Introduction

Public-funded research is expected to contribute to the wellbeing of society. At the level of farm systems, this implies that agricultural research should enhance adaptability of farms to changing external factors. In the search for adequate research methodologies at farm level a multiplicity of approaches have been developed. From an instrumental point of view, three groups of methodologies can be distinguished: (1) computer modelling; (2) farm system experiments at experimental stations (e.g., Delate, 2002, Mueller et al., 2002, Jordan, 1998, Jordan et al., 1997 and Helander and Delin, 2004); (3) research with commercial farms (‘on-farm research’). In the third group, a distinction can be made between research from a more detached or involved stance, here referred to as on-farm systems studies and action research (for background terminology see Alrøe and Kristensen, 2002). Note, in the literature the expressions ‘farming systems research’ (Collinson and Lightfoot, 2000) and ‘farmer participatory research’ (Okali et al., 1994) are frequently used instead of ‘action research’. The trend towards undertaking more action research has been especially strong in developing countries. On-farm action research seemed to fit the concern for appropriate improvements for and empowerment of small-scale, illiterate and resource-poor farmers (Collinson, 2000 and Okali et al., 1994).
In the more developed countries, questions about the multiple functions of agriculture in rural areas and the impacts of farming on the environment have left their mark on the development of systems research methodologies at farm level (Pacini et al., 2004, Gibon et al., 1999, MeyerAurich et al., 1998 and Edwards et al., 1993). Compared to the preference for action research in developing countries, scientists in more developed countries have adhered rather to computer modelling (e.g., Pacini et al., 2004 and Gibon et al., 1999), farming system experiments at experimental stations (e.g., Delate, 2002, Mueller et al., 2002, Jordan, 1998 and Jordan et al., 1997; Helander and Delin, 2004) and on-farm systems studies (Drinkwater, 2002). Some of the few documented examples of action research in Europe are projects working with the ‘prototyping’ methodology (Vereijken, 1999). The main features of prototyping are: (1) quantification of goals; (2) emphasis on multiple societal goals; (3) designing as an organizing principle; (4) iteration of system analysis, design and on-farm testing. The methodology was implemented in a number of Dutch projects (Langeveld et al., 2005, Wijnands and Holwerda, 2003, Vereijken, 1997, Wijnands, 1997 and Wijnands, 1992) and two EU-funded projects (De Haan and Garcia, 2002 and Vereijken, 1999) on both experimental and commercial farms. On a smaller scale, the methodology was introduced in other sectors such as organic olive production (Kabourakis, 1996) and outside Europe (Stoorvogel et al., 2004). At the end of the 1990s, 10 years of proposals for conceptualization of the practical experiences culminated in a manual for prototyping arable farming systems (Table 1).

Table 1. The five steps of the prototyping methodology

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Hierarchy of objectives</td>
<td>To develop a hierarchy of objectives as a basis for a prototype in which the strategic shortcomings of current farming systems are replenished</td>
</tr>
<tr>
<td>2. Parameters and methods</td>
<td>To transform the major objectives into multi-objective parameters and to quantify them. Subsequently, system technologies (Sumberg et al., 2003) are selected which are assumed to contribute to achievement of the objectives</td>
</tr>
<tr>
<td>3. Design of theoretical prototype and methods</td>
<td>The selected system technologies are linked to the parameters on which they have an impact. In this way, the major and minor technologies and the (conflicting) conditions to the technologies become visible. On basis of this analysis, the technologies are further designed -in a logical order and guided by the set of conditions- resulting in a consistent package, a ‘prototype’</td>
</tr>
<tr>
<td>4. Layout of prototype to test and improve</td>
<td>Laying out the designed prototype on experimental or commercial farms to test and improve it in relation to the formulated objectives</td>
</tr>
</tbody>
</table>
In the Netherlands, development and implementation of the prototyping methodology on both experimental stations and commercial farms at the beginning of the 1990s have been the first steps in a series of action research prototyping projects. These projects shared the same overall goal: to develop and to introduce more sustainable farming systems in the agrarian community. Yet, the projects differed in set-up from 1 with 10 intensively supervised farmers in a region to those with a national network of both intensively and extensively supervised groups, comprising more than 100 farmers. Although very complicated to properly assess, project evaluations suggest that management practices as well as the mindset of the participants changed due to project activities (Langeveld et al., 2005, Klein Swormink, 2003 and Van Weperen et al., 1995). This is the kind of output which can be regarded as successful for efforts to mobilize science and technology for sustainability (Cash et al., 2003). However, the project reports merely present what was done but not how it was done, i.e., it is not indicated how, and by who, objectives or alternative management options were identified, whether prototyping practice changed simultaneously with project set-up, etc.

