Interpretation of results from on-farm experiments: manure-nitrogen recovery on grassland as affected by manure quality and application technique. 2. A sociological analysis

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Abstract

This article discusses the outcomes of a re-analysis of a grassland experiment, by locating it within the wider institutional context composed of well-established routines used in agronomic research and the dominant epistemological tradition of agricultural sciences. It is argued that both, research routines and epistemological tradition, are strategic pillars of the reigning socio-technical regime. They contribute to path-dependency, thus reinforcing the uni-lateral development tendency centring on technological solutions that fit within the dominating regime. An important, albeit probably unintended consequence is that promising novelties are obscured within and through research, thus blocking a potentially highly effective road towards sustainability.

Additional keywords: dairy farming system, nutrient use efficiency, socio-technical regime, novelty

Introduction

The introduction of legislation to reduce farm nutrient surpluses has forced dairy farmers in the Netherlands to drastically decrease external inputs of feeds and inorganic fertilizers, in particular nitrogen (N). The implementation of the Mineral Accounting System (MINAS) in the period 1998–2003 (Henkens & Van Keulen, 2001) necessitated large adjustments in farm management practices that had been tuned to a tradition of high-input agriculture. For commercial farms, nation-wide and regional nutrient management projects have emerged to perform on-farm analysis of N balances and to assist farmers in the transition to farming with reduced nutrient inputs (e.g. Oenema *et al.*, 2001). Environmental co-operatives emerged as a response to the highly generic and means-centred agro-environmental policy that prevails in the Netherlands (for a critical discussion see Frouws, 1993; Anon., 2003; Bouma, 2003). Farmers were legally obliged to adopt a range of prescribed technologies (e.g. injection of manure into the soil) and to align their process of production to very strict rules, procedures and parameters. This external prescription and sanctioning (Benvenuti, 1989) tends to petrify farming: it increasingly excludes whatever deviation from the imposed rule. The co-operatives with their negotiated space for manoeuvre form, in this respect, an important exception.

VEL (Vereniging Eastermar's Lânsdouwe) and VANLA (Vereniging Agrarisch beheer Natuur en Landschap in Achtkarspelen) were amongst the first environmental co-operatives of the Netherlands (Renting & Van Der Ploeg, 2001). Environmental co-operatives are farmer associations built upon a negotiated exchange between state and farmer collectives (Wiskerke *et al.*, 2003). The co-operatives committed themselves to an early and convincing realization of general environmental goals, including a reduction of mineral losses to less than 180 kg N per hectare per year and a far-reaching reduction of ammonia emission. Meanwhile, the state offered the involved farmers space for manoeuvre, i.e., the possibility to develop their own strategies and means to reach these goals. So the co-operatives function as 'field laboratories' (Stuiver *et al.*, 2003). As alternative to the agro-environmental regime imposed by the state, the VEL and VANLA farmers developed, together with a few scientists, a different approach that became known as 're-balancing' (Reijs *et al.*, 2003; Verhoeven *et al.*, 2003).

Following an agreement with the Minister of Agriculture, the VEL and VANLA co-operatives could start with an extended test of the proposed re-balancing. This test, known as the Nutrient Management Project, was designed as on-farm research in which 60 farmers participated. Out of these 60 farmers, 20 were allowed to practice surface application of manure. This was an exception to the legal prescription that all manure is to be injected into the soil. They could equally apply additives to the manure and implement other novelties. The condition for this enlarged room for experimentation was, firstly, that the co-operatives and especially the participating farmers had to reduce environmental pressure as mentioned before and, secondly, that the outcomes of the novel practices were to be documented carefully through scientific research. So several lines of inquiry started, some regarding soil biology and the interaction between patterns of land use and properties of the land, other focusing on e.g. socio-economic and environmental impacts of the different novelties (Groot *et al.*, 2006). This implied, amongst other, measuring ammonia emissions (both *in situ* and in the laboratory), soil, feed and manure analyses, and a careful record keeping of farm accountancy data. A grassland experiment was equally part of the accompanying research.

