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► **To cite this version:**

Pierre Dupraz, Karine Latouche, Francois Bonnieux. Economic implications of scale and threshold effects in agri-environmental processes. 90. EAAE seminar : Multifunctional agriculture, policies and markets : understanding the critical linkage, Oct 2004, Rennes, France. 8 p. hal-01931556

HAL Id: hal-01931556

<https://hal.science/hal-01931556>

Submitted on 7 Jun 2020

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90th EAAE Seminar
Multifunctional agriculture, policies and markets:
understanding the critical linkages

October 27-29, 2004
Rennes, France

Economic implications of scale and threshold effects in agri-environmental processes

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Key words : agroenvironmental schemes, environmental thresholds, policy design, transaction costs, microeconomics

Abstract :

Starting from the present knowledge of farmers' participation behaviour, this paper explores how the contract specification and the design of AESs may take into account non linearity of the agri-environmental technology. In the polar case of a pure threshold effect, the total amount of payments and related administrative costs is spent for nothing if the threshold is not crossed. In some cases, the AES implementation agency may avoid such a loss by retaining the conclusion of the first contract until a minimal rate of participation is met in the targeted area.

¹ "This document presents results obtained within the EU project SSPE-CT-2003-502070 on Integrated tools to design and implement Agro Environmental Schemes (<http://merlin.lusignan.inra.fr/ITAES>). It does not necessary reflect the view of the European Union and in no way anticipates the commission's future policy in this area."



1 Introduction

While negative externalities are usually regulated by mandatory policy tools like taxes or command and control instruments, the private procurement of public environmental goods is mainly promoted through contractual policy tools based on a voluntary approach. The good targeting of most relevant areas/farms regarding the policy environmental objectives is a critical issue.

The existence of ecological discontinuities and thresholds has been revealed in many empirical studies (Muradian, 2001). Multiple theoretical developments in ecology predict the existence of ecological discontinuities triggered by threshold values of internal or external variables to the ecological systems.

The complexity of ecosystems, because of strong nonlinearities or interrelations between several ecosystems often entail misallocation of funds for conservation programme. For threshold effects a two stage allocation of conservation funds has been proposed to optimally target conservation efforts: in the first stage, the allocation across the eligible sites ensures that thresholds are met in every selected site while within site fund allocation only needs to be based on a physical criterion of environmental effectiveness (Wu, 2004).

An important issue related to threshold effects is the uncertainty with which they are associated. Perrings and Pearce (2004) provided a general framework to design the optimal mandatory policy dealing with certain and uncertain ecological thresholds.

Because of threshold effects and scale economies in the provision of some environmental services, reaching a critical mass of contracted area is also important for the effectiveness of many policies based on a voluntary approach. Studies have brought interesting information on the behaviour of farmers regarding uptake of AES. The characteristics of the subject of the contract and farmer play an important role.

Of course uptake mainly depends on the economic incentive offered to eligible farmers. However the success of such schemes also depends on social context. Indeed farmers are more likely to participate if they know someone who already participates. This a clear indication that networking matters (Dupraz et al., 2001).

Previous studies showed that the uptake of measures also depends of personal and farm characteristics. Uptake is also higher among better-educated and informed farmers and among those with a positive attitude towards the environment (Morris and Potter, 1995). This indicates that education, information and extension are all important in explaining participation, and that these factors can gradually shift farmers' behaviour (Dupraz et al, 2002).

In several empirical studies regarding particular schemes and EU wide sample, evidence shows that farm households derive a direct satisfaction from their production of environmental services. Such utility variation decrease their willingness to accept for delivering a given bundle of environmental services (Dupraz et al., 2002 and Dupraz et al., 2003). Especially Vanslebrouck and al (2002) analyses the interest of farmers in two measures: plantation in yard and extensification of field margins. They found that the adoption of the measure plantation in yard is mainly explained by personal and farm characteristics. In fact the measure plantation in yard gives more personal benefits to the farmers, confirming that personal satisfaction influences the decision of farmers to participate.

The willingness to participate in agro-environmental schemes of farmers may be partly improved if farmers are interested in environmental improvement and if the contract they sign have significant impact.

