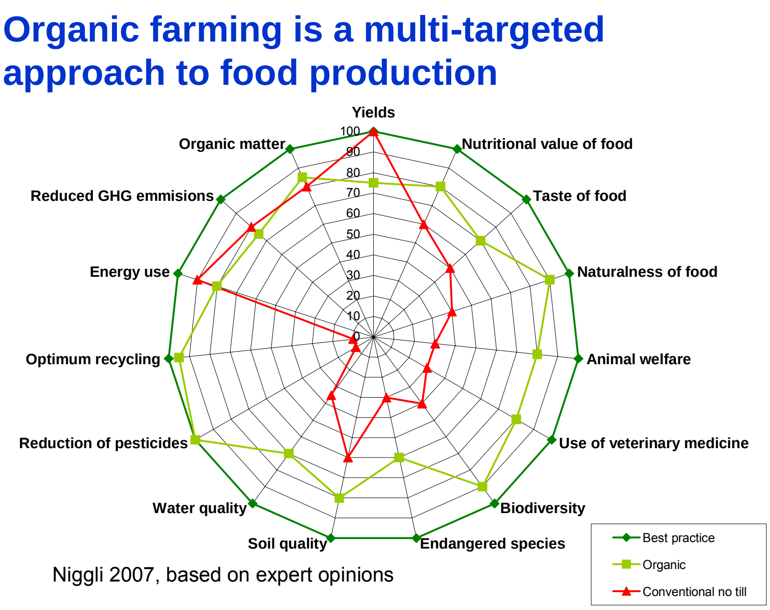

Figure 11 Organic farming as multi-targeted approach to sustainable food production

Future challenges of organic agriculture with regard to sustainability There is enough scientific evidence that organic agriculture greatly contributes to conserve and maintain natural resources and public goods such as soil, water, air, biodiversity etc. In addition, it can significantly reduce external costs of agriculture and it responds well to a fast growing number of consumers.

However, there are still some deficits in organic farming which should be solved by research projects and intensified knowledge transfer:

- preservation of rare species, landscape;
- wild animal friendly production;
- parasites and zoonoses in animal production;
- emissions of farmyard manure in the air (improved manure management);
- energy use and use of renewable resources;
- economic sustainability (improved yields).

In the European Action plan for organic food and farming (EC, 2004) the pathways of further R&D activities are well defined. Unfortunately, these priorities are not yet reflected in the on-going work programs of the 7th Framework. The most important R&D areas are:

- High-animal welfare husbandry and feeding,
- Veterinary medicine (biocontrol of parasites, complementary medicine, fodder crops with bioactive compounds against parasites)
- in biological plant protection (more resistant varieties, adapted prognosis systems, more efficient use of mineral and plant-based protection agents (EU research projects Blight-Mop, REPCO, ISAFRUIT) ,
- in careful processing technologies (smart technologies and functional ingredients instead of additives)
- and mainly in better adapted for *low-input* conditions plant and animal breeding (e.g. better ecotypes adapted to organic farming with improved quality parameters, resistance and nutrient absorption efficiency and better competition against weeds).

It is important to strengthen both basic and applied research focussing on interdisciplinary and participative projects where the agro-ecosystem approach of organic farming is underlined.

Conclusions There is still a huge gap between the scientific concepts of sustainability, the awareness of policy makers concerning which actions should be prioritised and the desultory implementation into real food and farming practice. These gaps can only be overcome by production schemes which are relatively easy to learn and easy to control, and this is exactly what organic farming is about. Unfortunately, the full potential of organic farming has not yet been exploited, mainly due to a still insufficient research support. Low (external) input farming and organic farming should cooperate on key areas such as breeding or improved preventive strategies. Sustainability and high productivity must not be a contradiction. There is a need of an ecological intensification with a low external input approach!

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Plant breeding and low input agriculture

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Keywords: Sustainable agriculture, domestication, selection, GxE interactions, genomics

Summary Agriculture is an history of a real symbiosis which developed between crops and man; crops have made it possible to sustain an ever increasing human population. During the nineteenth century a real revolution occurred in agricultural systems, characterized by sharp and significant increases in crop yields and thus in food supply. However, it has been estimated that the global human population will rise substantially in the next 40-50 years. To limit the disruption of natural habitats and the processes of desertification and land degradation, the increases in agricultural production will need to be derived mainly from increases in the productivity of agricultural systems. Increasing crop productivity by increasing agronomic inputs appears not to be feasible in developed countries because given the actual levels of inputs used in most of our agricultural systems, no additional yield return could be obtained. In this context, over the next few decades we will be facing a major challenge: to increase the productivity of agriculture systems in terms of goods and services, while reducing its environmental costs. This idea is the basis of the concept of sustainable agriculture. Sustainable agriculture differs from conventional agriculture in that it aims to maximise our dependence on naturally occurring biological systems. Such systems are less important in conventional agriculture, which is highly dependent on synthetic external inputs, tillage and irrigation. A major consequence of the differences between sustainable and conventional agriculture is that the varieties of plants best suited to the two approaches can be significantly different. As a consequence, breeding strategies that can address these new production circumstances are needed, which means breeding practices that can sustainably enhance agricultural productivity and profitability, while simultaneously addressing food security and biodiversity conservation challenges. On the basis of these considerations, plant breeding for sustainable agriculture has to be implemented considering the following main points: crop and agro-ecosystem diversity, selection environments and genotype x environment interactions, target traits, genomics-assisted breeding and biotechnology, socio-economic context.

Introduction The history of agriculture is strongly connected to conscious and non-conscious plant breeding, as its origins correspond to plant and animal domestication, which consisted of a selection process for the adaptation to cultivation of many plant species and for the herding of animals. An emblematic example is given by one of the major traits selected during the domestication of wheat and barley. In wild cereals at maturity, kernel dispersal is due the disarticulation of the spike (fragile rachis). This is a crucial trait in natural habitats, and indeed wild plants maximise their fitness by promoting the space dispersal of their seeds. In contrast, domesticated cereals have a tough rachis, which means that the plant is unable to disperse its seeds, facilitating kernel harvesting directly from the plant. Due to the selection process that operates during domestication, crop plants have acquired sets of new characteristics that have secured their adaptation to cultivated environments and have increased their usefulness to farmers and consumers. An examination of the wide diversity of crops shows a recurring pattern, involving a set of concurrent traits – the domestication syndrome – that distinguish domesticated crops from their wild progenitors. For instance, similar traits in most seed crop species have been selected during domestication, with major examples being an absence of or reduced seed dispersal, a lack of seed dormancy (over-time dispersal), compact growth, and a large seed size (Gepts and Papa 2002).

A real symbiosis has developed between crops and man: crops have made it possible to sustain an ever increasing human population, while on the other hand, man has developed particular agro-ecosystems where crops are defended from weed competition and helped in their propagation processes through the use of external factors, such as, for example, ploughing, irrigation and fertilization.

Three different steps can be highlighted in the development of crops:

1. domestication;
2. progressive introduction of the domesticated forms into different environments and the consequent adaptation processes that have been driven by natural forces and helped by man, with the production of the so called agro-ecosystems;
3. modern plant breeding and the increases in yields made possible by synergistic actions between modern plant varieties and increases in agronomical input and crop protection technologies.

During the nineteenth century, and particularly after the Second World War, a real revolution occurred in agricultural systems, characterized by sharp and significant increases in crop yields, and thus in food supply. For instance, over 40 years (1960-2000) the global cereal production more than doubled. This success, which has had a tremendous benefit for humans, was achieved through the development of new, high-yield crop varieties, together with the adoption of several agronomic inputs, such as mechanization, fertilization, irrigation, and the chemical control of weeds, pathogens and pests. In general, 50% of the yield improvement is estimated to be due to the role of plant breeding (Duvick, 1992).

However, it has been estimated that the global human population will rise substantially in the next 40-50 years. Indeed, considering the most 'optimistic' (low fertility) scenario, the population will grow from the present 6.5 billion to reach 7.8 billion, although when considering the other three scenarios that assume average, high or constant fertility, the World population is expected to grow to 9.2, 10.8 or 11.9 billion, respectively (http://esa.un.org/unpp/). Following these projections, the global food demand is expected to double over this period, and thus a further increase in agricultural production is needed (Alexandratos, 1999, Cassman 1999; Cohen 1999). This is also supported by the new role of agriculture as a system for the production of biofuels and other bioproducts (Ragauskas *et al*., 2006). As most of the arable lands around the World are already under cultivation, to limit the disruption of natural habitats and the processes of desertification and land degradation, the increases in agricultural production will need to be derived mainly from increases in the productivity of agricultural systems. Increasing crop productivity by increasing agronomic inputs, such as nitrogen fertilization, appears not to be feasible, at least in developed countries, because given the actual levels of inputs used in most of our agricultural systems, no additional yield return could be obtained. In contrast, different conditions are present in some areas of the World, where the use of agronomic input is far too limited. Moreover, some agronomic practices can have detrimental impacts on the environment, producing a cost for society that needs to be taken in consideration for farmer and society choices regarding production methods. Appropriate analyses of the costs and benefits that can be derived from human use of natural resources should consider the goods and services provided by ecosystems and agro-ecosystems (Tilman *et al*., 2002; Perrings *et al*., 2006). Indeed, to limit our attention to the industrialized countries, there is a growing awareness of the limitations and environmental consequences of the present energy-intensive farming systems. While in the second part of the last century attention was focused on industrial pollution, we are now at least equally concerned about erosion and land degradation, the effects of surplus fertilizers and pesticides that contaminate rivers, lakes and the ground water, and the loss of biodiversity.

In this context, over the next few decades we will be facing a major challenge: to increase the productivity of agriculture systems in terms of goods and services, while reducing its environmental costs. This idea is the basis of the concept of sustainable agriculture, which can be defined as "practices that meet current and future societal needs for food and fibre, for ecosystem services, and for healthy lives, and that do so by maximizing the net benefit to society when all costs and benefits of the practices are considered" (Tilman *et al*., 2002). Sustainable agriculture differs from conventional agriculture in that it aims to maximise our dependence on naturally occurring biological systems. Such systems are less important in conventional agriculture, which is highly dependent on synthetic external inputs, tillage and irrigation.

Some of the most likely changes that will occur in the near future were already under consideration at the end of the 1980's, at a symposium sponsored by Division C1 of the Crop Science Society of America (Francis, 1989). These included:

1. reduced pesticide inputs through better regulation and environmental controls;
2. higher energy and purchased nutrient costs, and more regulations regarding groundwater and surface surface nitrates;
3. reduced tillage and greater amounts of crop residues, and regulation of tillage;
4. higher irrigation costs;
5. greater recognition of benefits of specific location and system adaptations of varieties;
6. markedly increased use of crop rotation;
7. greater use of multiple species systems, and especially of crop mixtures and relay planting;
8. greater diversity in crops and potential products for a global marketplace;
9. increasing concerns regarding the nutritional quality of crops;
10. need for multiple purpose crops and plant types, to promote feeding residues and nutrient cycling;
11. need for perennial cereals and legumes, for use in compatible mixtures;
12. regulation of acceptable erosion levels.

It should also be added that a consideration of the literature reveals that, even if the changes needed in plant breeding were already clear almost twenty years ago, no great efforts have been made in this area in developed countries. In contrast, good examples of "sustainable breeding" can be found in the research activities of some international research centres (e.g. ICARDA, CYMMIT), which have included participatory breeding in developing countries (where new crop varieties can play crucial roles in the stabilization of crop yields).

In considering sustainable agriculture for developed countries, the idea of a general decrease in production per unit area to decrease the negative effects of agronomical inputs is not politically correct, as clearly stated by Bosemark in 1993: "While there is a general agreement that the developing countries will have to become capable of feeding their own growing populations, and that prolonged, unconditional food support may in this respect be counter-productive, the affluent countries have an obligation to maintain a high production to be able to provide the food and technological assistance required to stimulate and support the development of a productive and sustainable agriculture in the developing world. To achieve such a development will require crop varieties and cropping systems adapted to marginal lands and capable of gradually reconstructing over-utilized and nutrient-deficient soils". With limited possibilities for the increasing of the various inputs, better adapted varieties are the cheapest, most reliable and environmentally safe way to increase the efficiency of production and to secure the World food supply in the future.

On the basis of this, along with the comments of Bosemark (1993), the main targets of plant breeding for sustainable agriculture must be:

1. maximum yield production of saleable products at an economical level of input and with a minimum of negative environmental effects;
2. development of varieties with wide adaptation as well as varieties for local, specific environments;
3. production of varieties that have improved resistance to various abiotic stress conditions and which will make better use of crop inputs (e.g. efficiency of nutrient and water use);
4. development of crop varieties with better resistance to pests and diseases, and thereby with less dependence on agrochemicals;
5. provision of crops and varieties with wider ranges of end use.

As in the past, the main breeding objective is target 1; all of the other targets, with the exception of target 5, indirectly affect yields and often also quality.

A major consequence of the differences between sustainable and conventional agriculture is that the varieties of plants best suited to the two approaches can be significantly different. An obvious example is in relation to weeds, which in sustainable agriculture need to be controlled mainly by crop competition and by mechanical means, while in conventional agriculture are usually controlled by herbicide use.

As a simple statement, we can affirm that in the past, environments were adapted to new varieties through great physical changes and a large input of energy, while in the future, if sustainable agriculture is to be developed, the plants need to be adapted to the existing environments, to avoid the non-sustainability of agricultural production for the next human generations. As a consequence, breeding strategies that can address these new production circumstances are needed, which means breeding practices that can sustainably enhance agricultural productivity and profitability, while simultaneously addressing food security and biodiversity conservation challenges. On the basis of these considerations, plant breeding for sustainable agriculture has to be implemented considering the following main points:

Crop and agro-ecosystem diversity. As demonstrated by Phillips and Wolfe (2004), a major breeding problem of the most important crops greatly modified by plant breeding is that monoculture plant communities dominate modern agriculture. Monocultures are crops of a single species, a single variety and frequently a single genotype; hence the degrees of heterogeneity within these communities are severely limited. The modern wheat plant ideotype is a good example of a plant that has been designed for monoculture use. Wheat plants that perform well as a monoculture interfere minimally with their neighbours under high fertility conditions, where all the ameliorable factors are controlled. This breeding design has provided wheat with erect leaves, large ears, a dwarf structure and a relatively small root system, producing crop communities that do best where light is the only, or the main, limiting factor for productivity. Therefore, the products of this approach to plant breeding require inputs to raise the soil fertility and to control weeds, pests and diseases. For sustainable agriculture, the value of this ideotype must be questioned, and heterogeneous varieties, such as mixtures, would be preferred. Furthermore, well designed crop rotation offers advantages compared to monocultures (Cruse and Dinnes, 1995). For these reasons, sustainable agriculture systems imply the much wider use of the genetic diversity of crops and of agro-ecosystems, which can be considered according to the following spatial and temporal dimensions:

At a regional and farm level:

1) the reduction of inputs will enlarge the environmental variation both in space and time, and thus the exploitation of genotype-x-environment (GxE) interactions, and selection for specific adaptation will become more important than in conventional agriculture. Thus the number of varieties that will be grown in a given geographic region is expected to increase;
2) the wider use of crop rotation will promote the use of a larger number of crop species.

At the field level:

1) intercropping is known to be an efficient tool to maximise positive interactions between species;

2) varietal mixtures have been shown to be particularly relevant in reducing the effects of pests and pathogens. Indeed, a large-scale experiment conducted with rice in China showed that the use of a simple mixture of two varieties was highly effective for the limiting of rice blast infection, and thus for a reduction in the need for chemical control of the pathogen (Zhu *et al*., 2000).

In plant breeding programmes:

1) the adoption of new agronomic practices implies that new traits should be the targets of breeding programmes. For instance, the adoption of low or no-tillage can modify the relative importance of pathogen species, as has been shown in maize (Waed *et al*., 1997) and wheat (Cook, 2003); thus, new resistance traits will become important. Moreover, the adoption of crop rotation and intercropping will significantly change the target environments and thus new traits and new genes will become important. In most cases, these genes will be different (and even contrasting) from those selected for conventional agriculture, and thus their diversity in modern crop varieties is most likely very poor. For this reason, in sustainable agriculture, the role of introgression of new genetic variations from landraces and wild relatives, along with those from different species using genetic engineering, will be key factors for successful crop improvement;
2) new species will be domesticated and underused crop species will be adopted for more intensive crop improvements. For instance, the development of perennial cereals has been proposed as a long term target (Cox *et al*., 2002). New or underused crops can be developed to optimize crop rotation and soil conservation (e.g. cover crops) and can be used for the production of food, feed, fibre and fuel (Brummer, 2004).