This grassland experiment aimed at assessing the "effects of management of manure, additives and application techniques on grassland production and soil fertility" (Kok, 2004). Considerable debate accompanied the design, analysis and interpretation of this experiment (e.g. Schils & Kok, 2003; Verhoeven *et al.*, 2003; Groot *et al.*, 2007). The grassland experiment became a 'battlefield of knowledge' (Long & Long, 1992).

In this paper this debate is analysed and set in a wider context. First we briefly present the context of the grassland experiment by discussing the development of agriculture and agricultural science and research over the last decades. This is followed by a discussion of the relevance and applicability of the concepts of 'agriculture as a process of co-production' and 'novelty production' (Van Der Ploeg *et al.*, 2004) as alternatives to the prevailing epistemological tradition elaborated within the modernization paradigm. Next we provide an overview of the debate and the interpretations of the grassland experiment mentioned above. These interpretations are linked to the different epistemological approaches. Finally, some general recommendations for agronomic research and the interpretation of on-farm experiments are formulated.

The position of agricultural science within the prevailing socio-technical regime

Socio-technical regimes specify the rules that govern the development of scientific knowledge (Rip & Kemp, 1998). These rules are embedded in institutions and infrastructures. The socio-technical regimes that currently dominate western agriculture result in the formulation of generic regulations that are to be applied regardless of the specific circumstances (Van Der Ploeg *et al.*, 2004). So the reigning regimes increasingly induce a growing disconnection of farming practices from the bio-physical, social and cultural conditions and relations that traditionally determined its functioning and development. As part of the general process of modernization, these essentially local conditions and relations are replaced by global scientific insights and associated technological trajectories, which together often imply an adieu to the specificity of the local. Within the modernization paradigm, agricultural production processes are basically understood as the (more or less optimized) unfolding of natural and economic laws entailed in different subsystems (land, cattle, crops, water, markets, etc.) that together compose the production system. These 'underlying' laws, to be identified by scientists, are assumed to govern the behaviour of the implied resources. It is assumed that they do so independently of time and space – they are universal laws (Koningsveld, 1987; Van Der Ploeg, 1987; 2003; Vijverberg, 1996).

The socio-technical regime that has dominated agricultural development since the 1950s is reflected in the increase in grassland systems productivity in the Netherlands, as supported by increasing and eventually excessive nutrient inputs. This intensification trajectory has resulted in reduction of efficiency and in large environmental problems such as water pollution (eutrophication) and undesired gaseous emissions. Within the prevailing socio-technical regime the solutions were initially sought in technological adjustments of the existing farming systems. The related research results were reflected in the issued policy measures concerning compulsory farm practice adjustments, such as covering of manure storage and the use of low-emission manure application techniques. The introduction of strict regulations that forced farmers to reduce farm nutrient surpluses (Henkens & Van Keulen, 2001) resulted in drastic adjustments of farming systems and in a considerable decline of the room for manoeuvre at farm enterprise level.

Agricultural research is linked in several ways to the reigning socio-technical regime. The latter composes, as it were, the agenda for the former: it specifies what is needed and what will be feasible. The same agenda also delineates the relevant from the seemingly irrelevant. On the other hand, research helps to unfold the developmental possibilities entailed in the prevailing regime, whilst it informs policy making institutions operating within the same regime about the most appropriate means to govern and control the relevant domains of physical and social reality. This mutual dependence often implies that both policy making and research become locked into path dependence (North, 1990). Thus, "important changes within the relevant context are understood only in as far as they fit into the prevailing schemes for interpretation" (Jacobs, 1999: p. 59).

A strong focus on 'embodied productivity' is a major characteristic of current regimes in western agriculture. High and increasing levels of productivity are built into new resources (e.g. high yielding varieties, Holstein cattle and equipment for automated milking), often developed, tested and improved through agricultural research. The best way to use and to combine these new resources is also specified by research and often results in far-reaching and detailed regulations imposed by state apparatuses. This focus is reflected in institutionalized research routines: the identification of 'main effects' (under a range of different conditions) becomes a central feature.