Parallel to action- and experimental farm research, several farm system modelling studies were carried out in the Netherlands (Ten Berge et al., 2000). Hypothetically, action- and experimental farm research on one side and theoretical modelling on the other, could benefit from cross-pollination. Agricultural scientists, modelers specifically, have recently explored new ways to connect to social debates and farm management practice (Edwards-Jones, 2001, Keating and McCown, 2001 and Gibon et al., 1999). Incorporation in prototyping projects would offer farm system modelers opportunity to ‘connect’. On the other hand, the prototyping approach could benefit from modelling as well. Farm system models provide means to expand, refine and formalize expert knowledge (Ten Berge et al., 2000) and to integrate these and scientific agro-ecological (as defined by Dalgaard et al., 2003) knowledge at farm level. These model qualities could enable revealing options otherwise possibly overlooked and extrapolation of prototyping results to other conditions and scenarios.
Despite the promise, we observe that little cross-pollination between the modelling and prototyping efforts took place, even though the methodologies were applied in parallel and in one country. As stated above, existing reports on prototyping projects merely present their technical set-up and results but lack description of the implementation of the methodology. Therefore, to gain insight in how the prototyping methodology shaped action research and to investigate the potential for cross-pollination we need a better understanding of prototyping practice and especially the mobilization of agro-ecological knowledge herein. Hence, we formulated four research questions: (1) How was the prototyping methodology implemented in the series of Dutch action research projects? (2) How was agro-ecological knowledge mobilized to explore options for improvement and communicate project output? (3) Why was the methodology implemented in this way? (4) Why did hardly any cross-pollination between farm system modelling and prototyping happen?

After introducing the methodology in Section 2, Section 3 presents a number of analytical notions which guided the data presentation. In Section 4, almost three decades of Dutch experimental, farming system research inspired by the prototyping methodology is discussed. Subsequently, we return to the research questions and discuss the potential for mutual benefit of prototyping and farm system modelling in Section 5. In Section 6, we draw conclusions.

2. Methodology

The majority of the studied Dutch prototyping projects had ended when our research took place. Hence, the study had a reflective character. We could draw on the experiences of two of the authors. Wijnands has been actively involved in all projects discussed in this article. The first author has researched prototyping projects in the context of a PhD project over the past 3 years. For this research qualitative methods were applied: semi-structured interviews and study of internal and external project documentation. Also, the first author attended gatherings, such as project team meetings and bilateral encounters between project team members and farmers (so called kitchen table meetings). Informal conversations (i.e., unstructured interviews) were held with the participants during and after these activities to uncover their interpretations of what was going on.

3. Analytical framework
To address prototyping practice and at the same time elaborate on the potential for cross-pollination between this practice and farm system modelling, we identified two sets of structuring themes. From the first analysis of the prototyping project documentation and interviews we inferred four variables that shaped prototyping practice. These four variables guided the further analysis of prototyping practice:

• **Research strategy**, the perspective of the project initiator on innovation processes.

• **Policy environment**, influence of policy on the project.

• **Project network and role division**, project partners, who did what, relations between the partners.

• **Project methods**, the main activities structuring the project process.

Coupling the formalizing and integrating capacities of farm system modelling to the prototyping methodology resulted in three leads for the possible role of farm models in mobilizing agro-ecological knowledge in prototyping processes. These three leads focused the exploration of the potential for cross-pollination of prototyping practice and farm system modelling (the steps refer to Table 1).