Selection environments and genotype by environment (GxE) interactions. The requirements for making breeding progress towards any given trait are defined by selection theory; selection responses in a target environment (RT) are largest (Barziger and Cooper, 2001) when each of the four following factors is high:

$\boldsymbol{\sigma^2_G}$ the genetic variance;
i the selection intensity;
$\mathbf{h^2_S}$ the heritability in the selection environment;
$\mathbf{r_G}$ the genetic correlation between selection and target environment.

Whereby: $\mathbf{RT = \sigma^2_G\ i\ h^2_S\ r_G}$ (Falconer, 1996)

The **genetic variance** is a measure of the extent of genetic differences among the germplasm units evaluated, the **selection intensity** refers to the proportion of genotypes selected among those evaluated, a **high heritability** implies that the genetic variation for a trait can be precisely assessed from phenotypic observations and that the trait can be easily transmitted to the offspring of the selected plants, and the **genetic correlation** between trait performances in the selection and target environments refers to the relationships between the expression of the genes controlling trait variations in the environments where the germplasm is selected and deployed, respectively, and emphasizes that these environments often differ in space and/or time.

There is general agreement among plant breeders that GxE interactions have an important bearing on methods of breeding and in the usefulness of the resulting cultivated varieties (Allard, 1999). Breeding programmes are, in general, carried out in experimental fields where on the basis of economical production all of the components are at a maximum, while selected varieties may be cultivated in areas characterized by, for example, low nitrogen inputs or minimum-tillage. If this happens, GxE interactions become of paramount importance. As indicated by Haldane in 1946 (cited in Allard, 1999), two main types of GxE interactions can be considered (Fig. 1): with two genotypes (A and B) and two different environments (X and Y), genotype A may be superior to B in both environments (Fig. 1a, b and c) or superior in one environment and inferior in the second (Fig. 1d). In the former, genotype A can be taken as a universal variety, whereas in the latter a strong GxE crossover interaction is present and different genotypes have to be used in different environments. Of note, with two genotypes and two environments, only four different types of interactions are possible, while with just 10 genotypes and 10 environments, the number of types of possible interactions rises into the hundreds.

Genetic variance and heritability of traits of economical interest, such as grain yield, have generally been found to decrease when moving from high to low input conditions; as a consequence, the exploitation of genetic progress has often been connected to the use of inputs, and breeders have focused their efforts on those high-input conditions.

Even when low input environments have been targeted, plant breeders have usually preferred to conduct the initial stages of a plant breeding process (when a large number of different genotypes has to be evaluated at only a few sites) under high yielding, agronomically well managed, experimental stations where genetic variance, heritability and repeatability of experiments are high (Simmonds, 1991). Evaluating germplasm in environments representing yield levels more similar to those encountered under more normal farm conditions has usually been left to the advanced testing stage. As indicated by Banziger and Cooper (2001), a clear disadvantage of this approach is that genetic variance has been reduced by the breeding stage to that retained among a few selected germplasm units, and the selection intensity and breeding progress for performance under the farmer-representative conditions are consequently low.

Breeding carried out at high-input research stations fits conventional advanced agricultural situations very well, although almost ten years ago Allard demonstrated that such breeding often turns out to be less compatible with the realities of low-input agriculture. This point was confirmed in recent years by Ceccarelli at Icarda (see for example Ceccarelli and Grando, 2007), and it has to be considered also in relation to the developed countries if we want to develop breeding approaches for sustainable agriculture. Indeed, at the end of his seminal paper in 1991 entitled “Selection for local adaptation in a plant breeding programme”, Simmonds stated that, “The general trend of conclusion is that adaptation to an environment (weather high or low) is best achieved by selecting in that environment, but this stands in contrast to much plant breeding practice, which selects on the home station and hopes for adaptation elsewhere”.

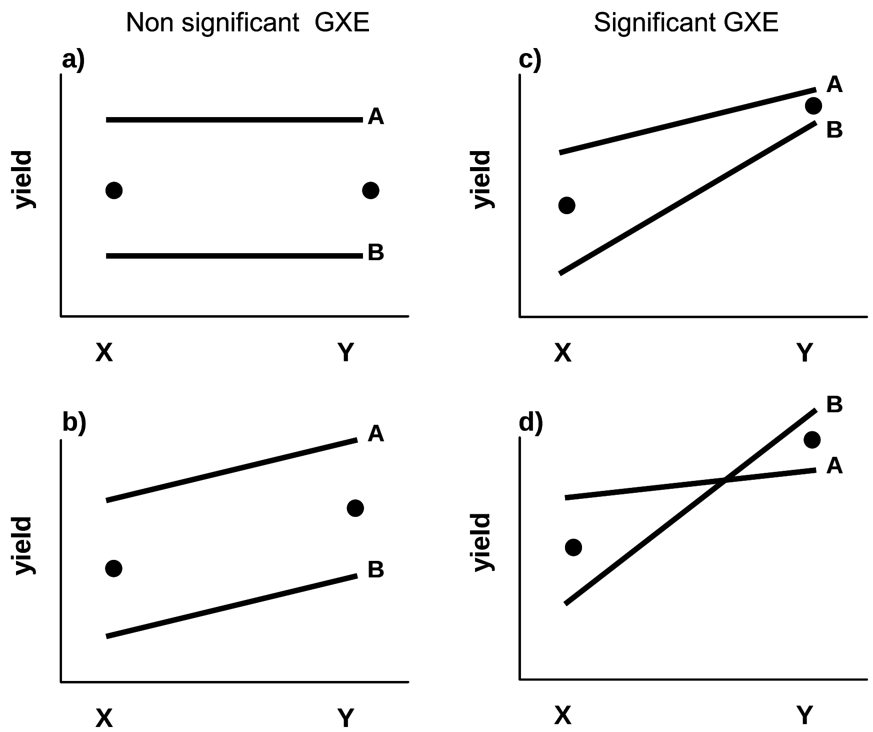

Figure 1. Schematic representation of the possible type of interactions from a combination of two varieties (A and B) and two environments (X and Y), dots represent the average value of A and B for each environment.

Target traits. As stated above, a major consequence of sustainable agriculture will be an increasing number of target environments, and thus the relative importance of different traits will probably vary substantially between these different environments. However, some target traits will be similar to those selected for conventional agriculture. For instance, crop yield will remain a major focus of every breeding programme, as will resistance to pests and pathogens and several other traits; in these cases, the major differences will be the relative importance of the different target traits.

If we need varieties for sustainable agriculture, we have to start specific breeding programmes to reach this target. For example, if we need wheat varieties suited to reduced-tillage management, we have to consider that conventional tillage operations have three broad objectives: to place the seed in the soil, to break the capillaries and aerate the soil, and to control weeds. Zero or reduced-tillage does not involve these operations and presents growing plants with conditions that differ substantially from those of tilled soils, particularly when residues are retained (Joshi *et al.*, 2007).

Wheat varieties for such an agronomical environment need to have particular stress adaptive traits, extensive root systems, a medium-tall stature, a high tillering capacity, and an increased potential for nutrient and water uptake; all of these characteristics do not necessarily correlated with high yields. As stated by Joshi *et al.* (2007), with the increasing adoption of resource-conserving practices, like reduced tillage, crop breeding programmes need to focus on developing varieties that fit with the new practices. Traits for this purpose should be included among the breeding objectives for the development of varieties that enhance the sustainability of agro-ecosystems.

Varietal development should be specifically targeted to tillage requirements, although in the modern wheat varieties that have been selected in conventionally tilled environments the presence of dwarfing genes is associated with a significant reduction in coleoptile length and poor emergence under deep sowing or stubble. A plant breeding solution would be to incorporate increasing seedling vigour and tolerance to eco-fallow/zero-tillage planting. Unselected and/or segregating materials, including progenies from divergent parents, should be included in a low-input programme and tested early in the breeding process. This would be a long-term breeding programme for sustainable agriculture. Witcombe and Virk (2001) suggested that a good approach would be to select and produce large segregating populations, thereby increasing the probability of recovering superior genotypes. In any case, there is a need to implement an investigation of adaptation that considers the effects of combinations of traits and examines their genetic correlations in the appropriate reference populations. The best approach would appear to be the continuous improvement of source populations designed to capitalize on the adapted gene pool as well as the genetic variability available in primitive varieties and wild relatives of wild species.

Genomics-assisted breeding and biotechnology. In this context, plant genomics and biotechnology could have a major role for sustainable agriculture. Molecular tools that have been derived from our increasing knowledge of the molecular and genomic bases of agronomic traits can be applied to the development of improved crop varieties that will allow producers to increase yields and quality, while reducing chemical inputs and production costs. For example, molecular markers for height genes other than GA-insensitive *Rh1* and *Rh2* in wheat are expected to have significant roles in improving coleoptile length (Joshi *et al*., 2007), a trait necessary for improved seedling emergence. Moreover the dissection of the genetic bases of GxE interactions for major complex traits should provide very important tools for the breeding of varieties with specific adaptations to given macroenvironments, as well as a set of wide, adaptive traits that confer higher stability (MacMillan *et al*., 2006; Manneh *et al*., 2007; Laperche *et al*., 2007). Similarly, molecular tools can favour the exploitation of the genetic diversity in wild germplasm that can have very relevant impacts on crop improvements, as has been shown in tomato (Gur and Zamir 2004). Furthermore, useful knowledge about traits of potential relevance for the improvement of varieties for conservation agriculture is expected to come from plant model systems, coupled with genomics research in *Arabidopsis*, rice and *Medicago truncatula* and comparative genomics studies for functional analysis (Varshney *et al*., 2005, Varshney *et al*., 2006). An important example is the need for a deeper knowledge about the molecular basis of symbiotic plant-microbe interactions (Zhu *et al*., 2006). As far as genetic engineering is concerned, it is important for an assessment of its likely long-term impacts to note that both the products already obtained and the emphasis of current research and development work generally concern resistance to pests and diseases, environmental stress factors and various quality traits. As already shown by Bosemark in 1993, these traits are precisely those which will reduce the dependence on agrochemicals and result in increased yields and improved product quality, and thus contribute to more classical breeding methods. When integrated with classical breeding methods, molecular techniques can speed up breeding programmes and also make possible the development of crop varieties for sustainable agriculture.

Contrary to molecular markers, which are solely an assisting technology and to which no objections can be raised, genetic engineering is often perceived as unnatural and risky, especially in Europe. It is also associated with the chemical and pharmaceutical industries, which are believed to be more concerned with safeguarding their own interests than those of farmers, consumers and the environment. To gain public acceptance of genetically engineered plants requires risk assessment and regulations that can be widely understood and legally enforced.

In any case, and in agreement with Bosemark (1999), advanced plant biotechnologies are not going to take the place of conventional plant breeding research and breeding methodologies, nor to diminish their value. It is therefore important that the less glamorous classical areas of plant breeding research continue to receive support and that as far as possible, such studies are closely co-ordinated with cell and molecular biology research.

Socio-economic context. If a transition to sustainable agriculture is to take place, this will be a very complex change that will be mainly driven by socio-economic forces rather than by scientific and technological factors.

The role of science will be to help society to identify the trade-offs between different production systems and to address specific research targets that can help with this transition. For instance, plant breeding research for adaptation to low or no-tillage conditions could facilitate the adoption of such technology. At present, the general trend is to eliminate or drastically reduce public breeding programmes. In our opinion, this situation is partially responsible for the concentration of the overall efforts for crop improvement in few crop species, with a special focus for high-yielding environments. In the absence of public research that can lead to the development of new varieties for less relevant species and/or for less favourable environments, the costs in terms of goods and services for our society will be very much higher than that of supporting a strong public breeding system.

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Low-input farming in new EU Member States

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Keywords: new EU Member States, fertilizer consumption, production patterns

ABSTRACT The role of agricultural production is a long-term basic and traditional constituent in the economy of most of the new EU Member States. An key question nowadays is how the land can be cultivated and agricultural goods be produced under the conditions of sustainable development, as well as under the EU regulations.Most of the new EU Member States, as well as their agriculture, now has two challenges, i.e. overcome economic difficulties and manage the land. Land use change scenarios prove that the natural conditions in these countries are suitable for agricultural production, integrating environmental and landscape protection and nature conservation.
The statistical data show that the EU population with these 12 countries has increased with 103 millions inhabitants, while the agricultural area enlarged with 54 millions hectares, (the ratio of agricultural area to the total area in the former 15 EU countries was 37.2%, while after the enlargement it has grown up to 40.2%). Inside the new EU Member States this ratio is 50.3% (Romania 62.1%, Hungary 61.8%, Bulgaria 55.9% and Poland 52.1%).

Introduction Historically, farming played an important role in the development of most of the European countries. In the past 50 years, however, the number of people active in the agricultural production has been steadily declining. There are several pending questions: can sustainable and equitable food production be established when many consumers have little little awareness of current agricultural processes? What is the future of the rural life and farmland ownership?
World population continues to grow, reaching now 6.3 billion. The rate of population increase is especially high in many developing countries. In these countries, the population factor, combined with rapid industrialization, poverty, political instability, and large food imports and debt burden, make long-term food security especially urgent. In a big part of the new EU member states there are economic and social problems associated with agriculture, which cannot be separated from external economic and social pressures.

State of the art

Table 1 shows the population, territory and land use data of the 27 EU countries.

Country	Population (1000 head)	Area (1000 ha)	Agricultural area (1000 ha)	Ratio of agricultural area from the total area (%)
		EU 15		
Austria	8 266	8 387	3 374	40,2
Belgium	10 511	3 053	1 394	45,7
Denmark	5 427	4 310	2 664	61,8
Finland	5 256	33 815	2 253	6,7
France	62 886	55 160	29 630	53,7
Germany	82 438	35 702	17 020	47,7
Greece	11 125	53 094	8 446	15,9
Ireland	4 209	7 028	4 297	61,1
Italy	58 752	30 131	15 097	50,1
Luxemburg	460	259	128	49,5
Netherlands	16 334	4 153	1 927	46,4
Portugal	10 570	9 239	3 716	40,2
Spain	43 758	50 478	25 239	50,0
Sweden	9 048	44 996	3 153	7,0
United Kingdom	60 400	24 410	16 986	69,6
	389 440	**364 215**	**135 324**	**37,2**
		12 new EU members		

Bulgaria	7 719	11 091	6 203	55,9
Cyprus	766	925	136	14,7
Czech Republic	10 251	7 900	3 631	46,0
Estonia	1 345	4 523	698	15,4
Hungary	10 077	9 300	5 751	61,8
Latvia	2 295	6 459	1 642	25,4
Lithuania	3 403	6 530	2 604	39,9
Malta	404	32	11	34,8
Poland	38 157	31 268	16 301	52,1
Romania	21 610	23 750	14 747	62,1
Slovakia	5 389	4 904	2 446	49,9
Slovenia	2 003	2 025	491	24,2
Total	**103 420**	**108 706**	**54 661**	**50,3**

The statistical data show that the EU population after the accession of these 12 countries has increased with 103 millions heads, while the agricultural area enlarged with 54 millions hectares, (the ratio of agricultural area from the total area in the former 15 EU countries was 37.2%, while after the enlargement it has grown up to 40.2%). Inside the new EU Member States this ratio is 50.3% (Romania 62.1%, Hungary 61.8%, Bulgaria 55.9% and Poland 52.1%).

This goes to show the importance of agriculture activities in the economy of these countries. What are the main charachterestics of their agriculture? a) unclear land ownership, b) small size of agricultural parcels, c) lack of capital d) technical and technological backwardness.

Because of the lack of lower EU subsidies received in the New EU Member States compared to EU15 countries the farmers are not able to do their best (not enough fertilizer and pesticide, less good quality seed, etc.). As a result, yields areand depnd greatly on weather conditions.. This is not only the problem of the amount of the harvested yield but also possibilities to make long-term contracts on the market (it is not possible without yield safety or security). Moreover, the free market is also a player which does not help this group of growers.

One of the most important thing in the sustainable agricultural production is the soil fertility. Soil fertility shows the effect of the natural nutrient supplying power of the soil and the past fertilizer and manure applications. It seems to be a good tool for making a comparison between the countries. Without a good and satisfying nutrient supply managable LIFS are almost impossible. The main unfavourable factor in the new EU member states is the low supplying power of the soils. NP balance studies should always be combined with investigations on the distribution of soil NP supply categories (very poor, poor, moderate, good and very good/excessive supplies) over the investigated area. The negative NP balances and worsening NP status in the new EU member countries are in sharp contrast to past practices in the former EU15 countries, where strongly positive NP balances and oversupplies with NP may lead to environmental and ecological threats, though, there is evidence that the level of oversupply in many of these countries is on the decline. In the new EU member countries, on the other hand, worsening levels of NP undersupply may result in increasingly low yields and in economic and agronomic problems. Significant differences in NP balances and soil NP supplies were observed both within and between the EU15 and the EU12 group.