The rationality of this behaviour is rooted in the privileged access to the local public good these farm households contribute to produce. In the case of pure public goods, such attitude would not be rational. This interpretation is supported by the results of Bonnieux et al (2001) where the effect of the farmers' environmental awareness is the strongest for the landscape maintenance, is weaker for biodiversity protection, and three times weaker, but still significantly positive, for the reduction of polluting practices.

Starting from the present knowledge of farmers' participation behaviour, this paper explores how the contract specification and the design of AESs may take into account non linearity of the agri-environmental technology. In the polar case of a pure threshold effect, the total amount of payments and related administrative costs is spent for nothing if the threshold is not crossed. In this example, the AES implementation agency may avoid such a loss by retaining the conclusion of the first contract until a minimal rate of participation is met in the targeted area.

2 Micro-economic framework

The underlying agro-environmental technology is $K = g(S, e)$ where K is the expected environmental good and S the total area which is managed according to specified farming practices (denoted e for "environmental effort") and $g(\cdot)$ is a non negative function increasing in S and e .

The thresholds effects are formalised with the critical area S_0 and the critical effort e_0 :

$$S \leq S_0(e) \Rightarrow g(S, e) = 0 \quad [C1]$$

$$e \leq e_0(S) \Rightarrow g(S, e) = 0 \quad [C2]$$

The social surplus function $W(K)$ is non negative, increasing and concave in K . It represents the social demand for K , which is expressed by the regulator who offers contracts. Standard contracts (e, p) are considered here for convenience². The environmental effort e refers to the

² Standard contracts are mainly used in EU agroenvironmental policies.

prescription bundle of the contract and the premium p is paid by hectare of land concerned by this contract. They are the same for every contractors who adjust their area under contract. Individualised contracts would specify each effort and the corresponding premium of one by one contractors and entail high negotiation costs for both the regulator and each contractor.

For the i^{th} eligible farmer, the willingness to accept for managing the area s_i according to the specified farming practices e is formalised by a cost function $c(\cdot)$: $c_i = c(s_i, e, K)$. It is increasing and convex in e and s_i and non increasing in K . This cost function also depend on the prices of the farm marketed inputs and outputs although they are omitted in the formulation. Facing a contract (e, p) where p is the premium offered per area unit, the farmer is expected to maximise her/his profit: $\text{Max}_{s_i} (p \cdot s_i - c_i)$.

S is the total area concerned by contracts signed in order to produce K : $S = \sum_i s_i$

Without any uncertainty, the policy problem is summarised by:

$$\text{Max}_{e, s_i} W(K) - \sum_i c(s_i, e, K) \quad [\text{P1}]$$

There are two cases: the case where the environmental good is produced and the case where it is not.

In the first case the optimal policy based on standard contracts (e, p) specifies the environmental effort e^* with the premium per area unit p^* .

$$p^* = \frac{\partial c(s_i^*, e^*, K^*)}{\partial s_i} = \frac{\partial W(K^*)}{\partial K} \bullet \frac{\partial g(\sum_i s_i^*, e^*)}{\partial s_i} \quad K^* = g(\sum_i s_i^*, e^*) > 0 \quad [\text{S1}]$$

Total payments are $C(e^*, p^*) = \sum_i p^* \bullet s_i^*$ and farmers' profit $\sum_i p^* \bullet s_i^* - c(s_i^*, e^*, K^*)$.

In the second case, the condition C1 or C2 holds because, for any strictly positive K , the social surplus $W(K)$ is too small to meet the baseline costs associated with the thresholds. The optimal policy is to do nothing. Offering any contracts (e, p) would generate a net exchequer cost, equalling the total payments $C(e, p)$ plus regulator's administration costs, which may spend the all budget devoted to K for no environmental benefits:

$$C(e, p) = \sum_i p \bullet s_i^* \quad p = \frac{\partial c(s_i^*, e, K)}{\partial s_i} \quad K = 0 \quad [\text{S2}]$$

The farmers derive a total profit $\sum_i p \bullet s_i^* - c(s_i^*, e, 0)$ and the net social loss is $\sum_i c(s_i^*, e, 0)$.

The situation S2 likely occurs when farmers' behaviour is not fully known or when the level of the thresholds is ignored. Consequences of asymmetric information are presented first and the consequences of uncertain technology afterwards.