As opposed to 'embodied productivity', Salter (1966) specified the dynamics of 'disembodied change': productivity increases are not exclusively entailed in, nor limited to exogenous resources. They might result as well from the ongoing re-balancing and fine-tuning of agricultural processes of production as such. Labour and the associated crafts, skills and forms of local knowledge are crucial in this respect [see Bray (1986) for a similar approach related to South-East Asian rice growing]. To come to grips with such dynamics, other research traditions have been developed, such as farming systems analysis. In the latter the specificity of local situations and practices often is paramount. The time dimension is also important. Whereas research that centres on 'main effects' often focuses on short-term and abrupt improvements, farming systems research pays more attention to long-term, gradual processes of change and the (endogenous) possibilities to exploit heterogeneity and variation (Ragin, 1989).

Co-production and the role of novelties

The different methodological approaches for agricultural research are related to contrasting conceptualizations of agriculture. Current socio-technical regimes are strongly grounded on the modernization paradigm. The understanding of agriculture as application of physical and economic laws feeds into the design of resources that 'embody' a new and optimized use of these laws.

Opposed to this view is the agro-ecological or constructivist approach in which agriculture basically is understood as co-production of man and living nature. Agriculture, then, represents the ongoing combination, interaction and mutual transformation of social and material resources. So agriculture is constantly being differentiated and transformed (Altieri, 1990; Sevilla Guzman & Gonzalez, 1990;

Toledo, 1992). New constellations emerge, containing remoulded resources and new resource combinations. Hence, 'nature' as entailed in farming is "not the one from Genesis" as Koningsveld (1987) beautifully phrased it. Instead, 'living nature' is constructed, reconstructed and differentiated within long and complex historical processes, through which particular characteristics are built into the resources concerned (be it cows, fields, crops or manure; Groen *et al.*, 1993; Wiskerke, 1997; Smeding, 2001; Sonneveld, 2004). So particular regularities emerge (understood in the modernization paradigm as fixed and unchangeable 'laws') that characterize the behaviour of the resources involved. However, these patterns of regularity are neither fixed nor universal. They might be modified, at particular conjunctures in time, into other or even into contrasting regularities (Anon., 1997; Groot *et al.*, 2003; Van Der Ploeg, 2003).

In theoretical terms this implies that the behaviour of natural resources cannot be properly understood outside the pattern of land use (or: style of farming) within which they are combined in a particular way (according to a particular balance) and through which they are reproduced, developed and particularized into distinct entities that fit adequately with the other entities that form part and parcel of the same land use pattern. Concrete resources are the outcome of co-production. They are shaped and reshaped in and through the constantly evolving interaction between man and nature. That is, co-production is feeding back on the resources on which it is built. Farming is not a one-directional, industrial process. It is not simply based on resources, but entails a two-way-flow of temporal and spatial effects through which the resources involved are unfolded in differentiated ways, each entailing specific regularities.

Novelties are located on the borderline that separates the known from the unknown. Novelties often are the vehicle of changing co-production. A novelty is something new – a new practice, a new insight, an unexpected but interesting result. It is a promising result, practice or insight (Wiskerke & Van Der Ploeg, 2004). At the same time, novelties are something that is, as yet, not understood. A novelty is, in a way, a deviation. It does not correspond with the reigning 'laws' – it is something that could not, or should not, happen or occur. A novelty seems to go beyond (or effectively goes beyond) the regularities produced and known so far. It escapes from the 'laws' that reflect existing regularities. A novelty potentially announces more or less far-reaching and indeed 'disembodied' shifts in regularities and 'laws'. It contains the promise of interesting shifts in the established patterns of co-production [a more extended discussion of novelties is entailed in Milone (2004) and Van Der Ploeg *et al.* (2004); empirical illustrations are given in Swagemakers (2002) and Wolleswinkel *et al.* (2004)].

Alrøe & Kristensen (2002: p. 3) argue that drastic changes in agriculture (partly induced by major changes within its context) imply the "need for re-thinking the general methodology of agricultural research". In the following chapter the need to do so will be underlined, using the grassland experiment as exemplary case. This experiment allows for different modes of analysis. Main effects might be put centre stage, but the data can equally be analysed using systemic research methodologies that are grounded on agro-ecological or constructivist concepts of agriculture. The main conclusions, however, differ sharply.