The FAO Statistical Database for Agriculture (2005) was used to evaluate how the various factors, such as per capita GDP or population density affect livestock numbers, fertilizer NP application or organic NP produced (Figures 1). Per capita GDP was calculated by CIA (2001) in the terms of purchase value. In general, the figures given in the FAO Database for the agricultural area of the countries were applied. Countries with less than 100 thousand hectares of agricultural land were excluded from the evaluation. In this way 129 countries remained in the database.

When seeking an explanation for the different amounts of mineral plus organic NP applied per unit of agricultural land, it can be seen that developed countries with a higher per capita GDP, as well as with higher population density, usually have more intensive agricultural production, involving higher mineral NP application plus organic NP production (Figure 1).

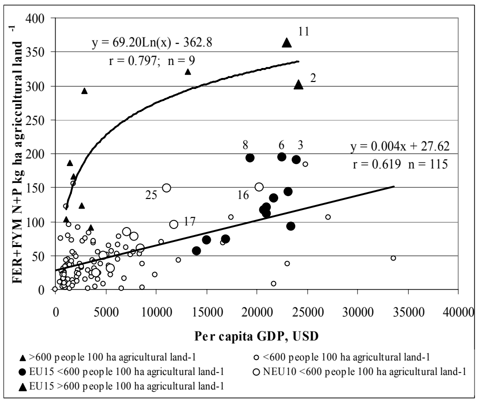

Figure 1. Correlation between per capita GDP and the magnitude of applied mineral N+P plus produced organic N+P, as grouped by the population density in the countries investigated in 2000

The numbers in Figures 1 refer for the following countries: 1: Austria; 2: Belgium-Luxembourg; 3: Denmark; 4: Finland; 5: France; 6: Germany; 7: Greece; 8: Ireland; 9: Italy; 11: Netherlands; 12: Portugal; 13: Spain; 14: Sweden; 15: United Kingdom; 16: Cyprus; 17: Czech Republic; 18: Estonia; 19: Hungary; 20: Latvia; 21: Lithuania; 23: Poland; 24: Slovakia; 25: Slovenia.

Per capita GDP was almost 2.5 times higher in the former EU15 countries than in the EU12 group. In 2000, 56% more fertilizer (FER) N+P was applied in the EU15 than in the EU12, indicating differences in the intensity of plant nutrition. The highest fertilizer NP rates were applied in the Netherlands, Germany and Belgium-Luxembourg. Almost twice as much NP was produced from farmyard manure (FYM) in the EU15 than in the EU12, with the highest figures for the Netherlands (196 kg per hectare) and Belgium-Luxembourg (181 kg per hectare). This is the result of the very high LU number per agricultural area. The amount of fertilizer + farmyard manure NP was 70% higher in the EU15 than in the EU12, with levels of over 300 kg per hectare in two countries (the Netherlands: 364 kg and Belgium-Luxembourg: 302 kg per hectare), and around 200 kg NP per hectare in three other countries (Germany: 195 kg; Ireland: 193 kg, and Denmark: 190 kg per hectare) (FAO Database, 2005).

Hungarian case study

From the early 1960s till the late 1980s in many countries, including Hungary, agricultural production had increased tremendously, the yield of the cultivated crops doubled even tripled because of introducing the intensive agricultural practices (IAP) in Hungary. There are several factors contributing in this impressive yield increase, such as

- introduction of new high-yield varieties of crops,
- improvement (or maintenance) of nutrient supply (fertility) of the soils by using fertilizers,
- plant protection,
- mechanization.

During this period the use of mineral fertilizers multiplied from yearly 168.000 tons (1960) up to 1.586.000 tons (1983). The changes in the fertilizer application can be seen in Table 2. The intensive application of fertilizers improved the fertility of the cultivated soils, the nutrient balances became positive. These long-term (over 20 years) positive nutrient balances resulted in the NPK enrichment of soils, which was proven by several national soil test series. This is why in the late 1980s our aim was to keep and maintain only this fertility levels (Németh, 1993, Sarkadi and Várallyay, 1989, Várallyay et al., 1992). The fertilizer application data also show a dramatic change from the early 1990s. Because of several reasons, i.e. privatization, changes in ownership, withdrawn of state subsidies on mineral fertilizer, drought, etc., the use of the fertilizers decreased sharply (Csathó and Németh, 1996). There is no doubt that during the intensive period of the Hungarian agricultural development a part of the cultivated soils were overfertilized but this decrease is not proportional to the former overdosage. The above mentioned oversupply and this dramatic change which is not caused by the development of agriculture turned our interest to elaborate an environmentally friendly fertilizer recommendation system. Such a system has to be sensitive enough to react to different conditions, i.e. great spatial variability of soil characteristics, mozaic-like soil cover, climate, crop rotation practices, soil nutrient supply, etc. To take the above mentioned conditions into consideration was another reason why the basic features of a computerized fertilizer recommendation system was developed in the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian

Academy of Sciences (RISSAC) to characterize the soil fertility levels in different region in Hungary under diverse agricultural practices and environmental conditions (Németh, 1996b, Várallyay et al., 1992).

Table 2. Farmyard manure and fertilizer use in Hungary, 1931-2005
(Statistical Yearbooks for Agriculture, KSH)

Year	Farmyard Manure, Million Mg year^{-1}	Fertilizer active ingredients, 1000 Mg year-1				For arable lands, kg ha^{-1} year^{-1}
		N	P_2O_5	K_2O	Total	
1931-40	22.4	1	7	1	9	2
1951-60	21.2	33	33	17	83	15
1961-65	20.6	143	100	56	299	57
1966-70	22.2	293	170	150	613	109
1971-75	14.8	479	326	400	1,205	218
1976-80	14.3	556	401	511	1,468	250
1981-85	15.4	604	394	495	1,493	282
1986-90	13.2	559	280	374	1,213	230
1991-95	6.0	172	25	26	223	44
1996-2000	4,80	235	40	42	317	63
2001-2005	-	284	65	75	423	94

Farm data are from the Hungarian Farm Accountancy Data Network (FADN) maintained and operated by the Agroeconomic Research Institute (Keszthelyi, 2006).
Five years data of three farms were selected to represent different – intensive, extensive (LIFS) and organic - agricultural plant production and land use forms. The size of the selected farms is varying around 60 ha. Geographical location of the farms is in the Vértes-Velence Hills near to Tatabánya. Fields of the three farms are within a 5 km radii circle. Soil features of the farmlands are closely similar since brown forest, chernozem brown forest and pseudomiceliar chernozem soils can be found on loess in that area (Marosi and Somogyi, 1990). Not only the land size and quality but also the economic size of the farms is similar. Their mean standard gross margin value is 4.6 million HUF. The SGM value of the extensive farm increased within the 5 years.
Yield of the produced plants, sown and harvested land area of the farms are shown in Table 3.

Table 3 – the data for the year of 2001 give example about the structure of data and demonstrate the production patterns of the farms.

Year	Crop	Organic farm		Intensive farm		Extensive farm	
		Land area ha	Yield t ha^{-1}	Land area ha	Yield t ha^{-1}	Land area ha	Yield t ha^{-1}
2001	Wheat	50	3.5	31	5.5	14	6.0
2001	Corn	5	4.7	24.6	7.3	20	1.7
2001	Potato			3.5	7.1		
2001	Barley	7	2.1			3	5.2
2001	Alfalfa	16	11.1			3	10.7
2001	Grass lay	12	3.8				

Summary

The agricultural practices in many areas of the new EU member countries are - in the meaning of low input definition - really LIFS. The most important reasons are the following: breakdown of the former markets, land ownership changes, disappearance of the governmental subsidies, strong (and sometimes negative) influence of the free-market, technical and technological – historical – backwardness, and last but not least one of the main remaining reasons is lack of capital.

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Sustainable low-input farming systems: the case of Marianis-Volpares farm

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Abstract A public farm (630 ha) located in Palazzolo dello Stella (UD) (L at. 45°48"N,Long.13°5'0"E) in the Friuli Venezia Giulia region of Italy, is managed by ERSA (Agenzia Regionale per lo Sviluppo Rurale) in order to promote environmentally friendly agriculture. The farm is a complex in which agricultural activities will be in harmony with the environment and landscape. Hedgerows, ditches, woods, ponds of fresh water, wet meadows and brackish wetlands will be introduced into the farm. Present high input farming systems (HIFS) is in transition to low input farming systems (LIFS) using good farming practices (GFP) to qualify the agri-environment. Seeds suitable for LIFS will be tested; techniques of soil management such as minimum tillage and direct drilling will be used. Traditional rotation maize-soybean and maize-lucerne will be integrated with more environmentally friendly crop rotation systems introducing minor cereals, legumes and multi-species meadows for ley-arable rotation. Crop rotation will be managed to improve soil fertility and carbon sequestration, to reduce fertilizing intensity, to protect soil from erosion, to maintain soil organic matter (SOM) and soil structure and to reduce the use of pesticides. Cover crops will be introduced for manuring and catch crops for reducing water pollution by nitrates. Crop rotation, soil cover, fertilizing intensity, fertiliser uptake, nitrate leaching, mode of manuring, landscape elements will be used as main indicators. The present herd of 650 heads of cattle will be reduced to about 540. Buildings, barns for dairy cows, calving pens, and milking boxes will be restored to improve animal welfare. Energy will be supplied by anaerobic digestion of organic matter mixed with slurry (co-digestion) by cogeneration and tri-generation processes. Meat, milk and dairy products of high quality will be certificated by labelling systems.

Introduction About 70% of the land in Italy and nearly half of land in the European Union are farmed. The importance of farming for the natural environment is evident and farming and nature are closely connected.
Human activity has contributed to creating and maintaining a variety of semi-natural habitats but high input farming systems (HIFS) have had a profound impact on nature conservation value and landscape integrity throughout much of Europe. In areas where intensive livestock production is practised a great loss of fauna and flora has been registered. The effects of inorganic fertilisers, purchased feed, application of slurry and pesticides and herbicides, removal of hedges and ditches, drainage work and a higher stocking rate have exerted high negative impact on the agri-ecosystem (Hopkins & Holz, 2005). In order to meet society's expectations and to help farmers meet the standards of high quality agriculture, the European Commission considers that it is necessary to establish and support an EU wide system of farm assessment for professional farms. This is determined by EC regulation No 1782/2003, establishing common rules for direct support schemes under the common agricultural policy and establishing certain support schemes for farmers. The Farm Advisory System (FAS) will cover at least the statutory management requirements and the good agricultural and environmental conditions. FAS may be supported by experimental farms managed according to the Common Agricultural Policy (CAP) which deals with the integration of environmental considerations into CAP rules and with the development of agricultural practices preserving the environment and safeguarding the countryside. Public experimental and demonstrative farms (PEDF) are good examples to promote environmentally friendly agriculture, to communicate the results to policymakers and the wider public and feed the global assessment process of agricultural sustainability. PEDF are farms in which agricultural activities are in harmony with the environment and landscape. The regeneration of naturalistic aspects such as hedges, ditches, woods, freshwater ponds, wet meadows, and brackish wetlands would be essential elements of the agri-environment to meet a new model of farming system. In PEDF the past HIFS may be converted to low input farming system (LIFS) using good farming practices (GFP) to qualify the agri-environment and to drive farmers to a new model of agriculture. It must be emphasised that LIFS is much more than just abandoning chemicals or using fewer fertilizers. It means quite radical and sometimes dramatic changes to the farming system as a whole and requires a different approach to farm management.

Materials and methods Two contiguos farms owned by the Regional Government of Friuli Venezia Giulia i.e. Azienda Marianis (400 ha) and Azienda Volpares (230 ha) were joined in a unique farm in 2006 and are managed by the Agenzia Regionale per lo Sviluppo Rurale (ERSA). The farm is located in the municipality of Palazzolo dello Stella (Udine) (Lat. 45°48'0"N, Long. 13°5'0"E, Alt. 0-8 m.a.s.l.) near the lagoon of Marano.

The Marianis-Volpares farm is a farm cultivated until 2005 using HIFS. A transition period and a resettling program started in 2006 and will be concluded in 2012 to reduce significantly external inputs, to adopt environmentally friendly techniques, to introduce landscape elements and to renovate farm buildings.
Agronomic aspects The soil is clay-loamy (pH 7.8-8.0). Irrigation is provided by sprinkling by center pivot and travelling big gun systems on maize and soybean.
The cultivated land is of 529 ha. The main crops are maize (174 ha), soybean (136 ha), lucerne and grassland (109 ha), barley and wheat (39 ha), poplar plantation (22 ha), rape (1 ha), sunflower (5 ha),and set aside (43 ha). Fertilisation of maize was carried out using about 280 kg/ha of mineral N, 90 kg/ha of P_20_5 and 50 kg/ha of K_2O. Soybean and lucerne without any mineral fertilisation. About 70% of the fodder is produced on the farm.
The Volpares farm was cultivated until 2005 by HIFS and crops (maize, soybean and poplar) cultivated for selling the products. The present agronomic treatments are reported in Table 1.

Table 1 Fertilisation, irrigation and yield of the main crops

	Fertilisation (kg/ha)			Irrigation	Yield
Crops	N	P_2O_5	K_2O	Mm/ha	t/ha
Maize	280	90	50	100	11.5
Soybean	0	0	0	50	4.3
Lucerne	0	0	0	0	9.5
Barley	100	80	50	0	5.6
Wheat	160	80	50	0	6.8
Rape	140	80	50	0	2.8
sunflower	140	80	50	0	3.4

The present total amount of fertilisers used in the farm (Table 3) is about 7000 m^3/y of dung from the farm and 33t/y of N and 18 t/y of P and 10 y/ha of K from mineral fertilisers.
An important reduction of fertilizers and input of energy from outside (-20%) started in year 2006.It will be much more significant in the next experimental and transition period (2008-2012). The aim is also to maintain a good quantity of dry matter (DM), high crude protein (CP) contents and milk feed units (MFU). New crops (raygrass, sorghum, pea, leguminous cover crops, triticale, rye, etc.) and improved grassland systems (Frame, 1992) as well as the traditional crops (maize, soybean, lucerne, barley, wheat, rape, sunflower, poplar) will be introduced in the rotation crop plans.
Rotational trials will be carried out to investigate:
- Energy crops and agroenergy;
- Cover and stubble crops;
- Agronomic techniques at low impact;
- Management techniques of nitrogen fixation and carbon intake.

A large part of the farm will be used for experimental trials to inform farmers and advisory officers. The main rotational plans will be: (A) 1-year rotation maize silage+ryegrass. (B) 2-crop rotations i.e. (B1) maize silage/sorghum-barley+soybean; (B2) ryegrass+sorghum-grain pea+foxtail millet; (B3) maize+pea/landsberger-sorghum+rape/crimson clover; (B4) rape-triticale/rye/ryegrass/barley+soybean; (B5) maize-soybean. (C) 3-crop rotations i.e. (C1) silomaize-ryegrass+soybean-wheat/crimson clover/fodder vetch; (C2) sunflower-wheat-rape+foxtail millet; (C3) silomaize-ryegrass+soybean-triticale/silorye+sorghum/foxtail millet; (C4) maize+horse radish-soybean-wheat+crimson clover/fodder vetch. (D) 4-crop rotations i.e. (D1) sunflower+crimson clover-maize+crimson clover+ryegrass-soybean-wheat; (D2) rape+soybean-maize+crimson clover-soybean-wheat.
(E) 5-crop rotations or more i.e. (E1) triticale/silorye+soybean-maize-sunflower+green manure pea-silomaize-ryegrass+soybean; (E2) maize-barley+lucerne-lucerne-lucerne-lucerne; (E3) maize-barley+soybean-wheat+lucerne-lucerne-lucerne-lucerne; (E4) maize-barley+soybean-silomaize-lucerne-lucerne-lucerne.
258 ha of the Marianis-Volpares farm will be employed for experimental trials during the period 2006-2012.
Agri-environmental aspects. Several small areas with important environmental components are present i.e. wooded grassland and open shrubland (3.01 ha), green belt around houses (2.87 ha), natural woodland (5.01ha), grass verges (7.41 ha), riparian zones (0.72 ha), wooded ditches (3.25 ha), side road trees (1.17 ha). Non cultivated land, such as river banks (7.70 ha), canals (1.65 ha), drainage ditches (47.08 ha), roads (20.79 ha), is an important part of the farm. In order to establish the most important agri-environmental interventions which must carried out on the experimental farm Marianis-Volpares an historical analysis was made to define the natural habitat. A map of the situation in year 1891 is reported in Figure 1.
Livestock aspects. 650 cattle of the Italian Simmenthal breed and Italian Fresian breed of which are 300 dairy cows. The present annual milk production is of about 2100 t/y.
Energy supply. About 30% of energy (fertilizers, electricity, fuel, fodder, etc.) is actually provided from outside the farm. The cost for the supply of electric and thermal energy is about 37000 Euro a year.
An experiment will be carried out using extruded oil from soybean which will be mixed with Diesel oil (30/70) and employed for one tractor Fiat 90 HP and one tractor Fiat 115 HP vs one tractor Fiat 90 HP and one tractor 115 HP using by traditional Diesel oil. After 100 and 600 working hours the quality of lubricating oil will be analysed.