2.1 Consequences of asymmetric information

As usual asymmetric information gives the agents the opportunity to deviate from the regulator expectations and benefit from their informational advantage. When the technology exhibit thresholds such behaviours may result in very high losses like the difference between situations S1 and S2. In the case we are dealing with, it is also important to notice that the private information of a farmer which is not known by the regulator also affects the knowledge and the decisions of other agents. In the situation S1, the potential contractors are certain that the expected environmental output K will be produced according to the underlying, well known technology. As soon as they are aware of the unpredictability of other agent behaviour and of threshold effects, some of them will anticipate the non production of K . This will increase their willingness to accept as far as its negatively depends on K (Bonnieux et al. 2001, Dupraz et al. 2003).

An adverse selection problem occurs when the regulator has an imperfect knowledge of the farmers' willingness to accept. Underestimating the farmers' costs and their profit seeking behaviour lead to the overestimation of the total area uptake S for a given contract (e, p) . Hence the regulator may propose a contract while C1 holds.

Considering the agro-environmental policies co-financed in the framework of the Rural Development Regulation, the European rules explicitly recommend to calculate the premium p according to the additional cost or the forgone profit of the AEP eligible farmers. Such a calculation often neglects the private transaction costs of the contractors. Moreover this calculation may not take into account the profit seeking behaviour of the farmers who adjust their supply s_i^* according to their marginal cost of compliance. If the premium is based on the average cost $p = c_i / s_i$ for a policy objective of s_i , the result will be $s_i^* < s_i$ (Dupraz et al., 2003).

The way to account for the heterogeneity of farmers and reduce their profit is to negotiate the following individualised contracts: the i^{th} farmer is offered a contract $(e, c_i + \varepsilon)$ in which the entire payment is tailored according to her/his costs for the suitable area and includes an incentive as small as possible to ensure her/his participation. The opportunity of this solution depends on the transaction costs involved in such a procedure. They are always higher than those associated with standard contracts, especially when asymmetric information initially prevails. This second order solution is worth to be considered when the farmers' profits which are squeezed enable the total contracted area to cross the critical value and provide a social surplus higher than total costs, regulator's administration costs included. The difficulty with this procedure is that the regulator don't know if such conditions hold when he starts the farm by farm negotiations.

A safeguard to cope with the adverse selection problem is to retain the State signature of the contracts until farmers' aggregate commitment reach a minimal area $S_m > S_0$ in each relevant designated zone. The corresponding contracts the farmers are offered are denoted (e, p, S_m) . If the minimal area is not reached, no contract is concluded and the loss associated with an inefficient payment is partly avoided. Indeed some public and private transaction costs associated with setting up the scheme and the contracts are still lost. This contract design will also guarantee the co-operation between farmers. Farmers will sign contracts which have a significant effect on environmental quality. These significant impacts will enhance the motivation of farmers to adopt a contract. Therefore such cooperative effort of the farmers derives from both the additional information S_m which is included in the contract specification and the characteristics of their preferences as they directly derive utility from the environmental output. In the first time the contract are offered, S_m and p are not supposed to be optimal since the farmers' cost functions are partly hidden to the regulator. He just know that p must not exceed $[W(g(S_m, e)) / S_m]$ in order to preserve the tax payer benefit. However, the outcomes of this first contractual round elicit the farmers' willingness to accept and give the regulator the opportunity to optimise the contract for future rounds. Dupraz et al. (2003) displayed an example where the contingent evaluation method is rather successfully used to ex-ante elicit the area the farmers would enter in the agro-environmental scheme for fixed per hectare premium offered by the State. In a preliminary stage, such ex-ante evaluation method may provide useful information to design the first contract.

The moral hazard problem derives from the regulator difficulties for observing the actual environmental effort e_i^* of the farmers or for enforcing the contractual effort e . Hence C2 may hold and reduce the environmental impact of the scheme to nothing. How surprising it looks, there are numerous examples of agro-environmental contracts with uncontrollable prescriptions (Instance nationale d'évaluation du contrat territorial d'exploitation, 2003).