1. Exploration of objectives, including parametrisation and quantification (step 1 and 2 of the prototyping methodology).

2. Exploration of options for improvement (step 3).

3. Communication and extrapolation of project output (step 5).

Concerning the fifth step of the prototyping methodology, the dissemination, and connected to it lead 3, we used a broader definition of what dissemination is. Not just farmers can be a target group but the government, other public organization and commercial firms as well. Besides, the dissemination phase can be directed at management change directly, but also indirectly, e.g., via further research, policy explorations on basis of project results.
4. Prototyping in action

Almost three decades of prototyping practice is analysed, by discriminating a first phase with experimental farm research, a second phase with prototyping on commercial farms, and a third phase just starting up. The four variables formulated in Section 3 were used to cluster the data. However, if data belonging to two different variables were strongly intertwined, we sometimes chose not to separate. Hence, the clustering is not fully consistent.

4.1. Phase 1: farm system experiments at experimental stations

4.1.1. Research strategy

The first Dutch experiences with the prototyping approach originate from the early 1980s, when three arable farming systems – integrated,$^1$ organic$^2$ and conventional – were laid out on an experimental farm at Nagele in the Flevopolders (Vereijken, 1989a and Vereijken, 1989b). Later on, a number of other experimental farms in other Dutch regions and sectors started working with the prototyping methodology (Langeveld et al., 2005 and Wijnands, 1997). The main reason for the initiative had been a call for an “entire farming system approach” (El Titi, 1992 and El Titi, 1989) in reaction to limited adoption of integrated pest management by farmers (Vereijken, 1989a).

4.1.2. Policy environment, project network and role division

System research at experimental farms can not be run without stable and long term funding, e.g. to investigate a rotation scheme might take up to 6 years, depending on the length of the scheme. The Dutch Ministry of Agriculture, Nature and Fisheries has been an essential partner in this sense. It has been the main sponsor of the prototyping research at experimental farms, though conditions for funding have changed. Till the end of the 1990s, the Ministry funded the owner of the experimental farms, Applied Plant Research (PPO). Internally, the money was distributed over the different projects. Hereafter, the Ministry funded projects directly on the basis of a proposal. Simultaneously, the Ministry became also more involved in the formulation of the project objectives. Besides, in the first years, it was mainly employees of Applied Plant Research doing the research on the experimental farms. In the 1990s, the experimental farms became part
of the prototyping action research projects. Consequently, researchers from other organizations got involved in the experimental farm work as well.

4.1.3. Project methods

We use the research work at the Nagele experimental farm (Wijnands and Dekking, 2002) to provide some illustrations of the implementation of the prototyping methodology for an organic farming system. Though not in a hierarchical order, five objectives were formulated for the system by the project team. We here further focus on the objective ‘clean environment/nutrients’ as an example to show the further elaboration of an objective. Five parameters accompanied by target values were linked to the nutrient objective (Table 2). Nutrient management in agriculture, especially nitrogen use, was highly debated in the Dutch policy arena in the 1990s. Hence, formulation of the nutrient objective, accompanying parameters and target values were to a great extent inspired by policy discussions about (im)possibilities. Earlier, when environmental policy was still in its infancy, researchers sought more inspiration from colleagues and professional literature according to respondents.

Table 2. Objectives, parameters and target values for the prototyping research at Nagele experimental farm