Farm buildings. At the moment the farm has several farm buildings. Barns for milking cows, milking parlours, beef cattle sheds, warehouses are covered by asbestos cement roofing. Facilities for offices are quite modern and have been recently restored. Slurry tanks, platforms for manure and facilities for outdoor clamp maize silage are unroofed.

Tourist facilities A cycle way of 2.38 km which borders the farm will be connected with a new cycle way towards the farm. There are also 3 houses used in the past by the farmers. At least one of these will be restored and made available for agritourism.

Economic aspects. The project, which started in 2006, will be concluded in 2012. An economic plan has been prepared to make the agricultural activities sustainable not only for an agronomical point of view. The farm will also be an example for all farmers affected by the new EU policies.

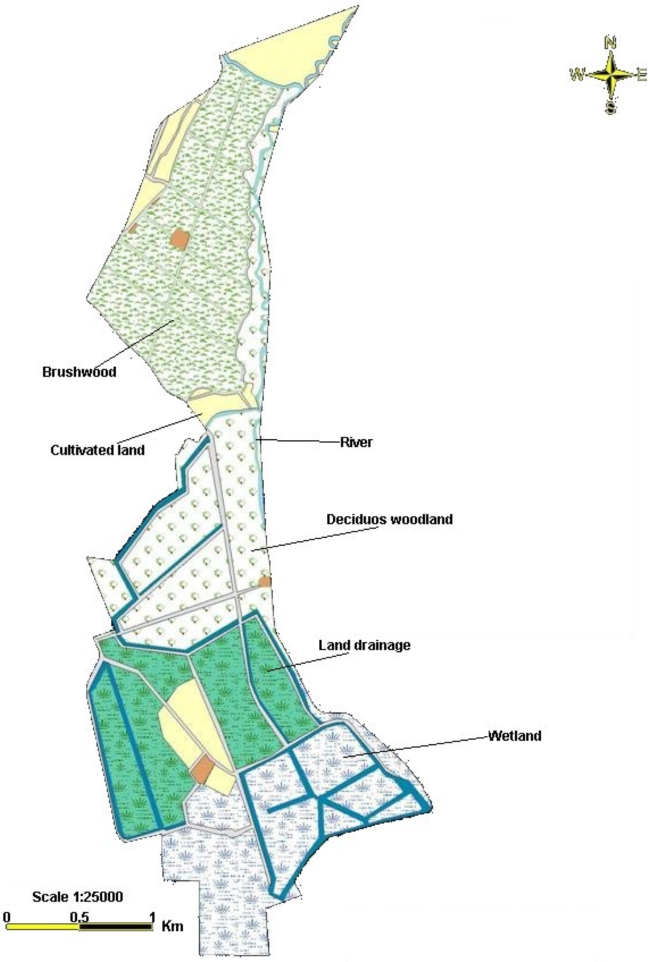

Figure 1 Marianis-Volpares landscape elements; historical situation in 1891

Results and discussion The farm with both experimental and demonstrative aims is a complex in which agricultural activities are in harmony with the environment and landscape. The regeneration of naturalistic aspects such as hedgerows, strips of hedges by the river bank, ditches, woods, fringe strips of woods, freshwater ponds, wet meadows and brackish wetlands will be realized. The past HIFS is converted to LIFS using GFP and a larger area covered by grassland (Parente, 1996 ; Vertès et al., 2007). The requalification activities are in progress and in the next five years the project should be completed.

Agronomic aspects. a) *Crops*. Seeds suitable for LIFS will be tested using techniques of soil management such as minimum tillage and direct drilling vs traditional techniques. Maize and soybean are the most important crops in this area both for economic and agronomic reasons. Moreover, these crops are also important for animal feed. About 60% of maize will be cultivated for silage production and 30% for maize grain production to be employed in the farm, while 10% will be used to produce biomass to feed a digestor to produce biogas (Amon et al., 2007). Maize will be cultivated using manure and slurry. Earlier cultivars for grain maize (400-500 FAO) and for silage maize (600 FAO) will be employed in order to reduce pests (Snidaro *et al*, 2004c) and diseases (e.g. corn borer, western corn root worm, etc.) and drying energy. Cultivars with a deep root system and prostrate leaves will be chosen over more popular varieties with erect leaves and small root systems, which are highly productive but require much more water and fertiliser. Maize will be mainly cultivated in long term rotation with soybean. (Rossell, 2000) Soybean varieties selected by ERSA and other varieties, all with low anti-nutritional factors content (trypsin inhibitor, lipoxygenase activities), will be cultivated, dried and employed to feed animals (Snidaro *et al.* 2004a; Snidaro *et al*. 2004b) directly on the farm (Kunitz, 2001). A larger area will be cultivated with lucerne to improve N in crop rotation systems (Lyons & Latta, 2003) and arable land will be converted to multispecies grassland (Wachendorf *et al*. 2005) in order to improve hay in the animal diet. The past monoculture system of maize or traditional rotation maize-soybean and lucerne will be integrated with more environmentally friendly crop rotation systems introducing minor cereals (e.g. sorghum, wheat, barley) and legumes (e.g. pea). In order to save water and to anticipate possible problems of western corn root worm a limited area with grain sorghum and grass sorghum will be introduced. This crop is in fact less water demanding and more pest resistant.

Legume winter and summer cover crops (red clover, crimson clover, hairy vetch etc.) will be used for 'green manuring' as well as incorporated into the soil (Schroeder, 2000). Grasses like raygrass will be established after the main crop (e.g. maize or soybean) and used primarily to reduce nutrient leaching from the soil profile and obtain important biomass (silage or hay) for animal feeding. Barley and wheat, already used, will be also improved both for providing more biomass for livestock and to be used as a catch crop. The experimental area of the trials and the main expected results on rotations A, B, C, D and E will be:

- A) A1) ha 10. This rotation provides the opportunity to distribute slurry before sowing to avoid winter nitrogen leaching. Ryegrass will be cut for hay or silage; ryegrass may be substituted also by a winter cereal for silage to seed a medium class maize (400-500 FAO). Maize may be also substituted by sorghum, which is less water demanding but also less productive. Annual Productivity of the Rotation System (APRS): 26.3/t/ha DM, CP 2.2 t/ha, 21000 MFU/ha. Soil fatigue, weeds and pathologies will be checked. Agronomic trials on distribution periods, effect of crops association, techniques of minimum tillage will be carried out.

A2) ha 10. Maize silage without fertilisation with slurry i.e. a legume cover crop will be used by sod-seeding. This crop may be used both for feeding an anaerobic digestor or for green manuring with no input of mineral N. APRS: 17.5 t/ha DM, 1.5 t/ha CP, 15000 MFU/ha.

- B) B1) 10 ha. In this rotation after maize silage a soil depleting crop (barley) is followed by a cleaning crop (soybean). Maize will benefit from N fixed by soybean and by a possible autumn manuring. Slurry may be used in spring or in autumn on soil covered by a grass. Basic dressing of barley may be possible with slurry. Soybean will be sown by minimum tillage or sod-seeding. Uptake of grain and straw will be calculated. APRS: 12.8 t/ha DM, 1.6 t/ha CP, MFU 12200/ha.

B2) 10 ha. Legumes are sown in autumn or spring to produce grain. Foxtail millet is sown in summer as an early crop to cut for hay or silage. Ryegrass may be sown after slurry distribution which will be repeated before sorghum. APRS: 17.3 t/ha DM, 1.7 t/ha CP, 13900 MFU/ha.

B3) 10 ha. Soil used for two cereals for grain are covered during winter by legumes, grasses and crucifers for green manuring. APRS: 8.3 t/ha DM, 0.9 t/ha CP, 10150 MFU/ha.

B4) 10 ha. In the rotation 3 groups of species are present (grasses, legumes and crucifers). Rape grain produced in this system will be sold. Soybean and cereals have to be used in the farm system. APRS: 6.7 t/ha DM, 1.0 t/ha CP, 5600 MFU/ha.

B5) 30 ha. This traditional 2-year rotation will be managed to evaluate the main agronomical aspects. APRS: 6.1 t/ha DM, 1.2 t/ha CP, 7750 MFU/ha.

- C C1) 12 ha. Maize silage, Italian raygrass and soybean must be used on the farm, while wheat will be sold. Organic fertilisers will be preferred and the system will benefit from the residual fertilising effects of legumes. APRS: 9.8 t/ha, 1.2 t/ha CP, 8450 MFU/ha.

C2) 12 ha. Grain produced will be sold, while foxtyle millet forage will be used in the farm system. APRS: 2.9 t/ha DM, 0.2 t/ha CP, 2000 MFU/ha.

C3) 12 ha. All products of this crop rotation system will be employed on the farm. The aim is to maximize the production of forage crops and silage, introducing a legume to improve the CP production. APRS: 16 t/ha DM, 1.6 t/ha CP, 13200 MFU/ha.

C4) 12 ha. Maize grain and soybean are employed in the farm. Cover crops are used for green manuring. APRS: 4.1 t/ha, 0.8 t/ha CP, 5100 MFU/ha.

- D) D1) 16 ha. In this crop rotation system, already studied in a previous experiment which produced very good results, legume cover crops are employed to maximise N fixation. APRS: 3.0 t/ha DM, 0.6 t/ha CP, 3800 MFU/ha.

D2) 16 ha. Similar to D1 in this case rape is substituted by sunflower followed by an early soybean cv as summer cover crop. Legumes and grasses are used in every other year. Rape yield as second crop is reduced of about 40%. APRS: 4.0 t/ha DM, 0.8 t/ha CP, 4500 MFU/ha.

E) The general principle of this crop rotation system is to alternate grasses and legumes with or without lucerne present in the rotation system at least three years. Lucerne may be used in a pure stand or in binary mixtures with a grass (cocksfoot and tall fescue).

E1) 20 ha. APRS: 10 t/ha DM, 1.3 t/ha CP, 9500 MFU/ha.

E2) 20 ha. Lucerne is undersown into barley. Maize grain yield improves by about 5% because of the residual fertility provided by lucerne. 8.0 t/ha DM, 1.3 t/ha CP, 7100 MFU/ha.

E3) 24 ha. Soybean yield as a second crop is reduced by about 25%. Lucerne is undersown into wheat. Maize yield improves by about 5% because of the lucerne effect. APRS: 8.0 t/ha, 1.1 t/ha CP, 6100 MFU/ha.

E4) 24 ha. Soybean yield as a second crop is reduced by about 25%. Maize yield improves by about 5% because of the lucerne effect. APRS: 8.0 t/ha, 1.1 t/ha CP, 7000 MFU/ha.

The main agronomic treatments are summarized in table 2.

Table 2 Main agronomic treatments used for the crop rotation experiments

		yield t/ha/y							
COD.	Surface ha	DM	CP	MFU	Slurry	Manure	Years	Cover Crops	Minimum tillage
A1	10	26,3	2,2	21000	yes	no	1	no	No
A2	10	17,5	1,5	15000	yes	no	1	yes	Yes
B1	10	12,8	1,6	12200	yes	yes	2	no	Yes
B2	10	17,3	1,7	13900	yes	no	2	yes	Yes
B3	10	8,3	0,9	10150	yes	no	2	yes	No
B4	10	6,7	1	5600	yes	yes	2	yes	Yes
B5	30	6,1	1,2	7750	yes	yes	2	no	No
C1	12	9,8	1,2	8450	yes	yes	3	yes	Yes
C2	12	2,9	0,2	2000	yes	yes	3	no	Yes
C3	12	16	1,6	13200	yes	yes	3	no	Yes
C4	12	4,1	0,8	5100	yes	yes	3	yes	Yes
D1	16	3,1	0,6	3850	yes	yes	4	yes	Yes
D2	16	3,6	0,8	4550	yes	yes	4	yes	Yes
E1	20	10,4	1,3	9550	yes	yes	5	yes	Yes
E2	20	8,3	1,1	6750	yes	yes	5	no	Yes
E3	24	7,4	1,1	6130	yes	yes	6	no	Yes
E4	24	9,2	1,2	7950	yes	yes	6	no	Yes

All data recorded in these trials are processed and every year disseminated in meetings and conferences with advisors and farmers.
Organic fertilizers produced on the farm (slurry and manure) will be employed in the crop rotation systems. Small quantities of mineral N and about 37% of phosphorus have to be purchased in the transition period. No potassium will be purchased. Fertilizers will be used only in quantities which respect the ratio out/input in the plant/soil system in order to save energy (Giustini, 2007) and the avoid environmental problems.

Table 3 Livestock units, mineral fertiliser quantities and contents in crop residues

Livestock (LW 400 kg)	-	540
Dung production	M3/y	7095
N utilised	t/y	33
P utilised	t/y	18
K utilised	t/y	10
N content in crop residues	t/y	26
P content in crop residues	t/y	11.3
K content in crop residues	t/y	23.4

b*) Soil*. Crop rotation will be used also in order to improve soil fertility and carbon sequestration, to reduce fertilizing intensity (Long & Todd, 2001), to protect soil from erosion, to maintain soil organic matter (SOM) and soil structure, to reduce the use of pesticides. Crop rotation combined with new tillage practices may have an important role in limiting water and wind erosion. Crops like small grains and permanent crops such as grassland provide more prevention against erosion. The addition of barley and grassland to the rotation may reduce soil erosion considerably when compared to continuous maize. The use of legumes as cover crops in the rotation will be used to improve the available soil nitrogen (Vavel, 2000). A more intense crop rotation system will improve the tilth and friability of the clay and silty-clay soils of the Marianis-Volpares farm. The resulting increased aggregate stability will reduce the tendency of the soil to puddle or crust and increase the rate of water infiltration and wind erosion.
Agri-environmental aspects. About 90% of the energy should be produced on the farm. Crop rotation, soil cover, fertilizing intensity, fertiliser uptake, nitrate leaching, mode of manuring and landscape elements will be the main indicators. Infrastructure like buildings, barns for dairy cows, the calving pen and milking boxes will be restored in order to improve human and animal welfare (Grasso, 2007).
The principal environmental retraining initiatives can be summarized as follows:
- The creation of a wooded buffer zone along the Turgnano river. The presence of a planitial forest (Selva of Arvonchi), adjoining the Marianis-Volpares farm, provides the starting point for the creation of a idrophylic

riparian zone (Del Favero *et al*. 1998) which from Selva of Arvonchi will be developed along the right bank of the Turgnano River. For the most part, tree species which are best able to avoid radical asphyxiation will be used: alder (*Alnus glutinosa*), narrow-leaved ash (*Fraxinus angustifolia*), smoothleaf elm (*Ulmus campestris*), along with while willow (*Salix alba*), black poplar (*Populus nigra*) and in the higher zone, mesophyllous species such as sessil oak (*Quercus petraea*), hornbeam (*Carpinus betulus*), etc.

-Enlargement of the existing strip of planitial woodland. The isolated strip of planitial woodland in the northernmost part of the Volpares farm will be extended and joined to the wooded zone in the project. The tree species used will be those typical of planitial woodland.

-The creation of hedgerows. Existing hedges will be restored along ditches and will be joined together and to the woodland zone by new hedges so as to create an ecological network. The following species will be used; field maple (*Acer campestre*), smoothleaf elm (*Ulmus campestris*), purple osier (*Salix purpurea*), dogwood (*Cornus sanguinea*), elderberry (*Sambucus nigra*) and hawthorn (*Crataegus monogyna*).