The classical second order solution is based on the risk aversion of the agents: the regulator performs costly controls on limited samples and applies very strong sanctions when the non compliance happens to be proved, in order to reduce the rate of non compliance. However the design of an appropriate control and sanction system is often limited by laws and pre-existing procedures that determine the maximum penalties in accordance with other references. Once again a cooperative approach might be proposed if the effort e_i of a particular farmer is easily observable by his/her neighbours. An example of such effort is the mowing of meadows from their centre to their periphery. This practice is recognised to be very efficient to preserve certain wildlife species. Although official controls are very difficult to organise, farmers frequently and easily observe the way their neighbours perform. The basic idea is to design a contract between the regulator and a consortium of farmers of a designated area. The consortium receive a global payment $P=C(p^*, e^*)$ for the provision of K^* and nothing if the environmental objective is not reached. Practically this means that the consortium has to reimburse the global payment, possibly with an additional penalty to cover administration cost and the opportunity cost of public funds. However the financial penalty per farmer would be much lower than the optimal sanction associated with individual contracts. As the consortium members are collectively committed and know each other, the enforcement of the contract makes use of social pressures based on personal relationships since few free riders endanger the payment of all the others.

2.2 Uncertainty on agri-environmental technology

The environmental technology is never totally unknown. In most cases, environmentalists have an idea of the underlying technology process and especially know if it exhibits threshold effects or doesn't. Under locally specific conditions, the exact threshold critical values are usually unknown. At least policy makers may use existing scientific references or similar experience to be aware of threshold effect and

possibly get a hazy idea of these critical values. It must be emphasised that the farmer themselves often have less information about the agri-environmental processes than policy makers.

The challenge of the scheme design is to offer and monitor contracts that will produce additional information on the agri-environmental processes, and particularly the threshold critical values. An iterative process that includes successive contractual rounds is needed.

Without any hidden information by the farmers, standard contracts are first offered in few selected representative zones which are delimited according to the targeted environmental output and the suspected scale and threshold effects which are associated. If similar sites are available, different contracts (e,p) may be tested in order to discover the critical values more rapidly and more precisely. Starting with rather high effort and payment, and providing a comfortable profit to farmers may provide advantages: the probability of the environmental good production being higher, the net social cost of the first contractual round will probably be lower, even if the social surplus does not reach the costs of the scheme. Moreover, a success will encourage the farmers for future contractual rounds while a failure might discourage them. Out of the monitoring of the scheme, the regulator will know ex-post if the thresholds have been reached or not. If it is relevant, an extra payment may be offered to associate the contractors to monitoring tasks. In the iterative process, where previous results are taken into account, the regulator can step by step reach the optimal contract and offer it in additional zones according to the recommendations of Wu (2004). A big difficulty is the common case of the delayed response of the environmental efforts which slows down the production of knowledge.

Consultations between scientists, decision makers, farmers and environmental organisations should create a dynamic and trustful context where the targeted level of environmental impacts, the monitoring procedures and the contract are step by step redefined taking into account previous results. In such a context, interrelations between different measures described in literature regarding conservation programmes for instance (Wu, 2004) could also be analysed and taken into account in future design of contracts.

When the farmers' cost function are partly unknown by the regulator, setting a minimal aggregated area to trigger the State signature of (e, p, S_m) contracts is no more useful in the context of uncertain threshold critical values. The ex post analysis of (e,p) contracts will also provide the required information on the farmers' environmental supply function. Once again the elicitation of the farmers' willingness to accept under different scenarios may provide interesting complementary information. For instance the influence of the probability of the environmental production associated with different contracts may be tested, before such probability is eventually approximated.

The moral hazard problem characterised by hidden efforts of the contractors is more difficult to deal with because the identification of the source of scheme failure is itself unknown. Still, the preceding proposal of a collective contract with a consortium of farmers may be preferred if the consortium is truly interested in the process of knowledge capitalisation about the agri-environmental technology. Obviously, the farmers won't accept their payment is entirely conditioned by the observation of an environmental output that does not entirely depend on their efforts. Some kind of risk sharing system between the regulator and the consortium must be negotiated.

When remarkable biotopes are endangered by the trend of economic changes, Perrings and Pearce (1994) pointed out that the uncertainty about thresholds is often associated with the uncertainty and irreversibility of potential damages and of their social costs. They show that these cases resist conventional applied economics because no optimum is calculable. Therefore decision making about preservation must rely on non economic criteria. Hence the preservation of the status quo is enforced with strong penalties compared to the private profit of trespassing the conservative standards. Many agro-environmental schemes are used to preserve remarkable sites like marshes, peat land or mountainous dried meadows, from land abandonment or agricultural intensification. Using Perrings and Pearce results justify payments high enough to deter alternative use of land in the sites which are selected by policy makers. Sometimes such payments do not correspond to any tangible effort of the farmer.