The debate over an on-farm grassland experiment

In a field experiment, a comparison was made between the manure application practices of two adjacent dairy farms in the north of the Netherlands. The two farms, located in Drogeham and Harkema, contrasted in manure application technique (surface broadcast versus shallow injection, respectively), quality of applied manure (slurry with a low nitrogen content, amended with clay mineral additive versus regular slurry with a high nitrogen content and no additive), and some relevant site characteristics (high versus low soil organic matter content and groundwater table). Effects of manure type and application technique, and treatment of the soil with a micro-organism supplement, were tested for 5 years in a factorial design at the two sites, in two blocks per site with and without additional application of 157 kg N ha^{-1} $year^{-1}$ as inorganic fertilizer.

Within this design, the Drogeham location represented the one containing a range of not yet understood, but probably promising novelties. These are, amongst other ones, 'improved manure' (low nitrogen content, amended with clay mineral additive), 'improved application' (surface broadcast during 'dark and wet' weather), and 'improved soil' (high organic matter content). It is important to stress that the performance of these 'improved resources' critically depends on their interaction and on the specificity of the Drogeham location. The Harkema location, on the other hand, lacked such novelties, whereas it represents a different context as well.

At the start there was considerable debate. Several of the points raised are, in retrospect, still valid. A field research including all 60 farmers would probably have been more adequate. But then, it is part of the established research routine of applied research institutes to translate research questions preferably into experimental set-ups. It was also asked whether the layout of the experiment would allow for an adequate analysis of possible interaction effects. And finally, both farmers and scientists wondered about the practical relevance of including treatments with manure only and no inorganic fertilizer. Later on it became clear that this was equally an important part of 'framing' the grassland experiment into the established routines. It allowed for an interpretation of the outcomes in terms of Mineral Fertilizer Equivalents (MFE): the recovery of applied manure-N relative to the N recovered from inorganic fertilizer.

The grassland experiment yielded an enormous amount of data (Kok, 2004; Groot *et al.*, 2006). It also provoked considerable debate because the results were 'read' in contrasting ways. Already after 3 years, applied researchers interpreted the preliminary results, thereby focusing on main effects of treatments, which resulted in the conclusion that none of the novelties had any positive effect – on the contrary (Kok *et al.*, 2002). This was echoed in a scientific publication that observed that the "N utilization of slurry manure was 18% higher with shallow injection as compared to surface application" (Schils & Kok, 2003: p. 63). This would imply that with surface application more nitrogen had been lost and that the combined novelties therefore represented a step backwards. It was also stated that "slurry manure type [...] had no consistent effect on the manure-N utilization" (ibid). The final report (Kok, 2004) states that "effective use of nitrogen out of slurry was, after on surface application, lower than after injection [...]. This decreased use might be caused by higher losses of ammonia". Equally, it was concluded "that no differences emerged between the different types of manure [...].

Beyond that, the difference between distinct types of manure cannot be but irrelevant" (Kok, 2004: p. 24). The same goes for the assumed ('disembodied') interactions between the different novelties: they are hard to find and if they are encountered they are of no use (ibid).

As indicated, the results of the experiment were 'read' in different ways. Figure 1 synthesizes the particular reading as done by the involved farmers for the average dry matter yield in the years 1999 and 2000. At the extreme left, there are the experimental plots that represent the farming system with simultaneous presence of all novelties. At the extreme right there are the plots lacking all these elements. In between there is, first, the optimum situation minus one ingredient, then (in the following column) the optimum situation minus two ingredients, etc. Within the sites, the highest dry matter yields were obtained on the plots treated with the farming practices that are characteristic for the system implemented at that particular site. Moreover, the highest overall yield of 13,598 kg ha^{-1} $year^{-1}$ was observed for the treatment combination typical for the farming system at Drogeham. However, no analysis of the origin of these differences in dry matter production was conducted. Application of multi-variate statistical analyses by De Goede *et al.* (2003) and Verhoeven *et al.* (2003) is built upon a view that is similar to the one entailed in Figure 1. It is factorial change analysis departing from the two contrasting farming systems. When perceived and analysed in this way, the grassland experiment confirmed the validity of the new approach towards sustainability elaborated by the VEL and VANLA co-operatives. It is to be assessed, however, that the applied statistics merely indicated whether or not there were treatment effects and interactions between treatments. They provided no further insight into the nature or relevance of these interactions.