-Freshwater wetland zones, of between 1 and 3 ha, will be created, surrounded by a buffer zone of wetland vegetation which will connect them to the woodland zone in order to avoid their isolation and to encourage bio-permeability between hydrophyllous woodland and wetland. Reed beds (*Phragmites australis*) will be established, creating an important habitat for many species of fauna. The coenosis could be integrated in the wettest tracts with reedmace (*Typha latifolia*), *Shoenoplectus*, *Sparganium* and grey willow (*Salix cinerea*).

-Brackish wetland. A pond will be created near the mouth of the Turgnano River, characterized by species adapted to varying salinity levels (*Scirpus*, *Juncus*) arriving at those typical of a "barena" habitat" ("barena" is a local term used to describe land which emerges from the waters of the lagoon at low tide).

-A wooded grassland area will be created around farm buildings of the Marianis farm to reduce their visual impact.

-The existing poplar plantation within the Volpares farm will be maintained because the farm originated as a centre for the cultivation of and research into poplars for paper production.

Livestock aspects. The cattle herd will be reduced to 540 (average live weight of 400kg) of which 180-200 are dairy cows, 40 dry cows, 200 heifers and about 100 fattening calves.A part of milk quota (300-500 t) will be sold and consequently the annual milk production will be of about 1400 t. A part of the milk will be transformed into dairy products in a local cheese factory and sold as a certified quality product under the Agricultural Products and Foodstuffs Quality Label called "AQuA" (Agriculture, Quality, Environment) established by the law n. 21/2002 of the Friuli Venezia Giulia Region.

A herd of about 20 heads of two cattle breeds indigenous to the area and in danger of being lost to farming (Pezzata Rossa Friulana and Podolica) will also be reared in accordance with EC Reg. n°817/2004.

Dairy cows will be milked by new robot milking facilities to improve animal welfare (Pirlo et al., 2005)

Energy supply. About 30% of the total energy supply (fertilizers, electricity, fuel, fodder, etc.) is currently provided from outside the farm. The cost for the supply of electric and thermal energy is about 37000 Euro a year (Table 3). The objective for the year 2012 is to reduce external energy to no more than 10%. The most significant tool to achieve this goal is to use an anaerobic digester (AD-Nett). The slurry tank will also be fed by crop residues and by dedicated crops (e.g. silage maize). The anaerobic digester will produce biogas (Jodice & Tomasinig, 2006) to be utilised for trigeneration processes (heat, fresh and electricity) (Figure 2). The quantities of biogas, electricity and thermal energy are reported in Table 3. By-products deriving from the process may be utilised to improve soil fertility.

More results are shown Table 4 and Figure 2.

Table 4 Farm supply in terms of biogas, electric and thermic energy

Stocking rate(lw m. 400 kg)	-	540
Dung production	t/y	6900
Biogas production	Nm^3*10^3/y	138
Electric energy	MWh/y	240
Thermal energy	MWh/y	400
Green Certificates	Euro	26186
Income from selling electricity	Euro	22844
Total	Euro	49030
Average energy requirement	Euro	37000

Soybean varieties selected by ERSA (Hilario, Aires, Ascasubi, Pedro, Bahia Blanca, Colorado) and other varieties all with low anti-nutritional factors content (trypsin inhibitor, lipoxygenase activities) dried and employed to feed animals have a content of 18-20% of oil and 34-41 % of CP. Nevertheless, the oil content is too high for the animal diet therefore about 65% must be extracted to make the soybean cake obtained useful for animal feeding. The extracted oil can be used as fuel for engines of the farm to save energy. From 100 kg of soybean it is possible to extrude by a use of cold press 10-13 lt of vegetable oil. This extruded oil is very viscous (33W vs gasoline 2-4.5W) therefore it must be mixed with Diesel fuel (about 30% oil and 70% Diesel fuel) to assure an appropriate

combustion. First results after 100 h show that the performance of all engines is not significantly different. The cost of the soybean oil is about 1/3 of the diesel oil cost.
The principal ecological objectives are:
- Self-sufficient livestock activity: Animals will be fed almost exclusively with farm produced feedstuff. A very small amount of concentrates will be provided from outside the farm system.
- Reduction of off-farm resources: Fossil fuels from outside the farming system will be provided and integrated with vegetable oil. A significant reduction of pesticides and mineral fertilisers will also be possible using more resistant varieties and less energy demanding cultivars.

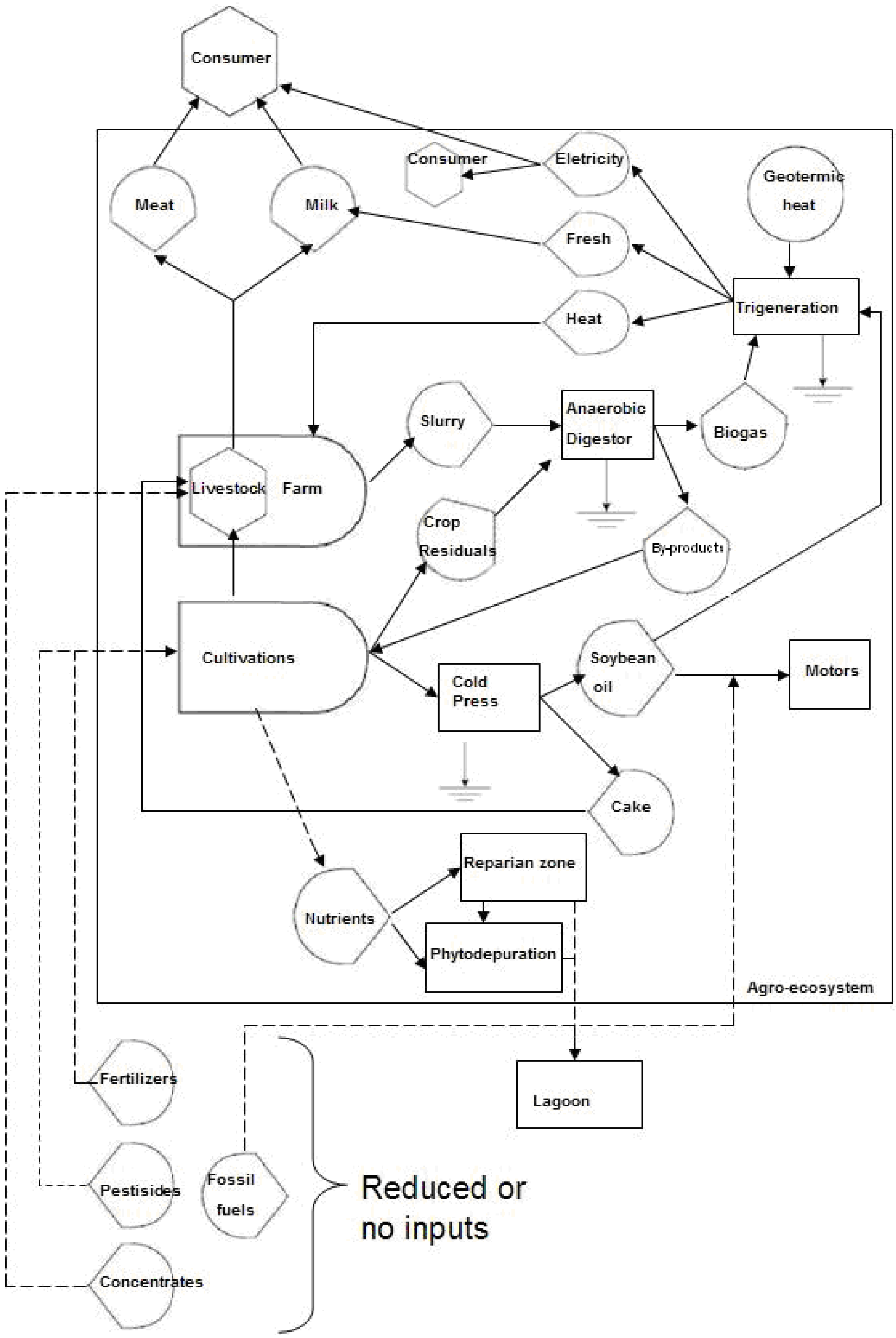

Figure 2 Energy flow diagram of the Marianis-Volpares Agroecosystem as proposed in the project. The utilized symbology is by H.T. Odum (H.T. Odum & E.P.Odum, 1982; H.T. Odum, 1996)

- Use of renewable energy. Oil extruded from soybean will be used to reduce fossil fuel consumption from outside and possibly the geothermic energy obtained from deep water present in the farm deep soil which has a temperature of 25 °C.
- Implementation of riparian buffer systems to reduce diffuse water pollution both into the soil and in the lagoon.

Farm buildings. A large part of the farm buildings will be restored. The present barns for milking cows, milking parlours, beef cattle sheds, warehouses will be restored while the substitution of asbestos cement roofs is in progress. Slurry tanks, platforms for manure and facilities for outdoor clamp maize silage will be also renewed and covered by roofs to avoid run-off effects.

Tourist facilities A cycle way of 2.38 km which borders with the farm will be connected with a new cycle way towards the farm of a total length of 18.31 km. In one of the restored houses the farm products will be offered to the tourists and visitors.

The design of the final project which will be realized in the Marianis-Volpares farm is shown in Figure 3.

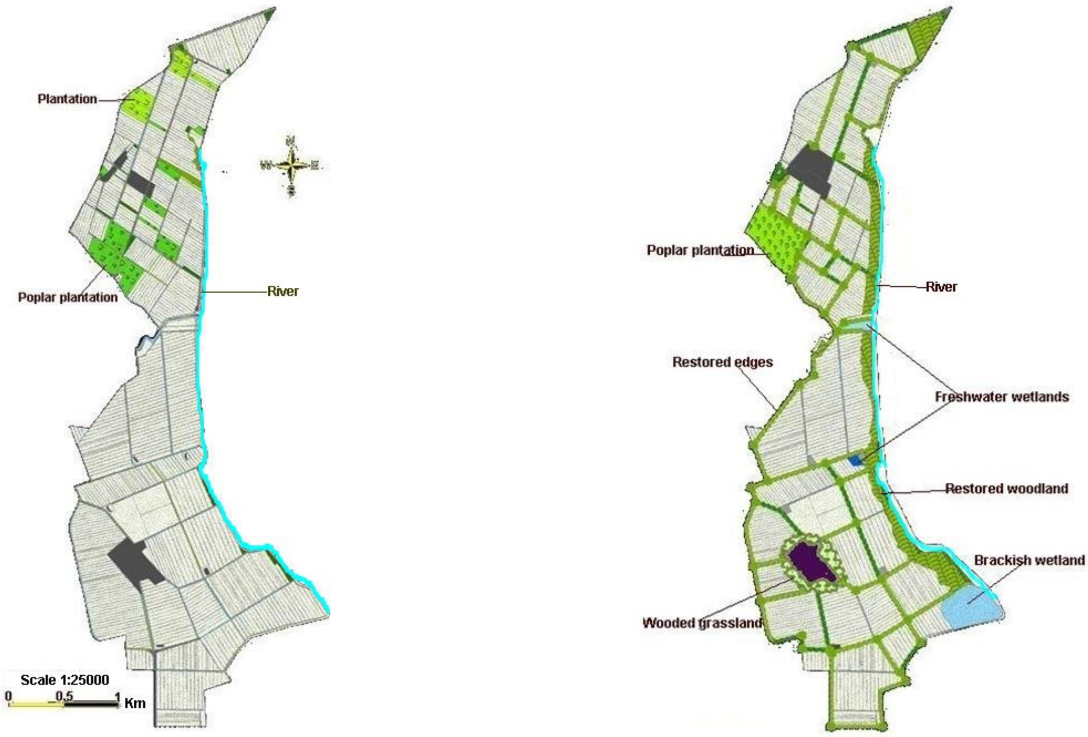

Figure 3 Marianis-Volpares environmental retraining: landscape elements in the current (left) and in the projected (right) situation

Economic aspects. The cost of the interventions which will be realized in the period 2006-2012 are shown in Table 5. The amortization plan should be carried over a period of 10 years. Considering the already financed actions (roof replacement, 495000 Euro) and a possible intervention by private companies (demolition and restoration of houses for agri-tourism activities, 780000 Euro) the real cost will be of 2660000 Euro.

Table 5 Economic sustainability.

Replacement of asbestos cement roofs *	495000
Reclamation of barns for dairy cows, boxes, paddocks, milking boxes, robot, slurry tanks, etc.	600000
Reclamation of barns for dry cows and heifers, boxes, dung management, etc.	240000
Agricultural and farm machines	350000
Facilities and roofs for dung and slurry	250000
Demolition and restoration of houses**	780000
Outdoor clamp for silage maize	300000
Digester plant, phytodepuration plant and facilities for energy supply	800000
Reforestation, freshwater and brackish wetlands, bank for cycle ways, parking areas	120000
TOTAL	3935000 EURO

*already financed and in progress
**with possible private intervention

Conclusions Agricultural policy in the EU has seen dramatic changes in recent years, with greater emphasis placed on the reduction of surplus output and protection of the environment. The misuse of resources, the inequitable distribution of income between consumers, increasing farm size and reduced opportunities for new entrants to agriculture, the decline in the rural population, damage to the environment from agricultural pollution, the increasing concern about the quality and safety of food and water supplies are the most important problems are acknowledged by the society. Therefore, many people recognize that the new agri-environmental strategy of the CAP offers the opportunity for a change in direction of agricultural development. There is a need to apply the perspective of an ecological approach to agriculture and to convert the present HIFS to organic farming systems (Lampkin, 1990) or at least to LIFS or lower input farming systems. Therefore, an ideal LIFS should be a system in which the output/input ratio is the highest possible in respect of the environment and in the principle of saving energy. To farm in LIFS means also relying on existing indigenous resources, biological processes and ecological interactions to maintain soil fertility, meet the real nutrient requirements of livestock and crops, control pests and diseases and provide sufficient food, food security and economic security for rural communities. The period of conversion from HIFS to LIFS, during which lower yields and increase of investments with or without benefit of premium prices occur, will be certainly very difficult financially and therefore farmers must be guided through it. Experimental and demonstrative farms like the Marianis-Volpares, managed by ERSA, may be important tools to meet al least some of the most important agricultural and environmental policy objectives.

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The ecopoint system of Lower Austria: an example of subsidising low intensive farming and evaluation of the ecological, energy and economic performance of farmers

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Abstract Firstly the ecopoint system is introduced as a subsidy system for farmers in Lower Austria for the upkeep of cultivated landscape and for the promotion of environmentally adequate farming methods and low intensive farming by using the parameters: crop rotation, soil cover, parcel size, fertilising intensity (FI), mode of manuring/fertilising (MMF) and pesticides used (PU) for the mode of production on arable land and permanent crops whereas on grassland the parameters are cutting rate for meadows and stocking rate for pastures, grassland age and again FI, MMF and PU. On each field parcel landscape elements are also counted and transformed into ecopoints.
So the variety of the farm landscape is very important. Also for all the other parameters the basic concept is „from – to". This means that the farmer achieves more ecopoints the better the actual farming is so there is a steady incentive to get always better. This can be shown with figures of 2435 farmers over several years.
Secondly a lot of data of 134 ecopoint farmers are analysed from various sides. Their ecological performance (expressed in ecopoints and in kilogram Nitrogen (kgN)) is combined with their energy performance (therefore the method of SOLAGRO is used; < 300 equivalent litre fuel/ha = low input farming) and their economic performance (receipts minus costs = income per farm or per ha). Evaluations are done comparing low input and high input farmers, comparing small scale (< 16 ha farmland) and large scale farms, comparing conventional and organic farming and finally comparing milk production and suckling cow production.