<table>
<thead>
<tr>
<th>Objective</th>
<th>Parameter</th>
<th>Dimension</th>
<th>Target value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality production</td>
<td>Quantity</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Quality</td>
<td>–</td>
<td>1</td>
</tr>
<tr>
<td>Clean environment; nutrients</td>
<td>Nitrogen-min November</td>
<td>kg/ha (0–110 cm)</td>
<td>Clay 70; Sand 45</td>
</tr>
<tr>
<td>Nitrogen leaching</td>
<td>ppm NO₃</td>
<td>&lt;50</td>
<td></td>
</tr>
<tr>
<td>Nitrogen surplus</td>
<td>kg/ha</td>
<td>&lt;100</td>
<td></td>
</tr>
<tr>
<td>Phosphate surplus</td>
<td>kg/ha</td>
<td>&lt;20</td>
<td></td>
</tr>
<tr>
<td>K₂O surplus</td>
<td>kg/ha</td>
<td>&lt;40</td>
<td></td>
</tr>
<tr>
<td>Objective</td>
<td>Parameter</td>
<td>Dimension</td>
<td>Target value</td>
</tr>
<tr>
<td>-----------</td>
<td>-----------</td>
<td>-----------</td>
<td>--------------</td>
</tr>
<tr>
<td>Clean environment; pesticides</td>
<td>Air exposure risk index&lt;sup&gt;a&lt;/sup&gt;</td>
<td>kg/ha</td>
<td>&lt;0.7</td>
</tr>
<tr>
<td></td>
<td>Application active ingredients</td>
<td>kg/ha</td>
<td>As low as feasible</td>
</tr>
<tr>
<td></td>
<td>Groundwater exposure risk index&lt;sup&gt;a&lt;/sup&gt;</td>
<td>ppm</td>
<td>&lt;0.5</td>
</tr>
<tr>
<td></td>
<td>Soil exposure risk index&lt;sup&gt;a&lt;/sup&gt;</td>
<td>kg days/ha</td>
<td>&lt;200</td>
</tr>
<tr>
<td></td>
<td>Aquatic environmental stress credits</td>
<td>% applications &gt; 10 credits</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Soil life environmental stress credits</td>
<td>% applications &gt; 100 credits</td>
<td>0</td>
</tr>
<tr>
<td>Sustainable management of soil and water</td>
<td>Pw&lt;sup&gt;b&lt;/sup&gt;</td>
<td>Pw (0–30 cm)</td>
<td>20–30</td>
</tr>
<tr>
<td></td>
<td>K-number&lt;sup&gt;c&lt;/sup&gt;</td>
<td>K-number (0–30 cm)</td>
<td>Clay 18–29; Sand 11–19</td>
</tr>
<tr>
<td></td>
<td>Supply of effective organic matter</td>
<td>kg/ha</td>
<td>Equal to break down of effective organic matter</td>
</tr>
<tr>
<td>Farm profit</td>
<td>Income per €100 costs</td>
<td>€s</td>
<td>&gt;100</td>
</tr>
<tr>
<td></td>
<td>Hours hand weeding</td>
<td>h/ha</td>
<td>&lt;20</td>
</tr>
</tbody>
</table>

Reproduced from Wijnands and Dekking (2002).

<sup>a</sup> Indicator for emission risk of synthetic pesticides, herbicides and fungicides, calculated on basis of specific characteristics and applied quantity.

<sup>b</sup> Pw is a Dutch indicator for soil phosphate concentration, expressed as mg P<sub>2</sub>O<sub>5</sub>/l dry soil.

<sup>c</sup> Indicator for potassium concentration, expressed as mg K<sub>2</sub>O/100 g dry soil.

Researchers identified two main system technologies with the nutrient objective: ‘multifunctional crop rotation’ and ‘ecological nutrient management’. These were not newly invented technologies or technologies not in use already. However, their purposive application to achieve quantified -and not just well-known economic, but also the new environment and nature related-target values was considered innovative. Via yearly cycles of regular and extensive
measurements, reflection and adaptation of the different system technologies, the farm system got a new orientation. The researchers’ network and professional literature were sources of inspiration in this phase. For the multifunctional crop rotation this iterative design procedure resulted in a set of guidelines, such as:

• Alternate tuber/root/bulb with mowing crops.

• Make use of mineralization from previous crops or green manure.

• Grow green manure crops whenever possible.

Table 3 shows how the set of guidelines was operationalised at the Nagele experimental farm. Project results were presented in reports, researchers were frequently invited to give a talk to diverse audiences, and open days at the experimental farms were organized regularly.