3 The French implementation of agro-environmental contracts regarding scale and threshold aspects

3.1 Existing measures taking into account scale and threshold effects

Several examples showing that scale and threshold effects can be found in the French case.

A first example found in Brittany can be presented. It is the implementation by the "Conseil général d'Ille et vilaine" (NUTS3 regional council) of particular contracts.

The regional authorities successively offered several contractual arrangement to favour the conversion of arable land in grassland buffer zone in areas along the river (Kerhouas, 2003).

The buffer zone aim at:

- catching and filtering ground flow
- slowing the streaming and avoiding soil erosion
- filtering streaming water fixing the solved substances
- avoiding river contamination which can occur after plant-care product spraying

Environmental impacts of buffer zones are well known. The installation of a buffer zone of 6m leads to the catchment of nearly 70% of plant-care products streaming. For a buffer zone of 18m, 90 % of plant-care products are caught.

The budget allocated to this program reaches 760 000 Euro for 2001-2006 period. Three types of contracts exist. The first one deals with implementation of grasslands long the river for 375 Euro/ha if the implantation of buffer zone concern crops. The second one deals with implantation of buffer zones on temporary grassland for 259 Euro/ha. The last one is extensive management of grassland for 63,6 Euro/ha.

These amount are increased of 20% if the measures are adopted in a CTE "*Contrat Territorial d'Exploitation*"

The agreement concerns the installation of maintenance of grassland buffer zone of 20 m large. These agreements aims at protecting the rivers.

Their installation must be based on a precise diagnostic of the territorial conditions. Buffer zones have to be implemented on relevant positions on the watersheds.

This offer was contingent and would have been effective only if at least 60% of river bank of the targeted area was under contract. The eligible parcels were those described at 1/25000th from IGN (*Institut Géographique National*).

To gather 60% of river bank of a targeted zone under contract was first an objective of the NUTS3 policy. This threshold of 60 % was chosen according to an audit led on the previous 1994-1999 AES contracts aiming at creating grassland buffer zone. The conclusions of this audit showed that a minimum rate of 60% of conversion was needed to lead to efficient environmental impact on a catchment area. During 1994-1999, 536 contracts concerning 1,406 ha with creation of grassland buffer zones were signed. The total budget was 2 900 000 Euro and spent for nothing. The spatial dispersion of contracts signed did not permit any measured significant environmental impact. No consistent reasoning regarding catchment areas was initiated. It illustrates our situation S2.

After 1999, the "*conseil général*" contracts were proposed on a particular catchment area to test farmer reactions. After two years, the balance was disappointing because only 11 farmers had contracted and the parcels under contracts did not represent the 60% of the targeted area.

On the second chosen area, the threshold of 60 % of the targeted area became not only an objective, but a necessary condition to engage contracts. Hence, this necessary condition aimed at reaching a minimal impact on environment and avoiding to give money without any results guarantee. Farmers, gathered around a project leader, signed a declaration of intent. They finally signed contracts once the area under contract reached the threshold. 34 contracts were signed on a particular watershed following an territorial approach. The chosen watershed was preferentially belonging to a "*Contrat Eau paysage Environnement*" (water landscape environment contract) signed with the "*conseil général*". The story of this particular example illustrates how the procedure using (e, p, S_m) contracts initiate a cooperative behaviour of the farmers, at first to reach the threshold.

At a national level, the National Rural Development Program proposes measures to farmers in which threshold effects at the farm level are taken into account. For example, the sub-measure 8.1 "Introduction of integrated crop protection" is paid only if a precise part of the farm area is concerned by the decrease in the use of pesticides. The minimum part of the farm which has to be under contract is defined at the NUTS3 level to fit local conditions.

Scale effects are considered at the farm level in measures such as "Winter covering of arable land with intermediary culture". If the farm area committed in this measure reaches 40 % of the farm area, then the paid amount is increased by 20% and if the area committed is less than 10% of the farm area, then the amount paid is decreased by 20 %.

The involvement of local and regional councils must be emphasised. Although scale and threshold effects are considered at the farm level by nationally designed measures, it seems that higher level threshold effects and the necessary coordination farmers' environmental efforts are only considered where local authorities are involved (Instance nationale d'évaluation du contrat territorial d'exploitation, 2003). In the few success stories which are reported they take advantage of successive experiences despite the deep changes that have affected the French agro-environmental policy framework. In contrast the schemes that are managed by the usual agricultural networks clearly privilege the access of all farmers to the wider range of contractual measures, without any knowledge accumulation strategy at the local level.