Farming system Drogeham	**1 change**	**2 changes**	**Farming system Harkema**
	Harkema Surface, Additive DM yield 11599 kg/ha	Harkema Surface, Regular DM yield 11840 kg/ha	
Drogeham Surface, Additive DM yield 13598 kg/ha	Drogeham Surface, Regular DM yield 13427 kg/ha	Harkema Injection, Additive DM yield 11735 kg/ha	Harkema Injection, Regular DM yield 12104 kg/ha
	Drogeham Injection, Additive DM yield 13402 kg/ha	Drogeham Injection, Regular DM yield 13387 kg/ha	

Figure 1. The farmer type of comparison of dry matter (DM) yield for farming systems and treatments, averaged for years 1 and 2 of the experiment. The experiment was conducted at sites Drogeham and Harkema, with surface broadcast and shallow injection application of regular manure or manure containing a clay mineral additive.

The two approaches of analysis were discussed in popular magazine publications. This debate involved reaction of yet other scientists, postulating that the change analysis was just 'selective shopping' (Anon., 2003) and that the indicated differences would probably be just an incidental effect of differences in soil fertility. So a controversy was born that, in turn, requires 'reflexive objectivity' (Schiere *et al.*, 1999; Alrøe & Kristensen, 2002).

On the interface of established research routines and novel practices

For the environmental co-operatives participating in the Nutrient Management Project the question underlying the grassland experiment could be phrased as: 'can a grassland system that uses surface application of low-N manure be more efficient in N use and dry matter production than a system that implements technology-based measures of shallow injection of regular high-N manure?'

However, the applied-research institute involved, rephrased this general question and split it into the following ones:

1. Does surface application of manure as such have advantages over shallow injection in terms of N recovery?
2. Does the use of additives like EuroMestMix® and Effective Microbes® have a significant effect on N recovery?

These essentially reductionistic questions (considering only *partial* relations) could have been useful within an *unaltered* pattern of dairy farming. However, in an exploration of novelty production in a systems context they are inadequate, basically because they ignore the possibility of newly emerging properties and interactions at higher levels of aggregation.

In addition to the foregoing issue ('what are the questions being asked') there are some decisive methodological issues related to the nature of on-farm experiments in contrast to standardized experimentation. Firstly, in on-farm research focusing on systems comparisons it is necessary to come as close as possible to 'real life' conditions. Similarity to these conditions is crucial if one wants to check the value of new approaches developed in practice. For this experiment, particularly in the first year, the amounts of manure applied per dressing were considerably higher than the rates normally applied by farmers in the area. Moreover, weather conditions at the time of manure application were not taken into account, although the question as to whether apply manure or postpone its application is crucial in the decision-making process of the farmers. Also mowing dates were not in line with farmer's practices. Secondly, in long-term experimental research it is crucial that relevant conditions remain as stable as possible. Dry matter and N contents of manure should represent, from year to year, a more or less constant difference in levels. However, the regular manure from farm Harkema highly varied in composition (Groot *et al.*, 2007). Moreover, the contrasts in climatic conditions between years interacted with the treatment effects on N delivery by the soil, N recovery and dry matter production, which requires a thorough monitoring and, if needed, appropriate corrections in the subsequent analysis.

The 'technicalities of research' as mentioned above interact with more general features at the epistemological level. In current research routines, properties of specific resources (application techniques, types of manure, soils, etc.) are mainly understood and represented as being intrinsic to the resources studied and not as emerging out of the broader constellations of which these resources form part. Properties of soils, for instance, are represented as being intrinsic to these soils. The same applies to e.g. manure and application techniques. Manure is what it is – regardless of the way it is produced, applied and combined with specific soils (Kok, 2004: p. 24). Within the context of relatively stable patterns of co-production such a segmented approach (which corresponds with the high degree of specialization in agricultural sciences) might be useful. However, when patterns of co-production are changing, the same approach might become, albeit not necessarily, a considerable pitfall.