Table 3. Characteristics of the crop rotation of the organic system at the Nagele experimental farm

<table>
<thead>
<tr>
<th>Year</th>
<th>Crop</th>
<th>Family</th>
<th>Mow/tuber, root, bulb crops</th>
<th>Nitrogen requirement</th>
<th>Nitrogen transfer</th>
<th>Manure (solid)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ware potato</td>
<td>Solanaceae</td>
<td>Tuber</td>
<td>++</td>
<td>+</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>Grass–clover</td>
<td>Poaceae/leguminosae</td>
<td>Mow</td>
<td>+</td>
<td>+++</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>Celeriac/onion</td>
<td>Umbellifers/liliaceae</td>
<td>Root/bulb</td>
<td>+++/+</td>
<td>+</td>
<td>Yes/yes</td>
</tr>
<tr>
<td>4</td>
<td>Wheat</td>
<td>Poaceae</td>
<td>Mow</td>
<td>+++</td>
<td>++</td>
<td>Yes</td>
</tr>
<tr>
<td>5</td>
<td>Carrot</td>
<td>Umbellifers</td>
<td>Root</td>
<td>+</td>
<td>+</td>
<td>No</td>
</tr>
<tr>
<td>6</td>
<td>Pea</td>
<td>Leguminosae</td>
<td>Mow</td>
<td>+</td>
<td>++</td>
<td>No</td>
</tr>
</tbody>
</table>

Reproduced from Wijnands and Dekking (2002).

a +: 0–50 kg N, ++: 50–100 kg N, +++: 100–150 kg N.

4.1.4. Mobilization of agro-ecological knowledge

If we single out the elements of the above analysis about the mobilization of agro-ecological knowledge and relate them to the three promising leads for cross-pollination (see Section 3) – (1)
the identification of objectives, (2) options for improvement, and (3) the fate of project output – a few observations can be made. Objectives were defined by the involved researchers and indirectly, later more directly, influenced by the policy environment. Similarly, ideas for adaptations of the farm system emerged from discussions of researchers within their network and from professional literature. Though the prototyping methodology was unconventional, especially during the 1980s, the dissemination methods were not. They did not deviate from the usual communication strategies of Applied Plant Research, i.e reports, talks and open days.

4.2. Phase 2: on-farm and action research

4.2.1. Research strategy, policy environment

After a decade of research at the experimental farm in Nagele, Vereijken concluded that considerable progress in the direction of desired system performance had been made, however “[…] experimental farms will never be similar to commercial farms. Therefore, it is recommended to develop […] prototypes on pilot farms, where scale, design and management are representative of a viable agricultural enterprise” (Vereijken, 1994). At the same time, the Dutch government accepted two policy plans to restructure and sanitize the national agriculture. ‘Integrated’ production was considered a major tool to reduce the adverse effects of high pesticide and nutrient inputs (Wijnands and Vereijken, 1992). Against this background, two projects with commercial farms were initiated, an integrated arable farming (Wijnands, 1992) and an organic arable and open-field vegetable farming (Vereijken, 1997) project, hereafter referred to as the IAF and OAF projects. These two projects were followed by one more integrated (Langeveld et al., 2005) and two more organic farming projects, i.e., BIOM (‘organic agriculture innovation and conversion’) I and II (Wijnands and Holwerda, 2003) up to now. The integrated version, ‘farming with a future’ (FwF), was launched in the frame of additional nitrogen measures. The new policy mainly encompassed an reinforcement of the 1990 standards.