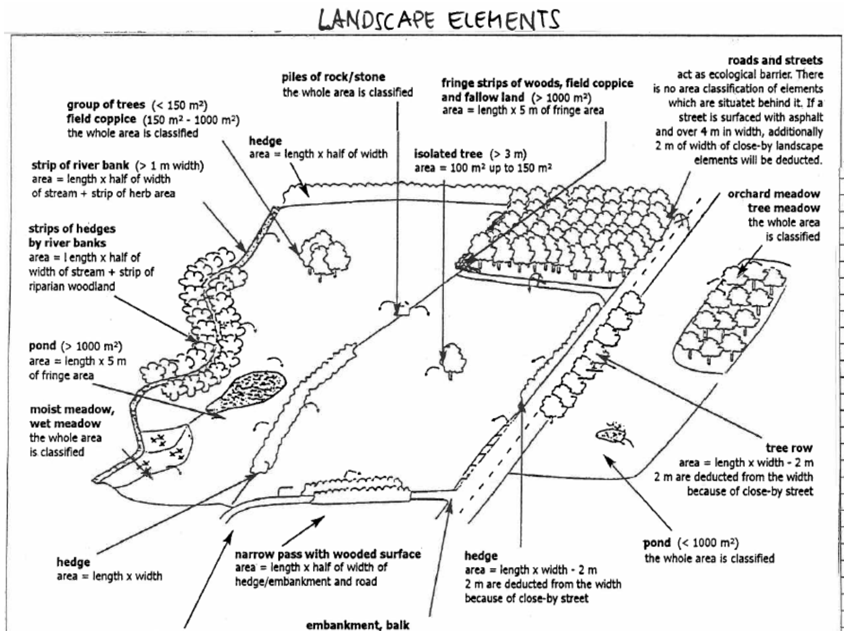
The ecopoint system is an independent program in Lower Austria in the framework of the Austrian Environmental Program called ÖPUL with the same cofinancing. It is a program for the upkeep of cultivated landscape and for the promotion of environmentally adequate farming methods. The variety of landscapes is very important for the program. That means that the program has an impact on very rich-structured regions in Lower Austria, and gives special consideration to mountainous regions. Farmers receive a premium which is calculated according to how hightheir "environmental standard" of cultivation per hectare agricultural land is. As a result, the ecological achievement is up to the farmer. He decides himself how environmentally adequately and extensively he wants to cultivate and accordingly how high his premium is.
Basically, the ecopoint system is orientated at the ecological achievement on each ha of agricultural land regarding all the environmentally relevant parameters fixed in the program (details included in the following survey). That means that single parameters cannot be chosen. Ecopoints 'from – to' (consequently also premiums "from – to") are awarded per parameter on account of the ecological achievement.
A further feature of the ecopoint system is that the ecopoint farmer does not have to commit to a specific mode of cultivation in advance, but he receives a payment according to his actual farming.
Of course, it needs to be taken into account, that the "environmental standard" (expressed by the average number of points) of the first year of participation in the program must be kept until the end of the period of participation.

Table 1 Ecopoints framework for single parameters (number of ecopoints for achievements)

ARABLE LAND and PERMANENT CROPS	Range of points	GRASSLAND (meadows + pastures)	Range of points
Crop rotation	0 to +7	Cutting rate (meadows) resp. Stocking (pastures)	0 to +6
+		+	
Soil cover	0 to +7(12)*	Grassland age	0 resp. +3.5
+		+	
Parcel size	0 to +5	Fertilising intensity	-6 to +8
+		+	
Fertilising intensity	-9 to +6	Mode of manuring/fertilising	-6 to +5
+		+	
Mode of manuring/fertilising	-6 to +7	Pesticides used	-7 to 0
+		+	
Pesticides used	-7 to 0	Landscape elements	0 to +25
+			
Landscape elements	0 to +25		

* up to 12 points in very low-precipitation areas

Crop rotation: a wide crop rotation with a high amount of forage crops (instead of row crops for example silage maize) means more ecopoints.
Soil cover: the longer the soil is covered during the year (intercropping, forage crops,…) the more ecopoints can be achieved.
Fertilising intensity: it is the most important parameter for the evaluation of the intensity of cultivation on arable land and on grassland. It is evaluated by the quantity of nitrogen (N). All N-amounts from farm manure-N, N-quantities through grazing, fertiliser-N, N-quantities from residues and the preceeding crop effects of leguminosae etc. are taken into account equally. In addition, it is also taken into consideration that "better" soils have a higher yield capacity, as a result higher amounts of N are acceptable than on "poorer" soils. An "acceptable level" (0 points) is reached if no higher N-amount is fertilised than needed. There are minus points for higher amounts and plus points for lower amounts. No fertilising means the maximum of points.
Mode of manuring/fertilising: if there are more solid and less easily soluble components in the fertiliser more ecopoints can be awarded - for dung and manure compost 2 points can be achieved, 0 points for slurry, dung water and mineral fertiliser. For the determination of points regarding the spreading of fertiliser: the smaller the amount of fertiliser per application, the safer for the environment. In addition, there are more ecopoints to achieve (up to 3 points). As a result, 5 points can be awarded. 2 additional points can be added in cropping, if the straw resp. harvest residues of the preceeding crop are worked in.
Cutting rate or Stocking: Again considering the soil quality more points can be obtained for these grassland parameters if there are one or two cuts less than usual or if there is a lower stocking intensity on pastures as usual. The absence of cutting ('fallowing') is not considered as an ecological achievement (0 points).
Grassland age: grassland renewed within the last 5 years means 0 points during this period. Natural and older grassland receives 3.5 points.
Parcel size: on arable land (and permanent crops) 5 points are achieved for a field parcel size of less than 0.5 ha, 4 points for < 1 ha, 3 points for < 1.5 ha, 2 points for < 2 ha, larger parcels (more than 2.5 ha) are not classified.
Pesticides used: once means minus 1 point, twice minus 2 points and so on up to more than 10 times minus 7 points.



VALUATION KEY

Prozent LE	Ökopunkte für LE bei einer WW-Punkteanzahl von		
	bis 6	6-13	über 13
1	0,8	1,0	1,2
2	1,6	2,0	2,4
3	2,4	3,0	3,6
4	3,2	4,0	4,8
5	4,0	5,0	6,0
6	4,8	6,0	7,2
7	5,6	7,0	8,4
8	6,4	8,0	9,6
9	7,2	9,0	10,8
10	8,0	10,0	12,0
11	8,8	11,0	13,2
12	9,6	12,0	14,4
13	10,4	13,0	15,6
14	11,2	14,0	16,8
15	12,0	15,0	18,0
16	12,4	15,4	18,5
17	12,7	15,9	19,0
18	13,1	16,3	19,5
19	13,4	16,7	20,0
20	13,8	17,1	20,5
21	14,1	17,6	21,0
22	14,5	18,0	21,5
23	14,9	18,4	22,0
24	15,2	18,9	22,5
25	15,6	19,3	23,0
26	15,9	19,7	23,5
27	16,3	20,1	24,0
28	16,6	20,6	24,5
29	17,0	21,0	25,0
30	17,1	21,1	25,0
50	18,2	22,2	25,0
100	21,0	25,0	25,0

Figure 1 Landscape elements and the valuation key

Each landscape element (LE) is classified to the plot of field on which it is situated. If it is not situated on a plot of field, it is classified to the close-by plot of field. The number of points results in accordance with the percentage of LE per area (see column "Prozent LE' valuation key). The maximum number of points to achieve are 25 per ha. If a plot contains 30% of LE this amount is equally to 100 %. This number of points can be achieved if the farming on the fields is very environmentally-friendly and extensive. This is the case in at least 13 ecopoints for mode of cultivation parameters per ha (see columns 'WW-Punkteanzahl').

Ecopoints per parameter are added per area and summed up for the sum of ecopoints of a farm. The premium per ecopoint was 13.08 € on arable land and grassland areas (resp. 26.16 € on areas of permanent crops like wine and fruit) for the program period 2001-2006 and will decrease to 10.7 € for the period 2007-2013.

Currently (2007) around 4000 farmers with about 78000 ha agricultural land participate in the program. The average premium for these farming enterprises was about 370 € per ha and year in the period 2001-2006 and will be around 290 €/ha in the period 2007-2013. The program allows numerous small scale farms and upland farms receive an adequate payment for their ecological achievement as well.

The development per parameter and in N-fertilising is shown in the next two figures taking into account 2435 farmers participating in the Ecopoints program within ÖPUL 2000 since 2001. The figures show the development in the first 4 years of participation in the program period 2001-2006.

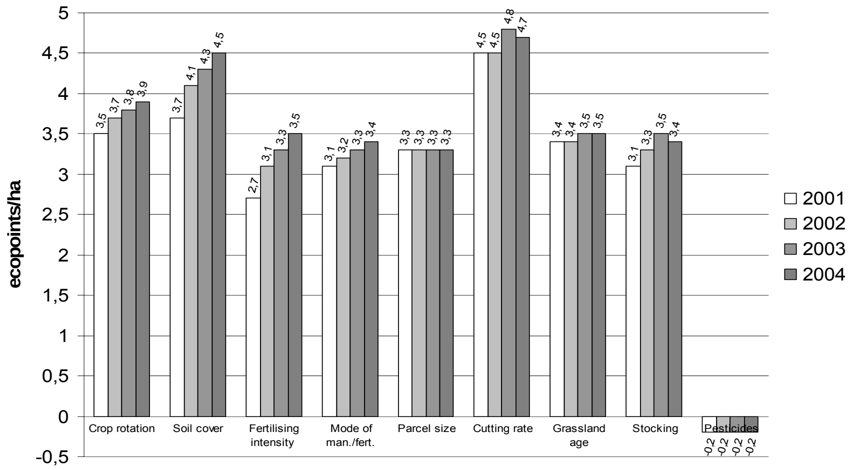


Figure 2 Development of Ecopoints/ha and parameter 2001-2004 (2435 farms with 43600 ha agricultural land)

In particular, crop rotation and soil cover, which are the main parameters indicating how environmentally-friendly the mode of production on arable land is, show a strong upward tendency. It is manifested as more forage crops, less row crops, more greening and intercropping. The high level in grassland use is maintained (parameters: cutting rate, stocking, grassland age). Also fertilising intensity and mode of manuring/fertilising as the main parameters indicating the intensity of land use point into the same direction. More Ecopoints/ha means lower amounts of N applied and a much better mode of manuring/fertilising. (see Fig. 3)..

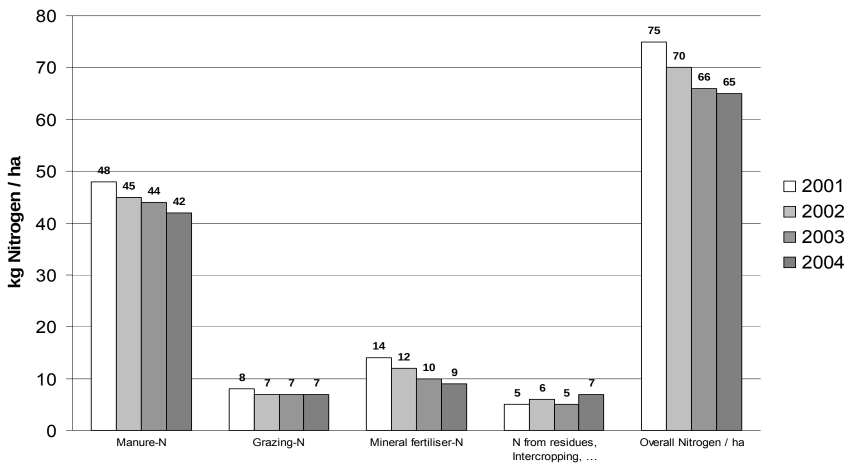


Figure 3 Development of N-fertilising/ha 2001-2004

12 % less manure-N/ha means a strong reduction of cattle on the farms, 35 % less mineral fertiliser-N/ha is remarkable; overall after 4 years of participation 2435 farmers have 13 % less N application on their agricultural land.Therefore, they have reached a high level of extensification, steadily promoted by the Ecopoint system.

Evaluations In addition to the participation in the Ecopoint program there is also an advisory system established for the farmers concerning various questions about the program. By using their own data collected year by year for Ecopoints concerning their mode of production the farmers can reflect on their current ecological performance and discuss and consider various possibilities of getting better together with Ecopoints farm advisors. So far around 2200 farmers (of the 4000 farmers in the program) have used this opportunity.

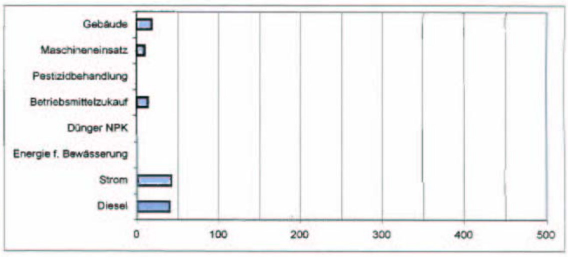
Since 2002 the farmers have also had the possibility to check their own farm not only from an ecological point of view (expressed in Ecopoint parameters and results and also in kg nitrogen application) but also in terms of energy (energy input and output of production, efficiency etc. expressed in equivalent litre fuel/ha; where the method of SOLAGRO is used) and at the same time their economical performance. That means that the farmer himself does the calculation of receipts (receipts of crop production and animal production and of subsidies from ecopoints and from compensation payments) on one side and his variable costs (costs of feedstuff, direct energy (electricity, fuel), fertilisers, pesticides,…) and fixed costs (for assurances, taxes, rented land, also taking into account the write-off of machinery and buildings) on the other side. In this way the farmer can analyse his farm from a very holistic point of view. In the years 2002-2006 134 ecopoint farmers did this holistic analysis of their farms.

Using the data obtained from those farmers some evaluations according to the topic of the JRC Summer University of „Low Input Farming Systems“ can be done, especially by comparing low input with high input farming systems. Using the method of SOLAGRO 300 equivalent litre fuel/ha of direct and indirect energy used is defined as the limit for low input farming. Having 71 low input and 63 high input farmers in the sample, in each local ecopoint region low and high input farmers can be found.

In the main grassland region "Voralpengebiet" there are figures of the energy performance of a low input milk production farmer (with 125 equiv. l fuel/ha) compared with a high input farmer (with 691 equiv. l fuel/ha) as follows (Fig. 4):

Energieverbrauch (direkt und indirekt) und Energieproduktion

Energieverbrauch	MJ / Jahr	äquiv. Diesel / Jahr	MJ/ha LN	äquiv. Diesel / ha LN
Diesel	30.672	851	1.431	40
Strom	32.508	902	1.516	42
Energie f. Bewässerung	0	0	0	0
Dünger NPK	0	0	0	0
Betriebsmittelzukauf	11.156	310	520	14
Pestizidbehandlung	0	0	0	0
Maschineneinsatz	7.974	221	372	10
Gebäude	14.521	403	677	19
Gesamtverbrauch	**96.831**	**2.687**	**4.516**	**125**

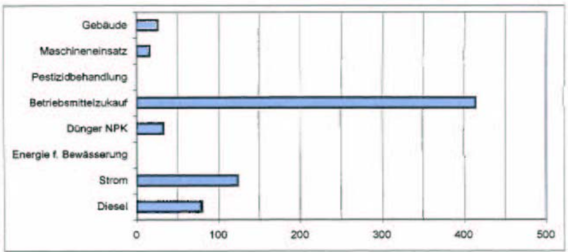


Energieproduktion	MJ / Jahr	äquiv. Diesel / Jahr	MJ/ha LN	äquiv. Diesel / ha LN
Milch	137.477	3.815	6.412	178
Fleisch	89.110	2.473	4.156	115
Getreide	0	0	0	0
Gesamtproduktion	**226.587**	**6.288**	**10.568**	**293**

Energiebilanz :	2,34
Energieverbrauch :	2.687 äquiv-l Diesel / Jahr
	125 äquiv-l Diesel / ha LN
	6 für 100 l verkaufte Milch

Energieverbrauch (direkt und indirekt) und Energieproduktion

Energieverbrauch	MJ / Jahr	äquiv. Diesel / Jahr	MJ/ha LN	äquiv. Diesel / ha LN
Diesel	72.000	1.998	2.874	80
Strom	111.456	3.093	4.449	123
Energie f. Bewässerung	0	0	0	0
Dünger NPK	29.475	818	1.177	33
Betriebsmittelzukauf	373.380	10.362	14.905	414
Pestizidbehandlung	0	0	0	0
Maschineneinsatz	14.400	400	575	16
Gebäude	23.233	645	927	26
Gesamtverbrauch	**623.945**	**17.315**	**24.908**	**691**



Energieproduktion	MJ / Jahr	äquiv. Diesel / Jahr	MJ/ha LN	äquiv. Diesel / ha LN
Milch	346.882	9.626	13.848	384
Fleisch	79.192	2.198	3.161	88
Getreide	0	0	0	0
Gesamtproduktion	**426.074**	**11.824**	**17.009**	**472**

Energiebilanz :	0,68
Energieverbrauch :	17.315 äquiv-l Diesel / Jahr
	691 äquiv-l Diesel / ha LN
	15 für 100 l verkaufte Milch

Figure 4 Energy performance of 2 milk production farms („LOW“, „HIGH“) in the region „Voralpengebiet“

The low input farmer produces 5100 l milk per cow and year, the high input farmer 5800 l. The higher milk production is achieved by much more energy used for production (especially indirect energy for feedstuff (‘Betriebsmittelzukauf’) and direct energy for electricity (‘Strom’) and fuel (‘Diesel’). The low input farm is a good example of an excellent ‘basic fodder’ management. Without the need of purchased feedstuff 5100 litre milk per cow and year can be produced.