Finally, there is the strong belief in the institutes for applied research that empirical findings, of whatever type and nature, are meaningless as long as they are not, or cannot be explained by reigning theories. In itself this is a rational position. If, however, the models used for the needed explanation reflect specific, historically rooted modes of co-production (and consequently exclude other), it becomes extremely difficult if not right away impossible to come at grips with newly emerging and promising practices, i.e., with novelties.

Analysis of interactions and comparison of systems

In a companion paper (Groot *et al.*, 2007) the experiment has been re-analysed for the complete 5-year experimental period, using response curves derived from the experiment, and placed in a simplified perspective of a grassland system. The conclusions regarding the treatment main-effects were in agreement with the previous analyses by Schils & Kok (2003) and Kok (2004). N recovery was on average (1) lower for the manure from farm Drogeham, containing Euromestmix® additive, than for the regular manure from farm Harkema, and (2) lower after surface application than after shallow injection. However, the comparison of manure types was hampered by the large variation in composition of the regular manure from farm Harkema, which influenced the availability of applied N. After correction for manure N availability the contrasts between manure types were no longer statistically significant.

When focusing on aspects of system stability, in contrast to the regular manure from farm Harkema, the manure produced at Drogeham, containing less N and an additive, was very stable in terms of dry matter content and chemical composition. Moreover, although the highest N recovery values were found for the system employed at Harkema (shallow injection of regular manure), for regular manure applied at Harkema also the largest difference in N recovery between application techniques was observed (20% and 47% for broadcast and shallow injection, respectively). The contrasts for regular manure applied at Drogeham (31% versus 42%) and for low-N manure containing additive at Harkema (23% versus 40%) were considerably smaller. From this statistically significant interaction between manure type, site and application technique (see Groot *et al.*, 2007; Tables 4 and 5), it might be concluded that the system at Harkema was tuned to attain a high N recovery, but is vulnerable to changes in the system, which would be perceived as sub-optimal. The over-tuning of specialized aspects of the farming system has been observed in other areas of agricultural development. For instance, in animal breeding a strong interaction between genotype and environment has been observed. Animals bred for high productivity only perform well in favourable and controlled environments, but perform less under less favourable conditions (Boelling *et al.*, 2003). So these interactions result in rapid rejection of novelties when studied in isolation in factorial experiments.

The systems comparison performed by Groot *et al.* (2007) demonstrates that the potential N emission is not necessarily the highest in the system applying slurry by surface broadcast, i.e., the Drogeham system. Moreover, the differences in potential N emission between systems vary between years, probably due to climatic conditions affecting the utilization of manure, the mineralization/immobilization turnover of N in the soil and the productivity of the grass. Despite these variations, the Drogeham system was characterized by a higher stability, as is illustrated by the relationships between dry matter production on the one hand and potentially lost N and crude protein content on the other. So high yields of dry matter of good quality in terms of crude protein content were more effectively attained in the Drogeham system, which entailed the different novelties elaborated by the two co-operatives. This implies that it is possible to realize a system based on 'disembodied', eco-technological farming practices with the same efficiency but higher stability than an 'embodied', technology-based system applying shallow injection of regular manure.

From the contrasts between the sites it can be concluded that the system at Drogeham is highly dependent on the production capacity of the soil (Groot *et al.*, 2007), which might be related to better soil moisture conditions. On the other hand, aspects related to long-term improvement of the soil in terms of soil biology (De Goede *et al.*, 2003) or soil organic matter content (Sonneveld, 2004) might also play a role here. Building on the earlier work of Pulleman *et al.* (2000), Sonneveld (2004) argues that understanding land as a genoform having its own intrinsic properties is not satisfactory. It is within the context of co-production that a particular genoform will be unfolded in contrasting phenoforms. Through contrasting patterns of utilization, land is moulded into different constellations having different properties that emerge from the differential relation between land and the way it is used. As Sonneveld & Bouma (2003: Table 2) demonstrated, one particular soil genoform (in this case of soil series cHn23) might be unfolded into at least three, highly contrasting phenoforms, each characterized by particular levels of organic C, organic N, particular C/N ratios and particular rates of mineralization.