4.2.2. Project network and role division and project methods

In the OAF project, a relative small number of just 10 farmers participated, concentrated in 1 region, and the extension service was not involved. The OAF project team believed that it was vital to concentrate all project resources in one region and make communication lines as short as
possible in order to limit diversity in biophysical conditions and to allow testing the farm systems properly. The IAF and all later project teams followed another approach. Based on the ‘Nagele’ research results, researchers of Applied Plant Research (PPO) developed courses about the tested system technologies (the so-called ‘toolbox’) to train the extension officers who would become partners in the projects. New researchers received an internal training as well. Furthermore, for the IAF project, five regional groups of farms were composed to create diversity in soil, farm and management conditions. The later farming with a future, BIOM I and II projects followed the IAF set up (for an overview of the partners in the different projects, see Table 4). The pros and cons of the OAF procedure versus the approach in the IAF and later projects were never evaluated. Hence, we are unable to pronounce upon the comparative fitness of these two approaches. The objectives of the different projects were similar to the ones listed in Table 2 for the Nagele experimental farm with one exception; BIOM II explicitly addressed the strengthening of organic market chains besides the more ‘conventional’ objectives. The inclusion of this new theme was a reaction to the importance the theme had gained in the communications in BIOM I.

Table 4. The phase 2 projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Collaborators</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Integrated arable farming (IAF)</td>
<td>PPO, PRI, LEI, DLV, farmers (38)</td>
<td>1989–1993</td>
</tr>
<tr>
<td>Organic arable and open-field vegetable farming (OAF)</td>
<td>PRI, farmers (10)</td>
<td>1991–1997</td>
</tr>
<tr>
<td>BIOM I</td>
<td>Farmers (54), PRI, PPO, DLV</td>
<td>1998–2002</td>
</tr>
<tr>
<td>Farming with a future (FwF)</td>
<td>PPO, PRI, LEI, DLV, farmers (33)</td>
<td>2000–2003</td>
</tr>
<tr>
<td>BIOM II</td>
<td>Farmers (40), PPO, PRI, DLV</td>
<td>2002–2006</td>
</tr>
</tbody>
</table>


Though the OAF project differed in set up from the others, in the execution phase all five projects functioned similarly. Every farm was put through an elaborate measuring- and registration scheme during the project, reported in yearly farm evaluations. Researchers, extension officers
and the farmers were each responsible for part of the scheme. The extension officer (read ‘researcher’ for the OAF project) visited the farms belonging to his regional group frequently, up to once every 2 weeks in the growing season. Main tools in the discussions were yearly nutrient management, crop protection and cropping plans. In these plans the toolbox was operationalized. It was particularly in the so-called ‘kitchen table’ meetings that usefulness of specific agro-ecological knowledge was probed. Researchers visited the farms to measure specific parameters such as the nitrate concentration in the drainage water at set times. This intensive farm performance monitoring and communication between extension officers, researchers and farmers was essential to interpret results in a credible way. Regional groups met regularly, facilitated by an extension officer. In summer, the participants made excursions to places of common interest and visited farms of members of the group. In winter, selected topics were highlighted in the meetings, such as nitrogen leaching or the management of a specific crop and the individual farm evaluations were interpreted by the group. The group meetings were organised to motivate the participants and to screen new management options. Usually, a farmer would not adopt all proposed system technologies in the first project year, he would rather make a selection from the ‘toolbox’. At a later stage, he might then start trying the other system technologies, e.g. because other members of his regional group were enthusiastic.

In phase 2, the project set up was assumed a major dissemination strategy, i.e. the participating farmers were supposed to share their experiences with their colleagues. In addition, courses on integrated and organic farming were offered to organisations that educate, train or advise farmers (extension service, private enterprises and agricultural schools or training centres) and farmers deliberating changeover to organic farming. Another strategy to create a broader support for integrated and organic farming was to extensively supervise farmers’ groups parallel to the intensively supervised groups. Furthermore, the Ministry of Agriculture, Nature and Fisheries did not engage with the contents till the end of the 1990s. However, the Ministry makes use of the project results to set its agenda since, according to respondents. Moreover, other researchers than those from PPO (e.g. PRI, see Table 4) made increasingly supplementary investigations zooming in on farm system components, often with the help of issue-specific model simulations, e.g., the relation between nitrate leaching and nitrate in groundwater. Partly, this work concerned policy explorations for the Ministry of Agriculture, Nature and Fisheries. For another part, the model
work elaborated on observations made on the farms and its results affected future project activities.