The next two figures show a short farm description and the „Ecology-Economy performance of the same 2 milk production farms.

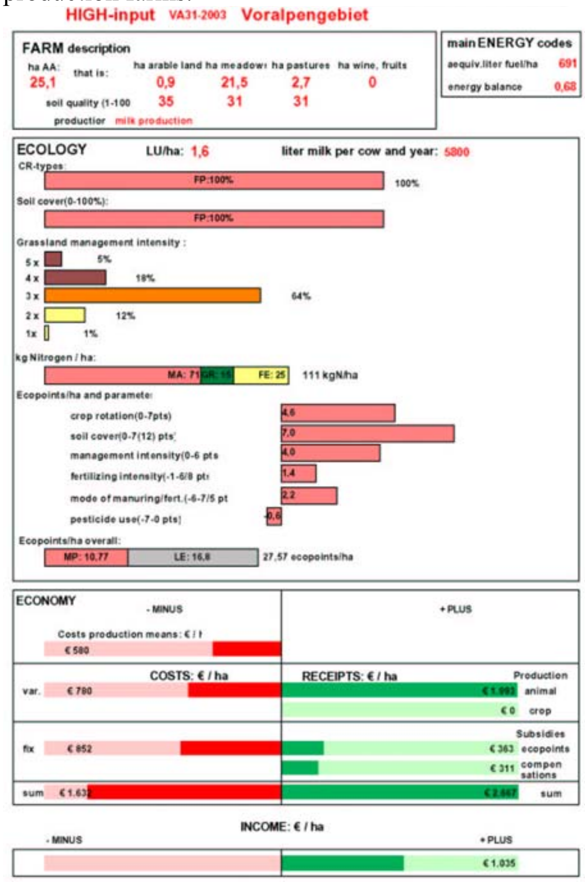


Figure 5 Ecology-Economy performance of 2 milk production farms (low/high input) - region „Voralpengebiet“

Comparison of the farms: both are situated in the same region with similar soil quality, almost the same farm size, LOW – 1.2 livestock units/ha (LU/ha), HIGH – 1.6 LU/ha. Application of nitrogen: LOW - 63 kgN/ha only from the cattle (MA = manure-N and GR = grazing-N), HIGH - 111 kgN/ha from MA, GR and FE = mineral fertiliser-N. That means how many Fertilising intensity ecopoints/ha: LOW – 5.1, HIGH – 4.1. Ecopoints for all mode of production parameters: LOW – 16.33, HIGH – 10.77. Looking at the economic performance: there are around 500 €/ha more production means costs for the HIGH farmer, but there are also around 1000 €/ha more receipts from milk production. It seems to make sense to produce with high input. 500 €/ha is also the difference in the overall income/ha between both farms.
Comparing farmers of one and the same region in the same way as we did above the results are very different. It would not be correct for example to say that low input means lower or higher income/ha, on both sides there are farmers with a positive income, but there are also some with a negative income (22 % of the low input farmers, 25% of the high input farmers).

On the next page two comparisons are made: Above the „Ecology-Economy performance“ of 71 LOW input and 63 HIGH input farms with the following main conclusions: indirect and direct energy used: LOW - 202, HIGH–500 equiv. l fuel/ha; ecological performance: livestocks: LOW – 0.9, HIGH – 1.1 LU/ha. Nitrogen application: LOW–58.9, HIGH–75.9 kgN/ha. Fertilising intensity ecopoints/ha: LOW – 3.8, HIGH – 2.7; and for all mode of production parameters: LOW–16.4, HIGH-14.4. So overall LOW farmers have a better ecological performance. Coming to the economical results: production means costs are: LOW – 177, HIGH - 441 €/ha. The difference is 264 €/ha, but the receipts of production overall are: LOW 715, HIGH – 1174 €/ha. The difference is 459 €/ha. Again it seems to make sense to produce with high input, because overall the income of HIGH farmers (421 €/ha) is higher than the income of the LOW farmers (276 €/ha).
Below the „Ecology-Economy performance“ of 44 SMALL scale farms (small scale = < 16 ha agricultural land) and 90 LARGE scale farms with very interesting main conclusions: there is no significant difference between SMALL and LARGE scale farms: SMALL/LARGE 325/350 equiv. l fuel/ha, 1.0/1.0 LU/ha, 65/68 kgN/ha, 3.1/3.4 Fertilising intensity ecopoints/ha and 14.9/15.5 mode of production ecopoints/ha overall.
There is also another aspect of economic analysis: similar production means a little bit higher receipts of LARGE farms but on the other side a little bit higher subsidies of SMALL farms lead to a similar income/ha. The income does not depend on the scale of the farm:15 of 44 SMALL and also 15 of 90 LARGE scale farms have a negative income!

Figure 6 Ecology-Economy performance of 71 LOW input farms and 63 HIGH input farms

Figure 7 Ecology-Economy performance of 44 SMALL scale farms and 90 LARGE scale farms

On this page 35 CONVENTIONAL and 14 ORGANIC (BIO) farmers of 2 grassland regions are compared:

Figure 8 Ecology-Economy performance of 35 CONVENTIONAL and 15 ORGANIC (BIO) farmers

Conclusions: Comparing the 2 groups of farmers we can see firstly that conventional farmers are overall higher input farmers (CONVENTIONAL – 355, BIO - 155 equiv. l fuel/ha).

All Ecopoint parameters show a better ecological performance of BIO farmers: CONVENTIONAL/BIO: 1.1/0.9 LU/ha, 62.8/48.4 kgN/ha, 4.0/5.1 Fertilising intensity ecopoints/ha and 15.3/16.9 mode of production ecopoints/ha overall.

Higher production means costs of CONVENTIONAL farmers (339 €/ha, BIO – 137 €/ha), but also much higher receipts of production (1116 €/ha, BIO - 559 €/ha). This can be explained because most of the CONVENTIONAL farmers have milk production, most of the BIO farmers suckling cows. Although BIO farmers get higher subsidies, especially from Ecopoints, their overall economical performance is not as good. That means that BIO production does not necessarily lead to a better farm income. The contrary seems to be true under current conditions.

As a final element of the analysis some differences between milk production and suckling cow production farmers are highlighted.

Table 2 Comparison of data of 69 milk production farms and of 32 suckling cow production farms

Evaluation:		MILK-PRODUCTION						SUCKLING COWS					
LOW				HIGH				LOW			HIGH		
liter milk/ cow and year	receipts - €/ha	costs prod. means = €/ha	difference € /ha	liter milk cow and year	receipts - €/ha	costs prod. means = €/ha	difference € /ha	receipts - €/ha	costs prod. means = €/ha	difference € /ha	receipts - €/ha	costs prod. means = €/ha	difference € /ha
4300	498	140	358	4650	651	386	265	472	220	252	402	287	115
4650	1210	170	1.040	4650	1094	196	898	781	168	613	435	278	157
4650	1242	176	1.066	5730	1065	248	817	432	259	173	508	280	228
4650	945	216	729	6930	1283	330	953	167	110	57	529	230	299
6230	1194	200	994	4650	799	343	456	530	119	411	550	235	315
4650	534	220	314	7700	801	529	272	308	291	17	⌀ 485	⌀ 262	⌀ 223
6000	985	278	707	4650	786	392	394	300	108	192		5 farms	
4650	667	186	481	6000	1658	478	1.180	496	261	235			
5950	542	209	333	5500	1088	422	666	500	157	343			
6000	723	268	455	6600	1618	500	1.118	680	253	427			
7420	1773	223	1.550	4650	2138	482	1.656	481	120	361			
4650	517	171	346	5475	1336	726	610	623	227	396			
5700	1452	284	1.168	4650	1105	502	603	817	122	695			
4650	326	196	130	6500	1456	517	939	268	102	166			
4650	1313	250	1.063	7200	1444	381	1.063	449	123	326			
7100	2098	261	1.837	4650	1417	269	1.148	518	163	355			
7090	1326	197	1.129	7500	2115	484	1.631	514	142	372			
5100	998	84	914	4650	1428	561	867	700	50	650			
6690	917	183	734	4650	2086	430	1.656	501	207	294			
4650	635	130	505	7200	1030	220	810	240	67	173			
4650	1092	206	886	6500	910	250	660	187	30	157			
8014	1246	278	968	4650	581	215	366	534	127	407			
4100	766	104	662	6190	1467	288	1.179	892	147	745			
5290	739	194	545	6910	1504	339	1.165	311	29	282			
6000	732	100	632	4490	731	405	326	442	24	418			
4650	392	79	313	6700	1156	390	766	97	64	33			
4650	1073	183	890	4650	919	270	649	416	143	273			
5800	1120	301	819	4650	1676	344	1.332	⌀ 469	⌀ 142	⌀ 327			
5650	627	194	433	5800	1992	580	1.412		27 farms				
4650	1256	286	970	7390	1567	405	1.162						
4650	1205	263	942	5888	894	293	601						
31 farms	⌀ 972	⌀ 201	⌀ 771	6218	1303	364	939						
				7794	1302	276	1.026						
				7900	1485	486	999						
				5610	1440	318	1.122						
				6000	1718	455	1.263						
				4650	1296	507	789						
				7100	1113	258	855						
				38 farms	⌀ 1.301	⌀ 391	⌀ 911						

LOW/HIGH: 55 % (38 of 69) of the milk production farmers produce with higher inputs than 300 equiv. fuel/ha, but 84 % (27 of 32) of the suckling cow farmers in the ecopoint program are low input farmers.

Focusing on the group of milk production farmers we can see that higher inputs in terms of production means that costs do not necessarily lead to better results concerning milk yields per cow and year. A good 'basic fodder' management of the farm can lead to the same milk yields per cow and year. But if we calculate the difference between receipts of milk production and production costs it is bigger for HIGH input compared with LOW input milk production farmers (Ø 911 €/ha HIGH, Ø 771 LOW). It „works" if a farmer uses more feedstuff and direct energy to produce more milk.

Focusing on the group of suckling cow production farmers, if we again calculate the difference between receipts of animal production and production costs, it is bigger for LOW input compared with HIGH input suckling cow farmers (Ø 327 €/ha LOW, Ø 223 HIGH). For suckling cow production it „does not work" if a farmer uses more feedstuff and direct energy for production. The more and the longer the cattle graze during the year the better it is.

Finally, comparison of both groups with regard to the amount of receipts from production shows that the group of milk production farmers reaches a much higher level (receipts LOW: 972 €/ha, HIGH: 1301 €/ha) compared with the group of suckling cow farmers (receipts LOW: 469 €/ha, HIGH: 485 €/ha).

The receipts of milk production are more than double as high as of suckling cow production!

Low input farming system: sustainable agriculture in the Ticino Park

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The Natural Park of the Ticino Valley is one of the first established in Italy. It follows the stream of the Ticino River in the Italian part and represents a natural corridor which connects the Alps with the Po River. This river, which flows from east to west, forms the largest Italian plain, which is crossed by the Ticino River from north to south.

The Park covers ca. 900 km^2 of natural (forests and wetlands), agricultural and urban areas and is managed in accordance with the Territorial Coordination Plan. About 200 km^2 are occupied by residential centres, with artistic and architectural testimonies that are among the most important in the Italian history of the art as well as archaeological areas that date back to VII-VIII century B.C. More than half of the Park (500 km^2) is under agricultural use.

The Ticino Park is one of the most important geographic areas for the Italian economy, with a population of about 450.000. It is cut perpendicularly by the motorway 'Turin-Milan' and by the new high capacity/high speed railroad lines.

The Park is particularly well-known for its extensive preservation of the river course which, devoid of artificial barriers, is surrounded by a wide range of areas covered by autochthonous plains forest. In this context the large cultivated surface assumes a high importance for the park.

Although the soil is greatly variable, it is very fertile, well irrigated and highly productive. There are 1.500 farms in the Park and most of them are well organized and highly productive.

The importance of an external agricultural band along the river forest of '*strict nature or managed reserve*' is manifold:

a) it has the function of a natural filter, which is essential for the good maintenance of the wooded areas and the riparian areas;
b) it contains the most important historical and cultural testimonies of Ticino's territory;
c) a great number of farms which provide income and employment are located in this zone of the park.

Several years ago the Park authorities decided that a territorial and social patrimony of these dimensions and value should not be used only as a buffer for a fragile river ecosystem. It was also necessary to safeguard the territory values focusing on social viability of the territory and economic and productive competitiveness increasingly based on product quality and diversification.

The tools which are available for this change in the rural world are for instance:

- a system of communication, information and animation of the rural areas, which is based not only on national range of instruments but also on European Union's policy;
- specialised technical assistance adapted to clear goals to be achieved;
- a normative system that permits interventions in building field and also in those professional activities that are indirectly connected with productive system;
- the creation of a logo for organic and integrated agricultural products;

These initiatives are giving excellent qualitative results. Although implemented inside a universe which is very closed and reluctant to deep changes, they have been created to consider the Ticino Park as an agricultural territory with more profitable functions. In this context, the essential perspective of the Ticino Park is to integrate and better organize the '*Plans of sustainable development*'.

Towards sustainable agriculture

The agricultural territory of the Park covers a surface of around 500 km^2, more than half of the whole protected area. The agricultural models change in relation to characteristics of the territory. Small livestock breeding and forest management are present in the zone of moraine hills, whereas cereal crops and cereal-livestock systems are present in the non-irrigated and in the irrigated plain, respectively. In the irrigated plain the main cultivated crops are maize and rice. Well organized dairy and beef cattle farms are also present. In the major part of Lombardy the agriculture was high input oriented agriculture: this orientation is also present in the plain part of the Ticino Park.

In the 1980s and in the early 90s, EU agricultural policies were production-oriented: the Park, in that moment, found itself in conflict with the agricultural world. Following modernisation, agriculture began to utilize higher rates of fertilizers and pesticides and to enlarge the cultivated surfaces to the detriment of hedges and hedgerow trees, which are essential elements of the landscape. Similarly, the historical cultivation systems, such as *marcite*

(permanent meadows which are productive also over the winter period thanks to an ingenious irrigation system) became unutilised due to the introduction of the total mixed ration (*unifeed*) as a feeding method in dairy farms.
The first great change happened in 1992 because of the approval of the 'Mac Sharry reform' of the Common Agricultural Policy of the European Community. For the first time agriculture was seriously oriented towards quality and not towards quantity and environmental topics gained attention thanks to the Regulation No. 2078/92/EEC which introduced the agro-environmental measures. The Park became aware of the historical moment: agricultural policy perspectives based on sustainability, particularly corresponding the with Park's goals.
It was necessary to add new development activities, to the institutional activities (i.e. estimation of the fauna decline, land reclamation authorisations etc.). First of all, the Park applied to the European Commission to join the rural Carrefour Network (Network of Rural Information and Animation Centres). Thanks to this new tool, the dialog with the farmers and with the public institutions has been strengthened throughout the whole regional territory and reached in a short time a very advanced operational level. The main examples of these activities are:

- direct assistance to many farms to maintain or rebuild the agrarian landscape (hedges, hedgerow trees, meadows, *marcite*);
- continuous promotion of these topics to the technicians and farmers', resulting in a constant increase of the number of farmers who applied agro-environmental measures;

A new approach was adopted to involve more farmers; many of them had asked 'Why would I want to introduce sustainable agriculture?' and the answer was: "Because you could:

- improve your income (thanks to cost reduction and subsidies)
- achieve a product diversification on the market
- restore landscape more appreciated by consumers and tourists
- achieve multi-functionality
- and, last but not least, protect the environment.'

This constant dialogue with farmers was coupled with exchange of experiences with other technicians at local, national and international level, with the main goal to extend the knowledge of organic and low input agriculture and to address their critical points.
Ticino Park has been responsible for the creation of support services useful for farmers in their search of sustainable models, such as:

- promoting ways of reducing chemical inputs (e.g. adjusting sprayers for weeds control), editing manuals and leaflets, introducing the use of personal computer in the farm for fertilisation plans;
- setting up experimental fields (12) for growing maize under "low input" system, based on a substantial reduction of chemical inputs and a subsequent dissemination of the results;
- assistance to the application of EEC Regulations (2078/92, 1257/99) and coordination of application plans, with production of handbooks, distribution of native plants, cooperation with regional authorities with the aim of constant updating of application rules, data publication, dissemination of the results;
- creation of a logo for organic and "low input" products, based on a rule which provides farmers with technical assistance and other types of support for marketing (fairs, promotions) free of charge.

The results have been very positive: in 1995 not more than ten farms joined the agri-environmental scheme, whereas in 2007 more than 400 farms are applying one or more agro-environmental measures (about 1/3 of all farms on the Park territory).