The differences between the sites observed in this experiment could not be linked directly to bio-physical conditions and the patterns of co-production. Nevertheless, the contrasts in effects of manure type and application technique treatments between sites and years clearly indicate that evaluation of farming practices should be considered in the *context* of the farming system (Schiere *et al.*, 1999) and that making generalizations about the effects of farming practices within different farming systems should be avoided. This would enable the acceptance of diversified development trajectories deviating from the prevailing concepts fostered by the mainstream institutions (Altieri, 1991; Schiere *et al.*, 1999).

Conclusions and recommendations

The institutionalized research routine and the related analysis of experimental data basically narrow down to a straightforward comparison of average results related to different experimental conditions (with different 'independent factors'). To check whether or not there is any statistically significant effect of e.g. surface application compared with shallow injection, all plots receiving surface-applied manure were compared with all plots where manure was injected. Consequently, potentially relevant exceptions disappear. Specificity, i.e., the creation of a specific balance of different resources and techniques, is central to the art of farming. In the regular applied science analysis, however, specificity gets lost and potentially powerful novelties are filtered out.

For research institutions operating in the context of a socio-technical regime it is difficult to deal with novelties. Several reasons have already been outlined extensively. They can be summarized as follows:

1. The established research routines are having difficulties in dealing with complexities and disturbances inherent to on-farm research.
2. In established research routines, especially experiments, land is seldom understood as outcome of co-production. With a better understanding of co-production the analysis of even simple experiments could be enriched considerably.
3. Novelties are not treated as such in the current forms of applied research. Deviating measurements and interactions are easily placed in brackets, considering them as anomalies. By solely 'admitting' outcomes of measurements and experiments that might be explained by current theories, institutionalized research blinds itself when it comes to the exploration of novelties.
4. It is strategic to take the specificity of local situations into account in agronomic research. The de-contextualization of research findings easily results in biased conclusions.

The results of the Nutrient Management Project indicate that the proposed approach to system-oriented adjustment of eco-technological farming practices presents a strong alternative to the currently reigning agro-environmental regime. The feeding track (feed the cattle with a diet that is rich in fibre and poor in protein so as to obtain nitrogen-poor manure with a high C/N ratio and a low percentage of ammoniacal N) is currently being applied by an increasing number of Dutch dairy farmers. However, since this trajectory is not in line with the objectives and perspectives of the institutions associated with the prevailing socio-technical regime, this promising approach is again lacking in new proposals for agro-environmental policies. From this it can be concluded that:

1. Applied research should function, amongst other, as a channel of communication that passes novelties encountered in practice to fundamental research.
2. As far as methods of analysis are concerned, the search for average results is to be replaced by the search for the exceptional. Equally, the inquiry into so-called main effects should be replaced by a focus on re-balancing, interaction and fine-tuning.
3. Acceptance of the importance of *context* of the farming system is required by policy makers and scientists, and implies that generic regulations and prescriptions should be replaced by or complemented with system-specific objectives (Schiere *et al.*, 1999).

4. Routinized research traditions, mostly focused on and thus limited to just one tiny segment of the broader processes of agricultural production, should be integrated into the complex 'mosaic' of available and neighbouring blocks of knowledge, instead of forming islands on themselves.
5. More attention is to be paid to long-term stability of agricultural systems (as opposed to vulnerability and sharp fluctuations on the medium run).
6. The formulation of agrarian policies is not to be based – in an uncritical and unilateral way – on results from (applied) research institutions clearly linked to a prevailing socio-technical regime. Especially if there is considerable heterogeneity (in this case a wider range of trajectories towards sustainability), the dependence of policy on applied research will only augment frictions and conflicts.

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