4.2.3. Mobilization of agro-ecological knowledge

Returning again to the three promising leads for cross-pollination between prototyping and farm system models (Section 3), a first observation is that few words are spent on the definition of project objectives in the analysis of the second phase. Although the prototyping manual (Section 1) suggests that the definition, parametrisation and quantification are major phases in a prototyping process, covering two of the five steps of the methodology, in practice objective definition took place prior to the projects in a rather elusive way with input from experimental farm work, researchers networks and the policy environment. In reference to our second possible lead related to the exploration of options for improvement, we observe that – within the window of opportunities of the toolbox – occasions for identification of options were amply present during the whole course of the project, e.g., during kitchen table meetings and in regional group activities. These occasions were characterized by a diversity in settings and hence a variety of sources of inspiration such as quantitative measurements and farm visits. Our third lead dealt with the dissemination step of the prototyping manual. From the analysis of second phase it transpires that the project results were formulated and communicated in three distinctive ways: (1) participating farmers were ‘ambassadors’; (2) project output was formulated in the form of farm management guidelines and communicated via reports, courses and farmers’ groups external to the project; (3) project data were input for model explorations with the aim to better understand behaviour of particular system components or to support policy making.

4.3. Continuation: phase 3

After 10 years of action research projects and even though the project evaluations were generally positive, the support for integrated and organic farming in the agricultural sector was judged insufficient by the Ministry of Agriculture, Nature and Fisheries as well as several representative organizations in the agricultural sector. Recently, projects have been started up following a new approach. Capitalizing on the extensive experience with the system technologies for integrated and organic farming, PPO researchers and extension officers now facilitate experimentation of farmers groups with (elements) of these system technologies. Measurements are only done in
relation to the experimentation, not to monitor the complete farm system. A larger number of farmers participates but the collaboration is less intensive. Organizing the active engagement in the project of relations having a stake in farmers management, such as fertilizer suppliers and authorities at the local and regional level, is a second major theme in the new approach. Because third phase projects have started only recently, it is not possible yet to analyse this phase any further. Apart from this so-called ‘new approach’ or ‘third phase’, entirely new visions, objectives and parameters have been formulated for a number of experimental farms, an initiative reminding of the first described prototyping phase in this paper (Section 4.1).

5. The evolution of prototyping and the potential for cross-pollination with farm system modelling

In Section 3, three promising leads in the prototyping methodology were identified for the integration of a farm system model. In Section 4, prototyping practice was pictured and the mobilization of agro-ecological knowledge analysed in relation to the three promising leads. Here, we reflect on the developments in prototyping practice over the years and the potential for cross-pollination of prototyping and model based farm system research.

5.1. Evolution of prototyping

Fig. 1 and Fig. 2 visualize what transpired as the main developments in prototyping practice over the years: a shift in project focus and in project stakeholders. The analysis of prototyping practice (Section 3) indicates that these developments were influenced by the project internal learning process as well as the policy environment. With respect to the latter factor, at the time the IAF and OAF projects were set up, ambitious environmental policy plans created a sense of urgency for the research, extension and farming communities to innovate and to innovate in the same direction, i.e. improving the environmental impact of farm management. The successors of the IAF and OAF projects were set up in the frame of additional measures to the earlier policy plans that did not create a similar sense of urgency. Consequently, in later projects, the strong focus on environmental aspects of farming decreased, and socio-economic ambitions became more guiding in the work approach (Fig. 1) in reaction to communications in the earlier projects.
Fig. 1. The focus on two categories of project objectives in the three phases of prototyping practice.

Fig. 2. Stakeholder involvement in the three phases of prototyping practice.