Low input and low impact

The particularity of the Ticino Park area is based on a combination of rules and support which give the opportunity to clearly identify different steps of efficiency for sustainable agriculture.
Outside the Park we can find conventional agriculture, which can be considered the departure step. All the farms inside the boundaries of the park must respect the Territorial Coordination Plan, with rules for biodiversity protection, land reclamation limitation, no herbicide use outside arable lands, landscape conservation and restoring, defence against urbanisation.
The third is the designation of the part of the Park as a Natura 2000 site (20.566 hectares of Special Protection Areas and 17.045 hectares of Sites of Community Importance), where the rules of Territorial Coordination Plan are stricter and a special regime of cross compliance is operating.
The fourth step is linked to the agro-environmental measures application, with low input farming systems (110 farms – 96 integrated, 14 organic), extensive crop growing such as meadows or *marcite* (167 farms), landscape and biodiversity measures such as hedges, hedgerow trees, wetlands (160 farms).
The highest step is based on a labelling farming system, where farms must follow organic or low input farming schemes and have to enter into voluntary agreements concerning landscape and biodiversity. In 2007, 26 farms and 1 processing plant (with complete traceability of the product) applied this system.

This last step aims at involving consumers in shaping agriculture orientation, rewarding farmers for their efforts. In the long run, subsidies cannot substitute market rules: for this reason it is necessary to improve labelling system for these agricultural products which are obtained with a low impact on the environment, while giving the consumers the choice and the possibility to select them (since European Eco-labels are not currently available for food products).
To complete the efforts of the Park in introducing agriculture with reduced inputs it is very important to consider also the energy aspect of the production chain. In this context, the Ticino Park coordinates the European project "*Wise-plans: Co-operation between Communities for Energy Action Plans",* which aims to create Sustainable Energy Action Plans (SEAPs) for more effective use and management of energy resources in Wales, Italia, Sweden and Spain. Agriculture is one of the main sectors involved in Parco Ticino SEAP (biomass and other renewable energies).

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SUMMARY OF THE DISCUSSION

Low Input Farming Systems (LIFS) definition

The concept of LIFS can cover many production systems (organic, integrated, conservation agriculture …). However, there is one constant: LIFS are seeking optimisation of on-farm resources, minimisation of off-farm resources use. This translates into having a more 'closed' production cycle (and, consequently, less external inputs) and requires more advanced agronomic skills. It also leads to mixed farming system, characterised by animal valorisation of vegetal production on farm and organic manure restitution to farm soil from farm husbandry. Mixed character of farming system optimally combines annual and perennial crops and animal production on the same farm.

A. LIFS Characteristics

- Lower Input Farming System means some extensification processes. This can translate into: (a) reduced production levels with larger area of land used in order to maintain the same revenue; or (b) reduced dependency on external inputs with similar production structure but improved valorisation of the product (through transformation and / or direct marketing, agro-tourism / multifunctionality). NB: reducing the length of the production chain is a sustainability concept (produce and consume locally). This, in turn, involves direct selling of agricultural products and short food chain. An important success factor is support for the development of multifunctionality (agri-tourism, crafts etc.).
- Minimising flow of water, manure and energy (energy efficiency).
- Taking space into consideration. Intensification is currently increasing in EU farming system but not in land used (space). Therefore, land abandonment in certain location can also be a consequence of intensification in others.
- Many LIFS farms also maintain Ecological Infrastructures (at least 5% in integrated farming) - which prove to be very beneficial for biodiversity - can provide shelter for organisms providing biological control and also be a source of raw material (wood) for producing on-farm energy.
- Optimum supply of nutrients for cultivated plants (not aiming for absolutely minimising them). In the light of recent analysis of characteristics of sustainable agriculture, the aim should not be to lower maximally the inputs but to optimise their use. Too great reduction in inputs may reduce drastically production levels which may in turn threaten the economic viability of a farming enterprise and lead to other environmental and socio-economic problems.
- Longer rotation systems, minimising risks of diseases and weed infestations.

B. Support needed to develop / optimise LIFS performance

- Independent advisory system, not linked to a particular company, cooperative or product
- Access to experimental farms open for farmers and agricultural advisors, offering up-to-date solutions for sustainable farming as skills of farmers can replace off-farm inputs;
- Environmental certification.

C. Perspectives

- The 2003 CAP reform gives EU farmers the freedom to produce what the market wants. This would translate into higher price volatility of agricultural products. In such context, a medium to long-term strategy would be to go for more resilient farming system (i.e. less intensive systems are better adapted to large fluctuations in prices of outputs (and also inputs). Strategy for selecting an optimal yield target rather than maximal, defining specific farming practices.
- A European label for LIFS products (green certificates) with respect to productions methods and food safety component (no pesticide residues …). The label should consider both the mode of production as well as reassure customers about quality and safety of products. Only this kind of label seems most likely to have the potential of attracting customer attention and persuading them to purchase the product, which would typically bear a higher price tag. To this end, there would be a need of a highly efficient information campaign, familiarizing customers with added value characteristics of the labelled products. On the other hand, to ensure wide participation in the proposed label system it needs to be affordable for farmers. This is pointed out in view of the current system of establishing a new label, which requires farmers to carry out costly yearly controls to remain in the system This constitutes a stronger burden for LIFS farmers, who normally have lower outputs and/or, due to the methods applied, do not produce a particular product in a sufficient bulk to be able to build a strong consortium of producers.

D. Policy aspects

- Recoupling (partially?), subsidies to LIFS (How?, via Cross-Compliance?)
- Shall Integrated Farming concepts become part of Cross-Compliance, instead of AEMs like today in some MS? This, however, can be dangerous because could water down / kill Integrated Farming.

E. Research needed

- Launch research activities on varieties, breeds adapted to LIFS in order to reach optimised results.
- Assess farm performances in a holistic way (economic / environmental / social). Develop methods for such assessment (Environmental / sustainable certificate)

Summer University
‘Low Input Farming Systems: an opportunity to develop sustainable agriculture’

Ranco, 2-5 July 2007

Summer University Scientific Committee:

Katarzyna Biala (JRC)
Philippe Pointereau (Solagro)
Maria Luisa Paracchini (JRC)
Jean-Michel Terres (JRC)

Programme

Monday, 2 July

10:00 – 12:00 Summer University and hotel registration

12:00 – 14:00 Lunch

14:00 – 14:45 Welcome/Opening of the Summer University **(JRC and Solagro)**
Presentation of the JRC and Solagro
Objectives and programme of the Summer University
Presentation of participants

SESSION 1 **Characterization of Low-Input Farming Systems (LIFS)**

Chairperson: **Jean-Michel Terres**

14:45 – 15:30 The stakes of low-input agriculture
Speaker: **Xavier Poux (AScA, France)**

Topics:
The importance of low-input farming systems in Europe
Driving forces behind low-intensive agriculture
Trends in the intensity of farming in Europe
Low-input farming systems and nature conservation.

QUESTIONS:

15:30 – 16:00 Characterization (+ elements of definition) of LIFS
Speaker: **Philippe Pointereau (SOLAGRO, France)**
Topics:
Discriminating variables allowing to build farming system typology
Inputs (fertilisers, pesticides & herbicides, energy, water, feedstuff)
Management intensity and efficiency
Efficiency of large-scale vs. small-scale farming
Energy balance at farm scale: PLANETE model – a study based on 1000 farms in France

QUESTIONS:

16:00 – 16:30 COFFEE BREAK

16:30 – 17:15 Farming systems and Life Cycle Analysis
Speaker: **Thomas Nemecek (Agroscope Reckenholz-Taenikon Research Station ART, Switzerland)**
Topics:
Methodical aspects: how does LCA work? What has to be considered, when LCA is applied to agriculture?
Results from the evaluation of low-input farming systems: comparison of the environmental impacts of intensive and extensive systems, conventional-integrated-organic farming.
Eco-efficiency of intensive and extensive systems.

QUESTIONS:

17:15 – 18:00 Farm typologies and farm management indicators as a tool for assessments of European agriculture with a special consideration of low-input farming systems
Speaker: **Berien Elbersen (Alterra, the Netherlands)**
Topics:
Main typical characteristics of LIFS in Europe and their broad geographical distribution
Possibility of identification of LIFS on the basis of existent European and national data sources.
Quantification of the low-input farms in the European agriculture based on FADN data

QUESTIONS:

18:00 – 18:45 DISCUSSION
QUESTIONS:
Towards a comprehensive definition of LIFS : adaptation of the description provided by Parr et al. in 1990:
Low input farming systems "seek to optimise the management and use of internal production inputs (i.e., on-farm resources) ... and to minimise the use of production inputs (i.e., off-farm resources), such as purchased fertilisers and pesticides, wherever and whenever feasible and practicable, to lower production costs, to avoid pollution of surface and groundwater, to reduce pesticide residues in food, to reduce a farmer's overall risk, and to increase both short- and long- term farm profitability"

Which are the best indicators to describe LIFS ?
Suggestions for a European survey able to provide adapted data for LIFS (inputs/ha, inputs/product) ?
Are LIFS a good model to decrease environmental impacts of agriculture?

Tuesday, 3 July

SESSION 2 **Diversity and sustainability of Low-Input Farming Systems (LIFS) in Europe**

Chairperson: **Josef Parente**

9:00 – 9:45 LIFS and livestock production – animal performance and environmental impacts of grassland- and legume-based systems
Speaker: **Erich Poetsch (The Research and Education Centre for Agriculture Raumberg-Gumpenstein, Austria)**
Topics:
Description and evolution of grassland- and legume-based systems for livestock production in Europe
Animal performance and environmental impacts
Socio-economic impacts

QUESTIONS:

9:45 – 10:30 Integrated crop production in arable crops
Speaker: **Philippe Viaux (ARVALIS – Institut du vegetal, France)**
Topics:
Concept of integrated crop production in arable crops: choice of plant, crop rotation
Potential to reduce pesticide and fertiliser inputs
Economic assessment of integrated crop production in arable crops

QUESTIONS:

10:30 – 11:00 COFFEE BREAK

11:00 – 11:45 Conservation agriculture and Low-Input Farming Systems
Speaker: **Matthieu Archambeaud (Agriculture de conservation, France)**
Topics:
Concept of conservation agriculture
Conservation agriculture and pesticide use
Conservation agriculture: an opportunity to save water?
Economic assessment of conservation agriculture
State-of-the-art and future of conservation agriculture in Europe (presentation of ECAF – European Conservation Agriculture Federation)

QUESTIONS:

11:45 – 12:30 Low-Input Farming Systems in Southern Europe: the role of grasslands for sustainable livestock production
Speaker: **Claudio Porqueddu (Institute for Animal Production System in Mediterranean Environment, Sardinia, Italy)**
Topics:
Grassland-base farming system typologies in Southern Europe;
Forage legumes to improve sustainability in Mediterranean Europe;
LIFS and their multi-functions.

12:30 – 13:00 DISCUSSION

13:00 – 14:30 LUNCH

Chairperson: **Katarzyna Biala**

14:30 – 15:15 Development of organic farming in Europe and sustainability
Speaker: **Otto Schmid (FiBL - Forschungsinstitut für biologischen Landbau, Switzerland)**
Topics:
Development of organic farming in Europe
State of the art of organic crop production – achievements and future challenges
System approach in crop and animal production - examples
Environmental impact
Economic profitability and social impact
Process and product quality
Future research needs for future development

QUESTIONS:

15:15 – 16:00 Plant breeding for low-input agriculture
Speaker: **Fabio Veronesi (University of Perugia, Italy)**
Topics:
Man and crops: a symbiosis
Plant breeding, food production and sustainability
Plant adaptation to the environment: a challenge for plant breeding in the near future
Plant breeding strategies to develop a sustainable agriculture: conventional and advanced approaches.

QUESTIONS:

16:00 – 16:30 COFFEE BREAK

16:30 – 17:15 Low-input farming in new EU Member States
Speaker: **Tamás Németh (RISSAC – Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences, Hungary)**
Topics:
Review of LIFS in new EU Member States
Driving forces behind low-input farmland management in the new Member States
Importance of small-scale agriculture - (semi-)subsistence farms

QUESTIONS:

17:15 – 18:00 Sustainable low-input farming systems: the case of Marianis – Volpares farm
Speaker: **Josef Parente (ERSA – Agenzia regionale per lo sviluppo rurale, Friuli Venezia Giulia, Italy)**
Topics:
Conversion from intensive to low-input farming
Energy balance
Minimum external input
High quality products
Diversification and multifunctionality
Biodiversity and landscape enhancement

QUESTIONS:

18:00 – 18:45 DISCUSSION
What are the limits of high inputs system?
Can LIFS produce enough to meet food security goals?
Are LIFS a good model for sustainable agriculture with regard to its 3 pillars: environmental, economic and social?

Ways to promote the development of LIFS in Europe: research programmes (plant breeding, associated crops etc.),
Means for dissemination of LIFS concept: farmer networks, chambers of agriculture, dedicated institutes?
Current state of development of other LIFS in Europe: horticulture, agroforestry

Wednesday, 4 July

SESSION 3 **Technical visit to farms in the region**

Thursday, 5 July

SESSION 4 **Policy options for safeguarding economic viability of LIFS**

Chairperson: **Philippe Pointereau**

9:00 – 9:45 Agri-environmental policy in Europe and LIFS
Speaker: **Jean-Michel Terres (JRC)**
Topics:
Cross-compliance
Agri-environmental measures
Good Agricultural and Environmental Condition (GAEC)

QUESTIONS:

9:45 – 10:30 Support to LIFS: ECOPOINT system in Austria, an example of livestock production
Speaker: **Peter Mayrhofer (Niederösterreichische Agrarbezirksbehörde, Austria)**
Topics:
Design of ECOPOINT system
Assessment of efficiency of applied measures
Main difficulties to develop and implement the programme
Advantages and disadvantages for farmers

QUESTIONS:

10:30 – 11:00 COFFEE BREAK

11:00 – 11:45 Pesticide Use Reduction strategies in Europe: successes, failures and the way forward
Speaker**: Nick Mole (Pesticide Action Network, UK)**
Topics:
Examples of pesticide use reduction strategies from Europe and assessment of their efficiency
Need for a joined up approach to planning and implementing such strategies.
How do low input farming systems fit into the broader picture of pesticide use reduction?

11:45 – 12:30 DISCUSSION

12:30 – 14:00 LUNCH

SESSION 5
14:00 – 16:30 FINAL DISCUSSION: Future of LIFS in Europe

SUMMER UNIVERSITY: Low-Input Farming Systems

HOTEL Conca Azzurra, Ranco

02/07/2007 - 05/07/2007

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European Commission

EUR 23060 EN– Joint Research Centre – Institute for Environment and Sustainability
Title: Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture – Proceedings of the JRC Summer University – Ranco, 2-5 July 2007
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Abstract
The concept of sustainability applied to agriculture developed mainly as a result of growing awareness of negative impacts of intensive farming systems on the environment and the quality of life of rural and neighbouring communities. Intensive farming systems are based on genetically uniform crops and livestock breeds, vulnerable to pests and diseases. High yields are obtained through dependency on external inputs (especially fossil energy, fertilizers and pesticides) which can cause decreased air, water, soil and food quality. Intensification and specialisation also bring about landscape changes, resulting in its homogenisation and destruction of traditional landscape elements and, consequently, loss of habitats. Marginal areas, on the other hand, are threatened with cessation of agricultural practices and land abandonment. All these factors also lead, directly or indirectly, to the loss of biodiversity.
Lewandowski et al. defined in 1999 sustainable agriculture as *'the management and utilization of the agricultural ecosystem in a way that maintains its biological diversity, productivity, regeneration capacity, vitality, and ability to function, so that it can fulfill – today and in the future – significant ecological, economic and social functions at the local, national and global levels and does not harm other ecosystems'*.
The search for sustainability of agriculture inevitably leads to the exploration of the potential of Low Input Farming Systems (LIFS) to achieve this goal.
Within this context, the European Commission Joint Research Centre, Institute for Environment and Sustainability and SOLAGRO organized a Summer University '**Low Input Farming Systems: an Opportunity to Develop Sustainable Agriculture'** which took place on 2-5 July 2007 in Ranco (Italy). The programme of the Summer University has been drawn to reflect the diversity of Low Input Farming Systems in Europe and the complexity of factors currently impacting on European agriculture.
This report contains the papers which were presented at the meeting as well as final conclusions, summarizing the main points of the discussions which suggested possible lines of future research and policy options which might support LIFS in Europe

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