3.2 Observed problems of French agro-environmental contracts

Attempts to take into account scale and threshold effects may be limited by the Commission degression rules:

The degression rule, introduced and enforced with 1257/99 AESs, is a new component in the budget management. Indeed, for 1257/99 AESs the annual area incentives are calculated following decreasing scale rules (punctual or linear elements/measures are not concerned by such rules). The degression rules do not concern already engaged areas under 2078/92 regulation.

Concerning area measures (apart from the conversion to organic farming that follows a specific rule), and if the total engaged area is above 2 minimum farming areas (*Surface Minimale d'Installation i.e. SMI*) the calculation is done as follows:

- by multiplying the whole area engaged by the correspondent incentive (= theoretical aid amount);

- this amount is then divided by the total area engaged (= average amount/ha);
- the aid is then calculated by brackets, multiplying the average amount by the adequate number of hectares (comprised within the concerned bracket) to which a depression ratio is applied, following the given rules:

Committed area up to 2 SMI	Committed area above 2 SMI and below 4 SMI	Committed area above 4 SMI
100%	60%	30%

The amount that should be paid to the farmer each year as incentive is the result of the addition of the products calculated. Defined in article L312-6 of the Rural Code, the SMI is presented as the minimum area (under mixed farming system) from which a couple will be able to get enough money for a basic living. The value of the SMI is set at the NUTS 3 level, and depends on the type of crop concerned as well as on the production area. Regularly revised, the SMI under mixed farming system cannot, in any case, be less than 30% of the national SMI (25 ha at present, revised every 5 years).

Thus in the French case, the depression rule can be in contradiction with the initial design of agro-environmental measures and CTEs. Scale and threshold are taken into account in few French measures and initiatives while the European rules decrease the incentives for farmers to increase the area under contracts.

Co-operative behaviour is not encouraged despite the farmers' preferences. Most of the contract signed are not involved in a territorial approach as developed in the NUTS3 region *d'Ille et Vilaine*, which is an exceptional procedure. Yet a CNASEA report published in 1996 (CNASEA, 1996) dealing with the results of a French survey on 1183 farmers under contracts 2078/92 highlighted the willing of farmers to avoid dispersion in contracts signed. They insisted on the importance of reaching a minimum area under contract in a precise area. 51% of interviewees proposed to enhance efficiency of agro-environmental contracts through a minimum rate of adoption. 48 % of interviewees also proposed that contracts should be applied on the whole farm instead of just a part of the farm. All this recommendations and farmers' advice were not taken into account in the French application of the regulation 1257/99

The low rate of compliance is a real problem in France.

In Basse-Normandie it indeed appeared that some 40% of the farmers faced some difficulties to enforce the 1257/99 contracts (Eureval-C3E, 2003) – mainly its environmental part – mainly due to the framework planning and to the technical respect of some of the prescriptions. Hence even in a ideal case of collective contracts signed only if the minimal targeted area is concerned, the provision of the environmental good can fail because the global effort of production (individual respect of contract commitments) is not effective.

The same holds in Brittany. The compliance controls lead nearly to the same results. The compliance with commitments failed in 84 % of CTE controlled. In 65 % the gap noticed between commitments and reality was major, in 12 % it was significant, and in 23% it was low.

4 Conclusions

Threshold effects have to be taken into account for implementation of agro-environmental policies. Overly geographical dispersion of public funds and the environmental objective multiplicity of offered contracts without any coordination, which prevail in the present situation in France result in high social losses and impede the knowledge accumulation about locally specific agri-environmental processes. A cooperative approach of the implementation of agro-environmental policies may deal with asymmetric information problems in certain circumstances and should be developed further. The design of agro-environmental schemes and of related contracts must include a knowledge accumulation strategy when uncertainty of agri-environmental processes prevails. It requires perennial dedicated agencies where local and regional councils are more involved than in present institutional settings of agro-environmental scheme management which are dominated by agricultural organisations.

ITAES project may highlight this possible evolution of contract design through a forthcoming survey on European farmers and a environmental assessment of agro-environmental schemes.

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