*Fig. 2* visualizes the increase in actively involved stakeholder groups. We hypothesize that this trend is not a coincidence, but at least partly the result of an internal learning process. One of the main pillars of this learning process has been the long-term involvement of a number of project team members and it has yielded three insights over the years. A first insight concerns the impact
of the policy environment on project orientation, elaborated above. Secondly, the project team developed expertise in action research and integrated/organic farming. For the latter, the earlier research at the experimental farms proved an essential basis to cope with the complex of social and biophysical factors characterizing action research projects. The experimental farm work laid the agro-ecological foundation, operationalized in the toolbox, for the later action research projects. Both the extension officers and researchers built on this work with their project activities. Lastly, the project team was confronted with their (implicit) theories about the spread of project results within the farming community. The main dissemination methods, i.e., (1) the project participants as ambassadors and (2) written material, did not produce the expected dissemination. Building on this gradually evolving understanding, the project team started to involve a larger range of stakeholders to construct a more supportive (policy) environment. As a result of this initiative the project team took on additional roles, such as that of a network facilitator. To improve the diffusion of the tested system technologies, a radically different strategy was proposed in phase 3, i.e., familiarizing many farmers with (components of) the system technologies instead of aiming at quantitative goals with a relatively small group of farmers. Supposedly, the emerging expertise in the project team has been essential to cope with the growing number and diversity in collaboration styles.

5.2. Prototyping and modelling

In Section 3, three promising leads for cross-pollination of modelling and prototyping were identified:

1. Exploration of objectives, including parametrisation and quantification.

2. Exploration of options for improvement.

3. Communication and extrapolation of project output.

Sections Sections 4.1.4 and 4.2.3 discuss how agro-ecological knowledge was mobilized to address these three themes in prototyping projects. Here, we explore the consequences for the potential for cross-pollination with farm system modelling. Note, in this exploration we assume that it is feasible to prepare a model timely, though this has proven a major hindrance in
experiences to date (Sterk et al., 2006). From the analysis it transpires that the definition of project objectives (lead 1) took place prior to the installation of the project organization. Besides, the set up (i.e. objectives and tested system technologies) and results of the work at the experimental farms (phase 1) had a significant influence on the objectives definition for the action research projects (phase 2). Thus, the formulation of objectives appears not to be a distinct activity within the prototyping action research projects themselves. Consequently, the potential for cross-pollination in relation to objective formulation in prototyping action research projects seems low. However, we did not find any indications that farm system modelling could not, in principle, play a role in the discussions about prototyping objectives for experimental farm research (phase 1).

Regarding the exploration of options for improvement (lead 2), the action research projects encompassed intensive and continuous communication between the project team and farmers about possible improvements, farm management activities and effects, often on-farm and supported by an extensive palette of tools, e.g. regular group and bilateral meetings, quantitative monitoring system and excursions. This approach resulted in a strongly localized research process. To be useful in this process, we hypothesize that a model has to be localized to the same degree. However, localization is not trivial for cropping system models such as APSIM (Carberry et al., 2002), let alone farm system models using parameters for many processes which are hard and very time consuming to quantify in a location-specific manner. Thus, though not impossible, it might well be impractical and perhaps not feasible to introduce a farm system model. In relation to the fate of project output (lead 3), issue-specific (i.e. focus on a component of the system) models were increasingly used in the projects. The prototyping project data were incorporated in model-based policy explorations, for instance with the purpose to elaborate the effect of diversity in nitrogen management for achieving (future) environmental policy targets. The application of issue-specific models could be due to its more advanced development in the past. Therefore, it might be a matter of time before farm system models are also mobilized for policy explorations in the slipstream of prototyping projects.

6. Conclusions
Analysis of more than two decades of Dutch prototyping research both on experimental and commercial farms indicated that prototyping on commercial farms is a highly localized process. Moreover, although the methodology manual suggests differently, goal formulation was not a distinctive phase of prototyping on commercial farms. Consequently, the chances that farm system modelling will be incorporated in the objective definition or testing phase of a prototyping project seem minimal. However, issue-specific (i.e. focus on a component of the system) models are increasingly used for policy explorations. We hypothesize that there may also be a role for farm system models for this purpose. With this type of models the diversity in farm management, which transpires from the prototyping work, can be formalized and then used to assess the effect of future environmental policy measures at the farm level.

References


